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Structural Assessment Report of Orlit Houses
Revision A
Ravensbury Estate Regeneration
For HTA Design LLP

Engineering at its Best

Report For

HTA Design LLP

Scheme No: 11264

Ravensbury Estate Regeneration

Structural Assessment Report of Orlit Houses

Revision A

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1.0 Introduction

1.1 This report has been prepared by Tully De'Ath for HTA Design LLP (HTA). It provides a structural condition survey of the existing Orlit Houses on the Ravensbury Estate and considers the structural implications of extending their useful life. The report is intended to assist with the selection of feasible options for the proposed redevelopment of the Ravensbury Estate. This follows instructions from Caroline Dove of HTA on 23 July 2014 as part of masterplanning services which HTA are providing for Circle Group.

1.2 The buildings covered within this report form 72 semi-detached Orlit houses on the Ravensbury Estate. Sketch number 11264/SK01 within Appendix A illustrates the location of these Orlit houses on the Estate.

1.3 The observations and comments made in this report are based on the following:

External and internal observations during four visits to site on 14th August 2014, 28th August 2014, 11th September 2014 and 23rd September 2014;

Site and plot layout plans provided by HTA;

BRE report titled 'The structural condition of Orlit houses', first published in 1983;

HTA Feasibility Study –Rev B, ref: CAG-REM-AR-001, dated 10th September 2012;

Concrete specialist, GBG 'Report on the Investigation of 4 No. Orlit Houses', ref: 3905, dated: 20th October 2014, and a revised copy of the report dated 27th October 2014 enclosing the petrographic examination results.

1.4 Observations externally were limited to where access was permissible - generally to the front and side elevations. Where houses were inspected internally too, the rear elevations were also observed.

1.5 Observations internally were possible to only four Orlit houses; 193 Morden Road, 217 Morden Road, 241 Morden Road and 20 Hatfield Close. All four properties were in occupation and for the most part, the structure was hidden behind wall, floor and ceiling finishes. The roof spaces of all four properties were viewed but much of the structure in these spaces was concealed behind stored items and/or insulation.

1.6 During the four site visits the weather was generally mild and overcast with some occasional showers. The visit on the 14th August was an exception to this when there was a heavy downpour in the afternoon.

1.7 Opening up works and structural testing of the concrete structure by GBG have been carried out in four properties; 193 Morden Road, 241 Morden Road, 20 Hatfield Close and 1 Rutter Gardens. Areas where finishes were removed were limited by what was acceptable to the residents.

1.8 Existing plans, details & sections of the Orlit form of construction, developed from onsite observations and the published BRE reports, are provided within Appendix B.

1.9 Photographs of the existing buildings taken during site visits are provided within Appendix C.

1.10 A summary of observations made during the visit to site is provided within Appendix D.

1.11 A summary of the proposed opening up works is set out in Appendix E.

1.12 GBG's (Concrete Specialists) report of the structural testing undertaken and their observations can be found within Appendix F.

2.0 Historical Context – Ravensbury Estate and Orlit Houses

2.1 Ravensbury Estate measures approximately 4.42ha and is located in South London between the town centres of Mitcham and Morden.

2.2 The Estate consists of both traditional construction, masonry buildings and non-traditional prefabricated reinforced concrete (Orlit) houses.

2.3 Historical records indicate the site was constructed in its current form in the 1950's. Prior to this records indicate that the site was undeveloped as open fields with two parallel engineered waterways running across the site, which appear to have been linked with industrial mills on the site periphery. These waterways were later realigned into a single waterway across the site. Since the development in the 1950's there are no longer signs of the watercourses on the Estate.

2.4 Prefabricated reinforced concrete (PRC) houses were commonly built after the Second World War as a quick and economic option to combat housing shortages. They were originally intended as a 'short term' temporary solution. There were a number of different prefabricated reinforced concrete house types developed and common types included Boot, Cornish Unit, Orlit, Unity, Wates and Woolaway.

2.5 Approximately 17,000 Orlit houses were constructed in the United Kingdom by 1956. Some 9,000 were in England and Wales and the remainder in Scotland and Northern Ireland. Of the Orlits constructed across the UK some of these had flat roofs and others pitched roofs. In certain instances, pitched roofs may have been added to the properties some significant time after they were completed and occupied.

2.6 The PRC houses constructed throughout the country were commonly retained for a much longer period than intended. By the 1980's, many of the PRC house types, including Orlit, were showing noticeable signs of deterioration and were becoming a concern. This prompted an investigation into the condition of a number of PRC house types and subsequently resulted in a many being officially declared defective under the Housing Defects Act of 1985.

3.0 Description of Existing Orlit House Structure

3.1 The following description of the existing Orlit house structure is based primarily on information within a BRE report entitled 'The Structural Condition of Orlit Houses' dated 1983. This has been compared to observations of the existing structure on site. These observations have generally been consistent with the description provided in the BRE report and so the report has formed the basis of this understanding. However not all aspects of the existing structure have been checked and only a limited number of houses have been viewed internally. As such, there could be discrepancies, which have not been viewed. Sketch plans and details of the Orlit house structure are enclosed in Appendix B

General Description

3.2 The Orlit Houses on the Ravensbury Estate are two-storey semi-detached dwellings with tiled pitched roofs. Each unit appear to be similar in construction and measures approximately 20 x 24 ft. deep. One noticeable variation is that some houses have gabled roofs and some have hipped roofs.

3.3 The load bearing structure of each house comprises of a prefabricated reinforced concrete (PRC) frame of columns and a grillage of primary and secondary beams at first floor and ceiling level. At first floor level, the secondary beams support timber joists and floorboards. The roofs are carpentered and supported on the grillage of PRC beams at ceiling level. The ground floor structure feels solid and is likely to be a solid ground bearing concrete slab although this has not been confirmed. The stairs to first floor are of timber construction.

3.4 Each house unit has a complete PRC frame – so that there are two lines of columns and primary beams on the party wall lines of the semi-detached units. It is not clear how adjacent frames are tied together.

3.5 The external walls are formed of cavity wall construction with an inner thin blockwork leaf and an outer leaf of interlocking precast concrete panels. The party walls are also of cavity wall construction consisting of two thin leaves of blockwork. Other internal walls form non-structural partitions and appear to be a combination of timber and/or lightweight concrete blocks.

3.6 The BRE report considers overall stability of the house structures is provided by diaphragm action in the external walls and internal cross walls. This is likely to rely mostly on the blockwork inner leaf and party wall which are built between the columns.

3.7 The local geology map indicates the natural ground conditions on the site comprise Alluvium across most of the site overlying River Terrace Deposits. These superficial deposits lie over the London Clay Formation. Whilst trial pits have not been excavated, it is likely the houses are formed on shallow concrete spread foundations bearing in the River Terrane Deposits provided the depth of made ground is not significant.

3.8 The original houses appear to have had a canopy over the main front entrance. This consisted of two prefabricated reinforced concrete columns supporting a concrete roof canopy which extends back to the concrete panels in the outer leaf of the elevations. These canopies and columns have been removed from some of the properties. Where this has occurred, some have been replaced with a plastic canopy and some have not.

Detailed description of structural elements

3.9 The BRE report indicates there are nine 5½ in. (approx. 140mm) square columns. Each column is made up of two prefabricated lengths jointed together with steel bolted connections just above first floor. Columns are connected to the ground floor slab in a similar fashion using steel bolted connections.

3.10 The primary prefabricated beams run front-to-back between columns at both first floor and ceiling level forming the primary frames. The primary beams are quoted in the BRE report as 8 in. (200mm) deep upside-down 'T' sections. The bottom width of the beam was measured on site as approximately 11.5 in. (290mm) wide. Where observed, connections of primary beams to columns appear to be via in-situ concrete connections.

3.11 Secondary beams run perpendicular to the primary beams at both first floor and ceiling level and provide lateral restraint to the three 'main frames' of each house. They are spaced at roughly 4ft (1.2m) centres. The secondary beams along the front and rear elevations are slightly set back internally of the external wall line. The BRE report indicates the beams as 4 x 7 in. (100 by 175mm) deep rectangular sections with filleted sectional profiles along the beam length. The ends of the beams are notched allowing them to rest on the primary beam flanges whilst maintaining the same top of concrete level with the primary beams.

3.12 In-situ concrete stitches secure the secondary beams to the primary beams. Continuity bars are present within some of these stiches on the line of the three column planes but not intermediate beam connections.

3.13 The timber construction at first floor level consists of 1 in. (25mm) deep timber boards supported on 3 x 2 in. (75 by 50mm) timber joists. These joists span between to the secondary beams and rest on top of the concrete beams. There are also separate timber battens fixed to the soffit of the secondary beams to which ceiling finishes are fixed. The battens appear to be held in place by steel hangers wrapped over the beams. The total depth of the first floor construction is therefore about 325mm.

3.14 There is no secondary timber floor structure or boarding on top of the concrete beams at first floor ceiling level within the observed roof spaces. Timber battens below the concrete beams support the ceiling finishes in a similar way to first floor level. The timber battens are hung from the secondary beams in the floor space using small (approx. 4mm) diameter metal bars, as illustrated in Photographs C1 and C13.

3.15 The timber roofs are carpentered with rafters extending down from a ridge plate on to secondary beams along the front and rear elevations. Additional support is provided via timber purlins which are propped via raking timber struts extending up off the concrete frame. The sole plates at the bases of the rafters are fixed to the perimeter concrete beams with metal straps – presumably to prevent the rafters from spreading. Photographs C5, C12 and C14, illustrate the timber roof arrangement and sole plate strapping.

3.16 The outer leaf of the external walls is described in the BRE report as 2 in. (50mm) thick PRC 'Orlit' cladding panels. These tend to be up to 4 ft. (1.2m) wide by 1 ft 4 in. (400mm) deep. Bespoke panels are used on the corners of the building and in line with the party walls. They are bedded on mortar and generally fixed back to the inner blockwork leaf using bespoke galvanised wall ties. There appears to be no intermediate support of the panels at first floor level.

3.17 The inner leaf blockwork is document within the BRE report to be.$2^1/_2$ in. (63mm) thick and consist of lightweight concrete blocks, however GBG quote the inner skin as 3½ in. (90mm) based on onsite measurements. The cavity width is not documented within the BRE report but has been measured on site as approximately 6 in. (150mm). It was noted that the cavity is vented via higher and lower level vents contained within 'grilled' cladding panels on the elevations.

3.18 The window frames are constructed using prefabricated reinforced concrete elements joined together on site. These PRC frames appear to support the concrete panels over.

3.19 On the party wall line, there is a chimney stack shared between adjoining houses. These are generally of brick construction. Properties between 28 and 34 Ravensbury Grove have a different style chimney stack formed from two separate rendered piers, lead flashed at the roof interface and topped with a capping section. (See photograph C26).

4.0 Summary of Issues Raised within BRE Report Concerning the Condition of Orlit Houses

4.1 During the 1980's, the Building Research Establishment (BRE) undertook a number of studies on the structural condition of Orlit houses. This was based on a review of 83 Orlit houses across the UK. The findings are summarised in their report 'The Structural Condition of Orlit Houses' dated 1983 and is set out below.

4.2 In relation to the structural components of the Orlit house types, the following issues relating to the condition of the structures were commonly found:

i. The most advanced deterioration in the structural components has been found in the secondary beams in flat roof construction where a combination of roof leakage and condensation has provided a damp environment for the components. Similar deterioration has been found, however, in some first-floor construction. The documented deterioration of the secondary beams comprises longitudinal cracking in the sides and soffits of the secondary beams and inclined cracking and disruption at the bearings. This deterioration has occurred in the presence of medium or high chloride content and where concrete has carbonated to the surface of the reinforcement.

ii. Longitudinal cracking has been documented within soffits and sides of main (primary) beams and the soffits of stiches in addition to some fine transverse cracking. Shrinkage cracks at the interface of in situ stitches and precast beams was also documented. The cracking was recorded as being a result of corrosion of reinforcement in carbonated concrete and in some instances, excessive chlorides in the concrete.

iii. Little cracking was recorded in columns.

4.3 In relation to the non-structural components of the Orlit house types, the following issues were commonly found:

i. Spalling of concrete cladding panels as a result of corrosion of reinforcement;

ii. Extensive deterioration of the corner cladding units in the same manner as the cladding panels;

iii. Cracking and spalling of the front door canopies and supports;

iv. Cracking of the chimney stacks;

v. Bowing and leaning-out of the uppermost layer of panels on the front elevations of the houses with pitched roofs;

vi. Cracking and spalling of the reinforced concrete soffit units in flat roof housing;

vii. Widening of the panel party wall junction.

5.0 Observations by Tully De'Ath Regarding the Condition of the Existing Structure

5.1 Set out below is a summary of observations made in relation to the condition of the existing structure. Many of the observations across the 72 properties can be grouped in to a number of categories which have been tabulated against each of the properties. This table is set out in appendix D. Photographs of some of the observations made are enclosed in appendix C. The observations are discussed in more detail below.

5.2 The following observations were made externally:

i. Cracking has occurred to a number of the PRC corner cladding units. The cracks range from hairline up to about 10mm wide and extend vertically up the corner of the building where they occur. In a number of instances the corner cladding units show signs of patch repairs or have been replaced with new cladding panels. Refer to photographs C9, C15, C16, C17 and C30 in appendix C.

ii. A number of party wall cladding units show signs of spalling or cracking and patch repair. The cracking observed varied between hairline to 1mm in size and ran vertically along the panels. Patch repairs were visible on some houses and tend to be to the mortar joints running vertically between the party wall and main elevation panels. See photographs C22, C27 and C31.

iii. These damaged areas of cladding on the corners and by the party walls tend to be more prevalent on the north and northwest facing elevations. Sketch number 11264/SK01 indicates the locations where spalling was observed.

iv. Across a number of houses, there are signs of patch repairs to the mortar between cladding panels. The table in Appendix D summarises where this was observed. The most extensive repairs were noted on the front elevation of 13 Hatfield Close (See photograph C27).

v. Some of the external columns supporting canopies have spalled close to the upper end of these units, immediately below the soffit of the canopy roof. In some instances, the reinforcement bars within the column sections have become exposed, showing signs of corrosion. Refer to photographs C16 and C23.

vi. Many of the houses have regular circular markings on the concrete panels, approximately 50 to 75mm in diameter. These appear to represent holes drilled in the panels which have subsequently been re-filled with mortar. Refer to photograph C18. This may be linked with works to inject insulation into the cavity of the elevations which appear to have been carried out much later than the original construction. GBG's observations support this theory as they found the cavities to 1 Rutter Gardens and 20 Hatfield Close were 'filled with a foam insulation'. This coincides with the circular markings observed on the elevations, which were not evident on 193 and 241 Morden Road where cavities were found to be clear.

vii. The elevations of the houses tend to have a painted finish. Seven houses have a pebble dash finish and some houses are unpainted. Where paint or pebble-dash has been added, the ventilation grills have been partly or completely sealed. There are also examples of what appears to be mortar filling of the grilled cladding units. Refer to photographs C8, C9, C9a and C31.

viii. A few of the PRC window frames have cracking running longitudinally along the top horizontal members. These vary between hairline and 1mm in size In some cases there were also small (approx. 10mm) chips to the edges of concrete elements. Photograph C9a shows an example of this.

ix. Whilst the downpipes and guttering could not be viewed up close, some of the guttering was visibly in a poor state of repair. This was particularly so at 54 Ravensbury Grove and 7

Rutter Gardens, where the eaves boarding was noticeably decayed and the rafters behind are visible. In all cases the guttering appeared to be plastic. See photographs C28 and C29.

5.3 The following observations were noted internally in the properties where access was possible. These are 193 Morden Road, 217 Morden Road, 241 Morden Road and 20 Hatfield Close. GBG Ltd were also able to view 1 Rutter Gardens internally during their onsite investigations.

i. Where access was gained to properties the structure was generally concealed (as documented within the BRE report) by wall, floor and ceiling finishes. However elements of the structure were available for visual observation within the roof space. Most areas of the roof space within 241 Morden Road and 20 Hatfield Close were accessible for visual observations of the tops and sides of primary and secondary PRC beams. Visual observations were more limited within 193 and 217 Morden Road due to stored items obstructing access and hence visual inspection.

ii. Observations within the roof spaces confirmed the general arrangement of the beams as outlined within the BRE report, section 3 of this report and as illustrated within 11264/SK02. It is worth noting that the roof spaces were dry with no signs of leaks where observed.

iii. Where observed there were no obvious signs of deterioration to the visible surface of the primary and secondary beams. The exception to this was within the roof space of 20 Hatfield Close where chips were evident in the top edges of a number of secondary beams. These vary between 5 and 40mm deep. Photographs C3, C6 and C7 show examples of the described chipping.

iv. Where access was available a number of primary and secondary beam in-situ ‘stitch’ connections were observed within the roof spaces. The stitches were generally as documented within the BRE report and illustrated in sketch no. 11264/SK02. There were no obvious signs of deterioration on the visible surface of the stiches observed. However there is one example observed within the roof space of 20 Hatfield Close where a gap of approximately 10mm wide exists between the connection of one of the central primary beams and secondary beams. This could potentially indicate movement in the structure. Although there are potential signs of horizontal movement within this joint the primary beam still provides approximately 40mm bearing to the secondary beam on its flanged section. Therefore, there is no obvious concern in the stability of the structure due to the potential movement seen and discontinuity in the concrete. Photographs C2 and C4 illustrate the discontinuity described.

v. The small diameter hangers (described in section 3) supporting the ceiling timber battens are not structural elements although it is worth noting that where observed, some show signs of surface rusting.

vi. Localised breakouts of concrete columns and beam elements were undertaken to expose the reinforcement within. Where exposed beans and columns were found to be traditionally reinforced with plain round bars. These bars generally exhibit light surface corrosion

vii. GBG’s visual observations are summarised within section 6.0.

6.0 Summary of Intrusive Investigations and Specialist Concrete Testing by GBG

6.1 Intrusive investigations and concrete sampling and testing were undertaken on four Orlit Houses;193 Morden Road, 241 Morden Road, 20 Hatfield Close and 1 Rutter Gardens.

6.2 These investigations were undertaken by concrete specialist GBG Ltd over four consecutive days starting on 22nd September 2014.

6.3 They consisted of:

Visual inspections;

Traditional intrusive inspections and breakouts;

Covermeter surveys;

Carbonation testing;

Chloride content tests;

Cement content tests;

Tests to check for the presence of HAC (High-alumina cement);

Petrographic examination of concrete samples;

Metal and impulse radar surveys of galvanised wall ties in cavities of elevations.

6.4 The testing and inspection regime was specifically developed to give an impression of the general condition of the concrete structure but also to target areas of concern that had previously been raised in the BRE report from the 1980's.

6.5 On completion of the inspections, concrete and blockwork walls were made good by GBG and reinstatement of finishes and redecoration was undertaken by others. v

6.6 A summary of the visual observations by GBG is noted below:

i. The opening up works carried out to the four Orlit houses confirmed their structural form was similar to that outlined within the BRE report.

ii. GBG found there to be no obvious visual signs of cracking or spalling to the surface of the concrete elements where these were inspected.

iii. Localised breakouts of concrete columns and beam elements were undertaken to expose the reinforcement within. Where exposed the precast reinforced concrete (PRC) beams and columns were found to be traditionally reinforced with plain round bars. GBG noted that these bars generally exhibit light surface corrosion.

iv. Within the roof spaces, the individual continuity bars were exposed at the connections of the primary-to-secondary beams where they rest over the central column of the house. Where

observed these bars appeared to be in a good condition although some light surface corrosion was observed.

v. The steel plated column-to-column connections were as outlined within the BRE report where observed. There was light-to-moderate corrosion noted on the steel surfaces.

vi. The cavities within the external walls of all four properties were viewed. 193 and 241 Morden road have clear cavities but those within 1 Rutter Gardens and 20 Hatfield Close were filled with foam insulation.

Concrete cover and carbonation Results

6.7 The level of risk of corrosion to reinforcement bars in concrete is largely dependent on the amount of cover to the reinforcement and depth of carbonation. Carbonation is a chemical process that reduces the alkalinity and hence the amount of protection the concrete provides to the reinforcement. Carbonation commences at the surface of exposed concrete and penetrates into the concrete with time. The rate of penetration of carbonation from the surface is a good indicator of the quality of the concrete for a given timescale.

6.8 GBG carried out a covermeter survey at forty eight test locations across the four Orlit houses. These showed that the cover to the reinforcement varied in the columns, primary beams and secondary beams. The minimum cover measured for each of these elements respectively was 3mm, 19mm and 2mm and the maximum cover recorded was 76mm, 58mm and 36mm.

6.9 Carbonation tests were also undertaken at the same forty eight locations. At eight of these the depth of carbonation had reached or had exceeded the depth of concrete cover to the reinforcement. At a further six locations the depth of carbonation was within 5mm of the depth of cover. The remaining thirty four samples tested appear to have a reasonable margin of un-carbonated concrete around the reinforcement.

Chloride content

6.10 Typically chlorides may be present as additives in the original concrete mix or from a later external source, such as de-icing salts. Chlorides are able to penetrate concrete in the presence of water (in solution) and increase the rate at which corrosion of reinforcement occurs.

6.11 GBG tested fifty dust samples for chloride content. These samples were taken from the PRC columns and beams and the in-situ mortar joints. The chloride contents of all seven mortar samples were low at 0.15% or less. Generally the chloride content of the concrete samples were also low at 0.07% or less. There were six exceptions to this however which showed a chloride content ranging from 0.16% to 1.33%. These were on two samples extracted from the secondary beams within 193 Morden Road, three samples extracted from columns within 20 Hatfield Close and a single sample extracted from a primary beam in the roof space of 20 Hatfield Close.

Cement Content

6.12 From visual inspections of eight samples, the cement contents vary between 10.3% to 18.7%. GBG consider these are indicative of reasonable to good quality precast concrete. The variability of cement content is considered not uncommon for structures of this age.

High Alumina Cement

6.13 High-alumina cement (HAC) is an alternative cement mix to Ordinary Portland cement (OPC). It became favourable within the industry as concrete made from it sets rapidly and has a high initial strength. However, under certain conditions it loses strength over time due to a chemical process. As such, it became classified as a deleterious material and was banned from use in 1975. The BRE report on Orlit Houses highlights that many of the precast reinforced concrete elements and in-situ

mortar stitches of the Orlit houses that they surveyed contain HAC.

6.14 Twenty four samples were tested by GBG across the four properties. None of these were found to contain HAC.

Alkali-Silica Reaction

6.15 Alkali-silica reactions (ASR) are expansive reactions that can take place within concrete causing it to crack. Certain types of aggregates react with alkalis that are present within the cement to form a gel with an increased volume. This internal expansion causes micro-cracking in the concrete. The potential for ASR will be confirmed following the petrographic examinations.

Petrographic Examinations

6.16 One sample from each of the four properties has been sent for petrographic examination. This will enabled the constituent parts of the concrete to be identified and whether any deleterious reactions, such as ASR, have occurred.

6.17 The results of all the petrographic examinations showed that the concrete appears to be good quality with no obvious evidence of significant distress.

Cavity wall tie surveys

6.18 Impulse radar and metal detection surveys were undertaken on some of the external cavity wall panels to determine the spacing of the galvanised ties within the cavity. Where openings were formed in the elevations internally, the wall ties were also visually inspected.

6.19 Where surveyed the spacing of the wall ties were found to be between 250mm and 900mm horizontally and 400 to 420mm vertically. There were limited ties however around door and window openings and no ties were identified on the corner cladding panels.

6.20 The wall ties observed appeared to be in a good condition with a drip detail groove generally well positioned approximately in the centre of the cavities. Visual inspections of the wall ties within 1 Rutter Gardens and 20 Hatfield Close were limited because the cavities were filled with a foam insulation.

6.21 The wall ties were found to be embedded by approximately 15mm within the horizontal mortar joints between the external leaf precast cladding panels and embedded approximately 35mm into the horizontal mortar joints of the blockwork inner skin.

7.0 Discussion on the Existing Condition of the Orlit Houses

7.1 Where observed the concrete framed structures of the four properties appear to be in a reasonable condition for their age and construction. This is supported by the concrete test results provided by GBG to date. The Petrographic examinations are outstanding so this will be considered further when the results are available. At present however, and based on observations carried out, the main issues associated with the condition of the building relate to the precast concrete cladding panels and the original entrance canopies.

The Concrete Frame

7.2 Where viewed there are no obvious signs of significant deterioration to the concrete frames. The main issues identified relate to some chips which were seen on the top surfaces of secondary beams within the roof space of 20 Hatfield Close and slight surface corrosion to a few of the steel dowel bars and steel plated connections. The chips appear to be due to mechanical damage possibly caused during construction and are not of concern structurally. The slight surface corrosion seen is indicative of a damp atmosphere or lack of ventilation within the cavity walls or roof spaces in the past.

7.3 The wide range of GBG results of cover to the reinforcement in the precast concrete elements suggests the workmanship during construction was variable. The depth of carbonation within the concrete also varies, supporting this view.

7.4 The levels of chlorides within the concrete were also generally low although there were a few samples with higher levels of chlorides. These higher figures may be linked with poorly washed marine aggregates or chloride-containing additives being used in the original construction. Again it supports the view that the original construction was variable.

7.5 The higher depths of carbonation and higher levels of chlorides are not of concern structurally provided water ingress into the concrete structures is prevented. If allowed to occur, embedded reinforcement is vulnerable to corrosion which could lead to cracking and spalling of the concrete elements. The higher levels of chlorides will tend to accelerate this process, if water ingress occurs.

7.6 High-alumina cement has not been detected in the concrete elements tested.

7.7 The petrographic examinations show no obvious signs of significant distress within the foul concrete samples tested.

7.8 It is worth noting that the most significant structural engineering concerns raised by the BRE in their assessment of the Orlit houses related to secondary beams within the flat roofs of houses. Such beams were particularly vulnerable to higher concentrations of potentially ‘standing’ water. All of the Orlit houses on the Ravensbury Estate have pitched timber roofs and – where four of seventy two have been viewed – have dry reasonably ventilated roof spaces.

The External Envelope of the Orlit Houses

7.9 The surveys carried out have shown there are galvanised cavity wall ties in the wall construction of the elevations. Whilst the ties appear to be in a reasonable condition where viewed, the depth of embedment of the ties in to the internal blockwork leaf is only 35mm and the corresponding embedment in to the mortar joints of the precast panels is only 15mm. Current British Standards recommend the minimum depth of embedded should be 50mm. The spacing of the ties recorded is also reasonable except around door and window openings. It also appears there were few, if any, ties tying the corner cladding panels back to the inner leaf. It therefore appears the ties may not be as effective as intended.

7.10 Whilst there were no obvious signs of bowing or leaning in of outer leaf of the elevations, the corner cladding panels have cracked or spalled in a number of locations. Without cavity wall ties, these corner panels are more vulnerable to the effects of thermal movements in the elevations. Such movement will encourage joints to open up in the junctions of the corner panels encouraging water ingress to occur. Such movements may also have caused the cladding panels on the party wall lines to open up too. The BRE report highlights these cladding panels are reinforced. Given the thin nature of these panels, reinforcement is more likely to corrode where excessive water ingress occurs and this may have caused the cracking and spalling seen. Freeze-thaw action will exacerbate the situation.

7.11 Cavity walls rely on the cavity being ventilated so that moisture that passes through the outer leaf has a means of escaping in to the atmosphere. In the original construction, ventilation grilles were incorporated in to the precast concrete panels to permit this. Where the cavities have been filled with insulation, this process can no longer occur. Where the grilles have been painted over, it has probably has a similar effect. Such measures will encourage water to remain in the cavities. The insulation within the cavities will also have created new pathways for moisture to pass across the cavity. Such issues will encouraged the panels to remain wetter for longer and could be increasing the level of moisture in the concrete structures where they sit in the cavity.

7.12 The damage to the concrete entrance canopies and precast concrete window frames is also linked with water ingress causing corrosion of embedded reinforcement.

7.13 The poor state of repair to some of the gutters and downpipes will also encourage water ingress to occur. This tends to affect timber eaves boards and the ends of timber rafters initially, but if left untouched, higher concentrations of water over a period of time can saturate the elevations. This could also be contributing to some of the issues seen in the cladding panels and could be affecting structural concrete elements where positioned in the cavity. The downpipes for instance are located close to the corners of the building where there are a number of corner cladding panels suffering cracking and spalling.

8.0 Concluding Remarks on Condition of Orlit Houses and Extending Their useful Life

8.1 The usual approach of dealing with existing buildings is to assess them and to address issues (by way of repairs) which are highlighted as a result of that assessment. Such an assessment considers the quality of the original design and construction, how the structure has been altered, if at all, and the condition of the building fabric. The strategy for repairs needs a discussion with the building owner as there is often a balance to be made between the costs of repairs and the building owner's expectations of how they want the building to perform.

8.2 The Orlit houses need to be considered slightly differently in that this type of proprietary construction has already been subject to concerns and thorough investigation by the BRE elsewhere in the UK. They have also been identified as defective.

8.3 However, if the reported defects from the BRE report can be proved to not be prevalent in the houses specifically being assessed, the historic concerns should not affect the approach to how the useful life of the building is extended.

8.4 The crucial point here though is how much investigation and appraisal is required to demonstrate this. Whilst the requirements of potential mortgage lenders and warranty providers such as NHBC cannot be commented on at this time, it is likely they would require a very thorough structural appraisal of the majority – or even all - of the Orlit houses to be carried out before the buildings can be accepted by them as having a 'clean bill of health'. Such an approach however would be very costly and disruptive, not only as it would have to consider most (or all) of the houses, but also because the investigations within each house would probably need to be far more extensive than has been possible to date. There is also a risk that some houses may be shown to have unacceptable defects and so do not 'pass' the test.

8.5 If the houses were to be retained for rent only, and a NHBC warranty was not necessary, then the extent of further structural assessments required may differ from what potential mortgage lenders and the NHBC require. This point needs further discussion with the interested parties however to understand their expectations.

8.6 Based on the observations and concrete testing carried out to date, the Orlit houses appear to be consistent in much of their construction with that described in the BRE Reports from the early 1980's. There have been no structural engineering concerns identified however and the concrete frames, where investigated, are in a reasonable structural condition. The main concerns highlighted with the BRE research related to concrete beams on flat roofs. The roofs of the Orlit houses at Ravensbury Estate are pitched. It should be recognised however that this conclusion is based on only a limited amount of investigations within a small proportion of all the Orlit houses.

8.7 If the conclusions reached from the assessment of the 4 Orlit houses were to be reflected in the other 68 properties, then the main issues to consider are linked with the effects of water ingress and the cladding panels.

8.8 Water ingress can affect the condition of the roof timbers through beetle infestation or decay. As has been seen with the entrance canopies, water ingress can also cause deterioration of concrete elements, especially where reinforcement is allowed to corrode. To extend the useful life of such buildings it is therefore important to have an effective maintenance regime in place to keep external finishes in good order and to limit potential for water ingress.

8.9 It is therefore important to keep gutters and downpipes clear for debris so they can work effectively.

8.10 The cladding panels need to be made good where the joints in the cladding panels have opened up. This will reduce the potential for water ingress. The spalled and cracked corner panels also need

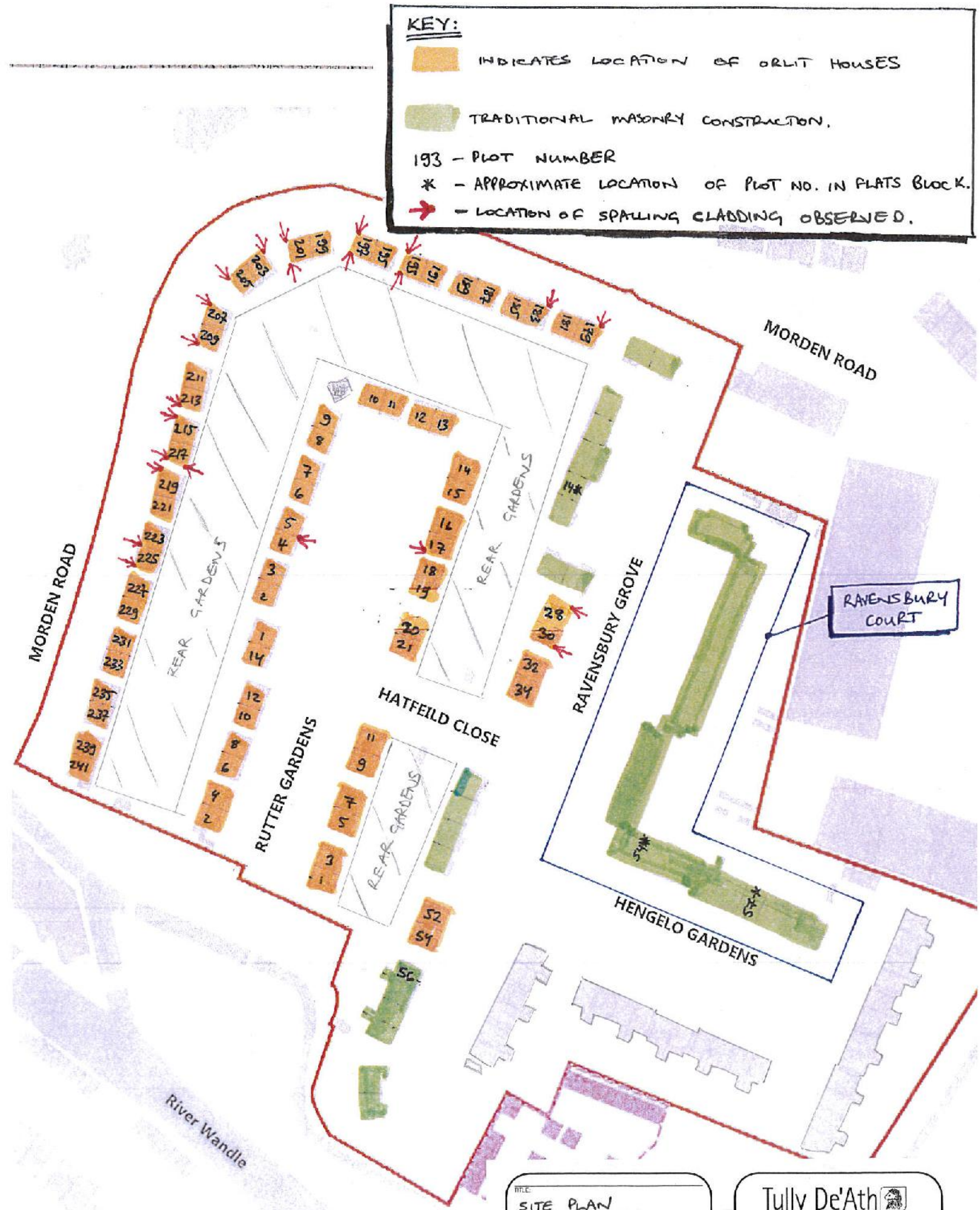
replacing and will require additional restraint to tie them back to the structure behind. This will take the form of remedial wall ties and these may also need to be introduced around window and door openings where there are currently a lack of ties. Such an approach will require both a visual and a radar survey of every elevation to be carried out.

8.11 The strategy for repairs to the cladding panels needs to be coordinated with non-structural matters to improve the insulation to the elevations. The cavities which are currently filled with insulation are potential encouraging water to become trapped in the building. Options here include removing the cladding panels so that the insulation can be removed or over-cladding the building with a new rainscreen

8.12 Similarly the cracking to the window frames should also be made good.

8.13 Although not significant structurally the concrete entrance canopies and support where deteriorated should also be made good and/or removed and replaced with new canopies. The junction of the canopy with the elevations needs to prevent water draining back on to the elevation.

Appendix A - Site Plan



undaries and areas

TITLE: SITE PLAN

PROJECT: RAVENSBURY ESTATE

SCALE: N.T.S DATE: 09/14 DRAWN: TP CHK'D:

JOB NO 11264 DRG NO SK01 REV

Tully De'Ath consultants

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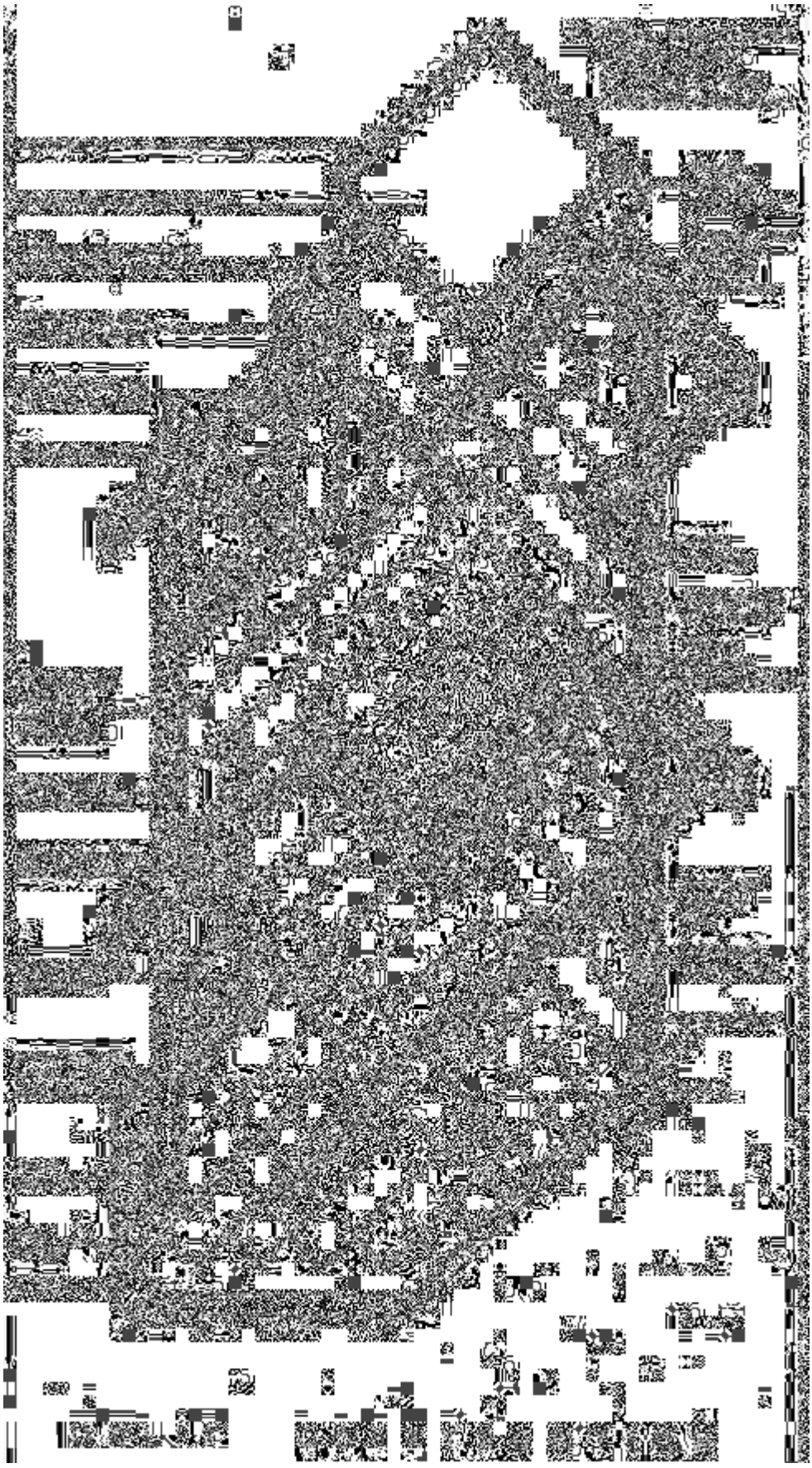
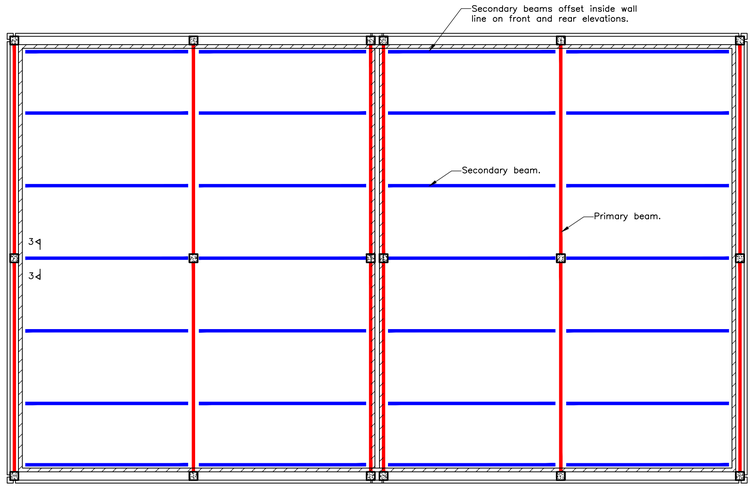
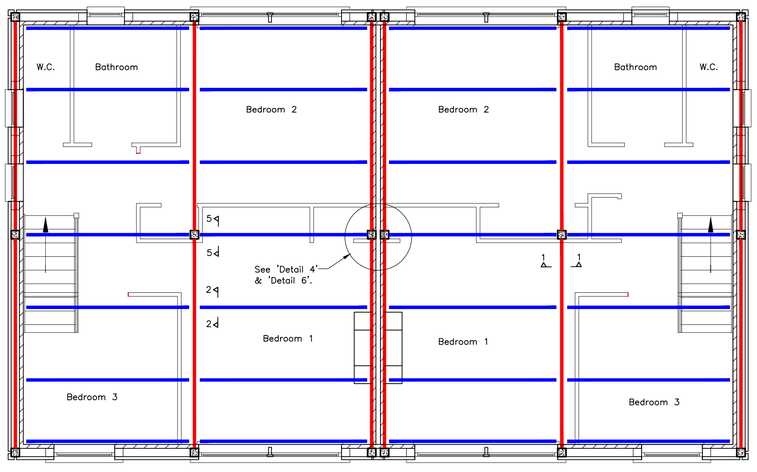
Appendix B – Existing Plans, Details and Sections of Orlit Form of Construction

Extract From BRE Report

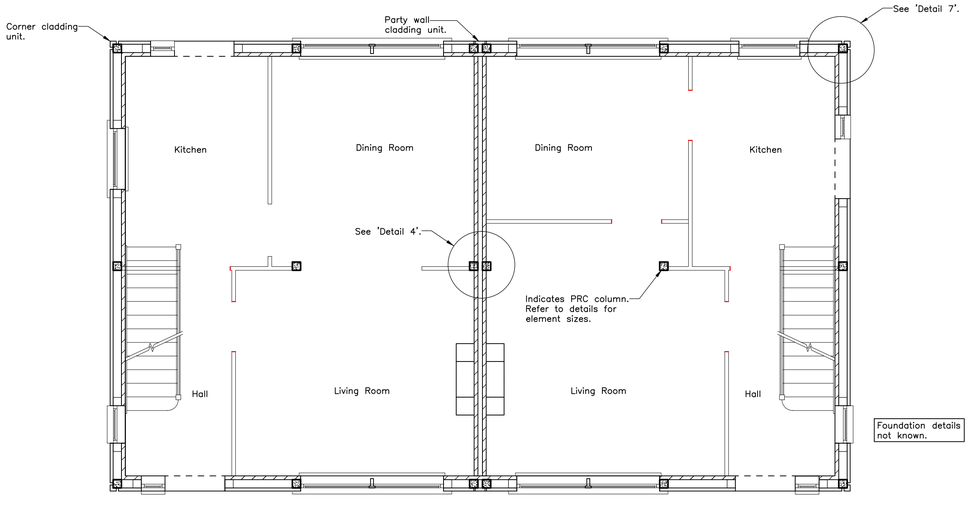




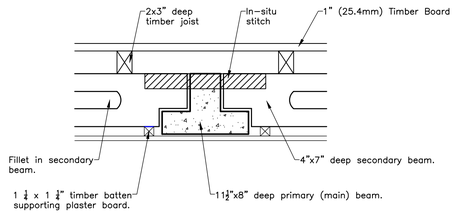
Roof.



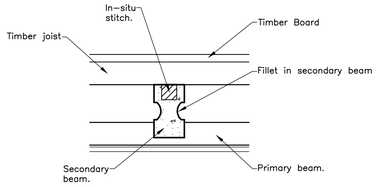
First Floor.



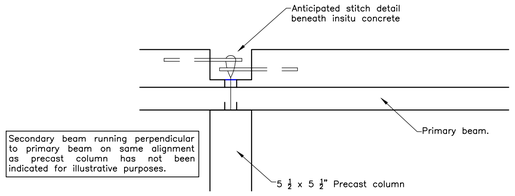
Ground Floor.



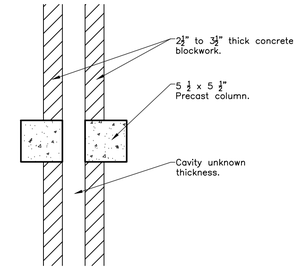
Section 1–1: First Floor Primary & Secondary Beam Connection Detail.



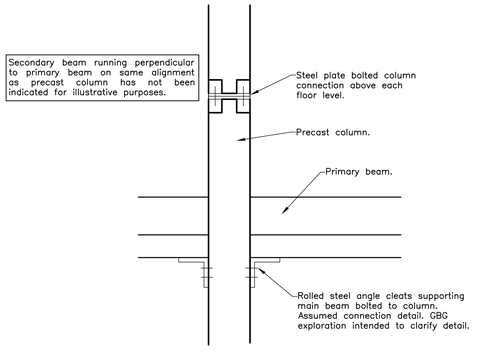
Section 2–2: First Floor Primary & Secondary Beam Connection Detail.



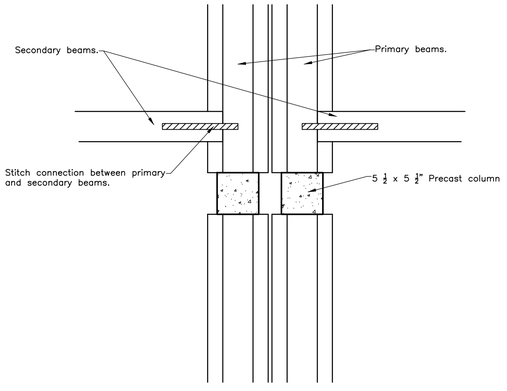
Section 3–3: Anticipated Primary Beam & Column Connection At Eaves Level.



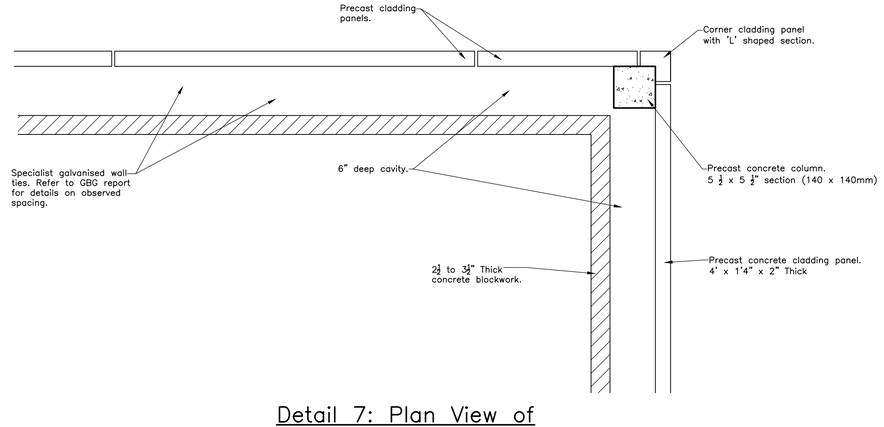
Detail 4: Anticipated party wall detail.



Section 5–5: Anticipated Primary Beam & Column Connection Detail at First Floor.



Detail 6: Plan View Of Anticipated Arrangement of Columns & Beam Connection on Party Wall Line.



Detail 7: Plan View of Corner Column & Wall Detail.

General Notes

1. Layout drawings produced from BRE document 'The structural condition of Orlit house', HTA plan drawings. Drawing to be used for discussion and illustrative purposes only and all dimensions and layouts to be confirmed on site.
2. Internal layouts illustrated are typical and may not represent site conditions. All layouts should therefore be confirmed on site.
3. Please note that similar labeled elements have the same dimensions. Where dimensions of elements are not provided on details/sections refer to another detail/section where they are.

Indicates location of main beam.

Indicates location of secondary beam.

REV	DATE	DESCRIPTION	BY	CHK'D
A	24.10.14	Updated following GBG observations.	TP	

HTA

TITLE:
Existing Orlit House Plans & Construction Details.

PROJECT:
Ravensbury Estate

SCALE: 1:50, 1:10 DATE: Sept '14 DRAWN: BD CHK'D: TP

JOB NO.	DRG NO.	REV.
11264	SK02	A

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Appendix C – Photographs

Photograph C1 – Primary beam and secondary beam connection and ceiling hanger

Photograph C2 – Discontinuity of mortar/concrete between primary beam and secondary beam connection

Photograph C3 – Damage to secondary beam

Photograph C4 – Discontinuity of mortar/concrete between primary beam and secondary beam connection

Photograph C5 – Roof sole plate strapping to primary beam

Photograph C6 – Damage to secondary beam

Photograph C7 - Damage to secondary beam

Photograph C8 – ‘Grilled’ cladding panels in elevation

Photograph C9 – Spalled corner cladding panel and covered venting cladding panel to rear of 193 Morden Road

Photograph C9a – Spalled corner cladding panel and covered venting cladding panel to rear of 193 Morden Road

Photograph C10 – Evidence of internal column projection on party wall line into room

Photograph C11 – Concrete stitch

Photograph C12 – 124 Morden Road roof structure

Photograph C13 – Primary beam and secondary beam stitch connection detail and ceiling hanger

Photograph C14 – 241 Morden Road roof structure

Photograph C15 – Evidence of corner cladding repair

Photograph C16 – Example of corner cladding and canopy support spalling

Photograph C17 – Corner cladding patch and repair

Photograph C18 – Circular markings on elevation

Photograph C19 – Example of no finishes to cladding and porch extension

Photograph C20 – Pebble dashed elevation

Photograph C21 – Porch alteration

Photograph C22 – Party wall cladding unit mortar repair

Photograph C23 – Canopy support spalling

Photograph C24 – Vegetation on elevation

Photograph C25 – Example of removed canopy

Photograph C26 - Double stack Chimney

Photograph C27 – Significant mortar repair

Photograph C28 – Damaged guttering

Photograph C29 – Damaged guttering

Photograph C30 – Patch repair to corner cladding

Photograph C31 – Painted vent in cladding and party wall cladding mortar joint cracking

Appendix D – Summary of External Observations

Summary of Tully De'Ath External Observations of the Orlit Houses on the Ravensbury Estate

No.	Street	Spalling to Corner Cladding Unit	Spalling to Cladding on Party wall	Spalling Canopy Supports	Signs of Mortar Repair to Cladding Panels	Regular circular Markings on Elevation	Cracking on Window Framework	Pebble Dashed Exterior	Entrance Canopy removed/not Original	Other Comments
179	Morden Road	●				●				
181	Morden Road					●			●	
183	Morden Road	●								
185	Morden Road									
187	Morden Road			●						
189	Morden Road								●	
191	Morden Road					●			●	Patch repair to mortar where canopy has been removed.
193	Morden Road	●					●			
195	Morden Road						●	●		
197	Morden Road	●								
199	Morden Road									
201	Morden Road	●		●						
203	Morden Road	●				●				
205	Morden Road	●				●			●	
207	Morden Road	●						●		Pebble dashed upper elevation, stone effect to lower elevation.
209	Morden Road	●				●				Corner cladding appear to have been replaced full height
211	Morden Road									
213	Morden Road	●								
215	Morden Road	●	●							
217	Morden Road	●	●						●	
219	Morden Road	●				●			●	
221	Morden Road								●	
223	Morden Road		●		●	●			●	
225	Morden Road	●	●							
227	Morden Road								●	
229	Morden Road					●		●	●	
231	Morden Road			●						
233	Morden Road							●		Blueish staining on elevation below roof soffit
235	Morden Road								●	
237	Morden Road							●		
239	Morden Road									
241	Morden Road			●						

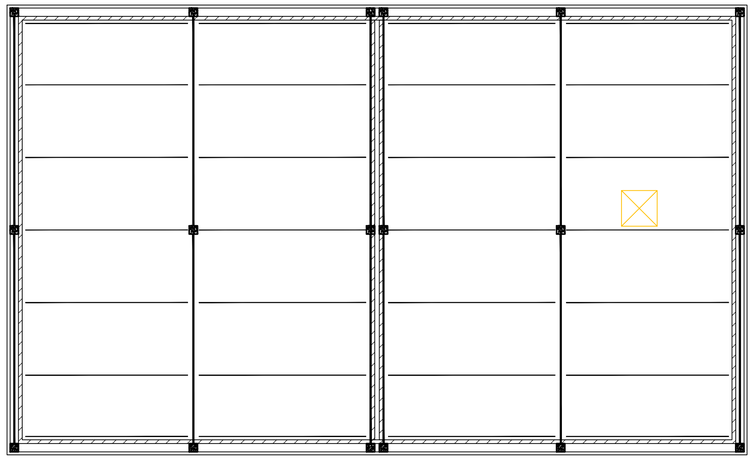
Summary of Tully De'Ath External Observations of the Orlit Houses on the Ravensbury Estate

No.	Street	Spalling to Corner Cladding Unit	Spalling to Cladding on Party wall	Spalling Canopy Supports	Signs of Mortar Repair to Cladding Panels	Regular circular Markings on Elevation	Cracking on Window Framework	Pebble Dashed Exterior	Entrance Canopy removed/not Original	Other Comments
11	Rutter Gardens					●				
9	Rutter Gardens								●	
7	Rutter Gardens					●				Gutters in poor state of disrepair.
5	Rutter Gardens					●			●	
3	Rutter Gardens								●	
1	Rutter Gardens					●				
2	Rutter Gardens					●				
4	Rutter Gardens								●	
6	Rutter Gardens					●			●	
8	Rutter Gardens					●			●	
10	Rutter Gardens								●	
12	Rutter Gardens					●			●	
14	Rutter Gardens					●			●	
1	Hatfield Close					●			●	
2	Hatfield Close					●			●	
3	Hatfield Close					●				
4	Hatfield Close		●			●			●	
5	Hatfield Close		●			●				
6	Hatfield Close					●				
7	Hatfield Close					●				
8	Hatfield Close									
9	Hatfield Close					●				
10	Hatfield Close				●					
11	Hatfield Close					●				
12	Hatfield Close					●		●	●	
13	Hatfield Close				●	●				Significant mortar repairs between cladding panels
14	Hatfield Close									
15	Hatfield Close					●				
16	Hatfield Close							●	●	
17	Hatfield Close	●								
18	Hatfield Close					●				
19	Hatfield Close					●				
20	Hatfield Close					●				
21	Hatfield Close				●	●			●	

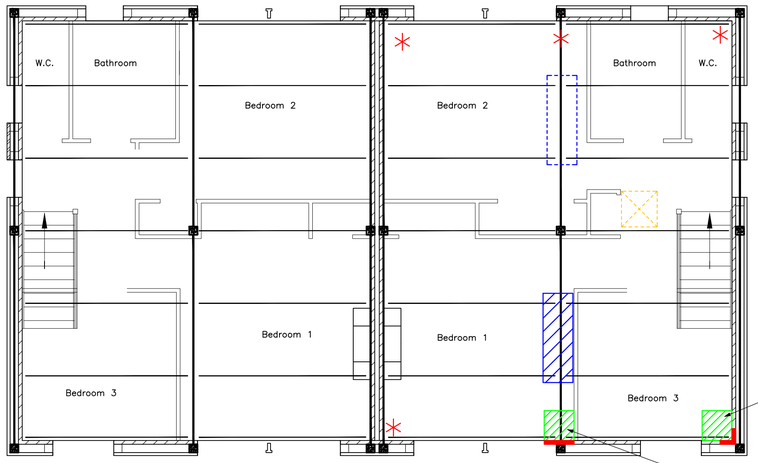
Summary of Tully De'Ath External Observations of the Orlit Houses on the Ravensbury Estate

No.	Street	Spalling to Corner Cladding Unit	Spalling to Cladding on Party wall	Spalling Canopy Supports	Signs of Mortar Repair to Cladding Panels	Regular circular Markings on Elevation	Cracking on Window Framework	Pebble Dashed Exterior	Entrance Canopy removed/not Original	Other Comments
28	Ravensbury Grove	●								Double stack rendered chimney with rectangular slab topping.
30	Ravensbury Grove	●	●			●				Double stack rendered chimney with rectangular slab topping.. Reinforcement in canopy exposed.
32	Ravensbury Grove			●		●				Double stack rendered chimney with rectangular slab topping.
34	Ravensbury Grove				●	●				Double stack rendered chimney with rectangular slab topping.
52	Ravensbury Grove								●	
54	Ravensbury Grove								●	Gutters in poor state of disrepair.

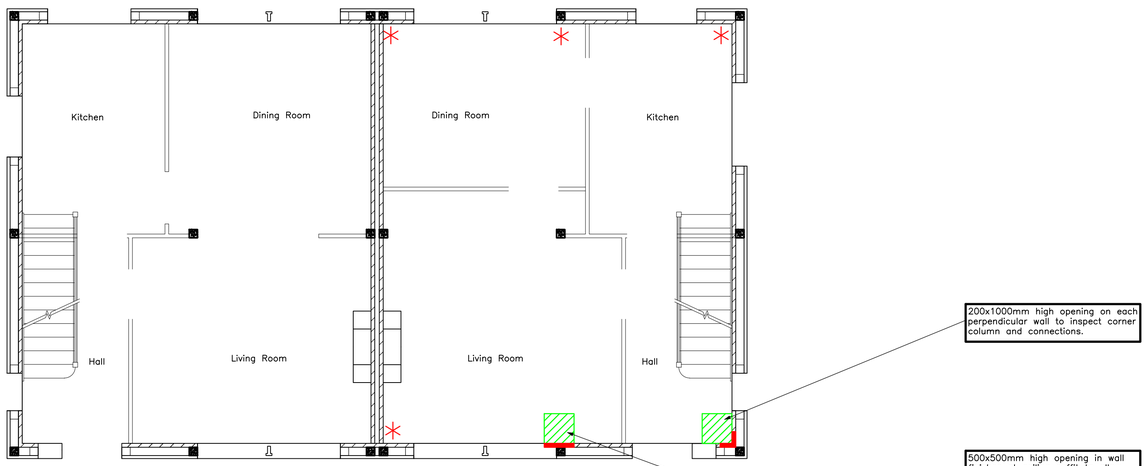
Appendix E – Summary of Proposed Opening Up Works



Roof



First Floor



Ground Floor

General Notes

1. Layout drawings produced from BRE document 'The structural condition of Orlit house' & HTA plan drawings. Drawing to be used for discussion and illustrative purposes only and all dimensions and layouts to be confirmed on site.
2. Internal layouts illustrated are typical and may vary between plots. All layouts should therefore be confirmed on site.

Key & Proposed Opening Up Notes:

Approx. location of roof access hatch. Access to all areas of roof required.

Area of floor boards to be lifted to inspect first floor construction from above. Anticipated 500x1500mm area and located to observe anticipated primary (main) beam and secondary beams.

Possible alternative area for lifting floor boards.

Indicates approx. location of proposed opening in ceiling finishes. Min. 500x500mm opening to expose anticipated beam and column connection details.

Indicates approx. location of proposed opening in wall finishes. Removal of finishes and anticipated blockwork inner skin to attempt to expose anticipated beam and column connections and galvanised wall ties. Proposed opening dims. noted on drawing.

Indicates possible alternative opening up location.

REV	DATE	DESCRIPTION	BY	CHK'D
A	24.10.14	Updated for final report.	TP	

HTA

TITLE:
Orlit House
Proposed Opening
Up Works.

PROJECT:
Ravensbury Estate

SCALE: 1:50@A1 DATE: Aug '14 DRAWN: BD CHK'D: TP

JOB NO.	DRG NO.	REV.
11264	SK202	A

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Appendix F – GBG – Report on the Investigations of 4No Orlit Houses Revision A

RAVENSBURY ESTATE, GREATER LONDON

REPORT 3905 REVA OCTOBER 2014

CIRCLE HOUSING

Ravensbury Estate, Greater London

Report on the Investigation of 4 No. Orlit Houses

Final Report – 3905 RevA

CIRCLE HOUSING

PROJECT: **Ravensbury Estate, Greater London**

TITLE: **Report on the Investigation of 4 No. Orlit Houses**

CLIENT: **CIRCLE HOUSING**

Report No: **3905 RevA**

Compiled By: **J Dear BEng**

Reviewed By: **S W Kemp CEng MICE**

Issued on: **20th October 2014**

Revision A Issued On: **27th October 2014**

TABLE OF CONTENTS

Appendices

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Tel. +44 (0) 1923 678800 Fax. +44 (0) 1923 678500 Email structs@gbg.co.uk

Report on the Investigation of 4 No. Orlit Houses

1.0 INTRODUCTION

1.1. Terms of Reference

Purpose:	To carry out structural condition surveys of four Orlit houses.
Location:	Ravensbury Estate, Mitcham, Greater London *Property No. 241 Morden Road, CR4 4DJ* *Property No. 193 Morden Road, CR4 4DJ* *Property No. 1 Rutter Gardens, CR4 4DS* *Property No. 20 Hatfield Close, CR4 4DJ*
Consultants:	GBG Structural Services
Instructed by:	Circle Housing
Date of Instruction:	9th September 2014

1.2. General

This report is the final report of this investigation. It therefore supersedes any previous reports whether written or oral, and completes all work currently ordered under this contract.

1.3. Background

The Ravensbury Estate, which lies between Morden and Mitcham in South London, is understood to contain 70 Orlit houses. Orlit houses are of precast reinforced concrete (PRC) framed construction, and were commonly built between WWI and WWII and in the post WWII years when there was a housing shortage. It is understood that the Orlit houses on the Ravensbury Estate were constructed in the 1950's.

Further information on the typical construction and structural condition of Orlit Houses can be found in the Building Research Establishment (BRE) Report *The Structural Condition of Orlit Houses*, published in 1983.

The BRE report describes the typical Orlit domestic house construction as comprising a structural frame clad in small precast reinforced concrete panels with flat or pitched roofs. The primary load bearing structure is described to comprise two bay, two-storey precast reinforced concrete portal frames with cast in-situ joints in the beams and bolted connections in the precast columns. The floor and roof structures are described as being carried by precast concrete secondary beams which span between the primary frames. The outer cladding and the inner blockwork of the external walls are described as being connected with galvanised mild steel ties across the cavity, with the frame columns being accommodated within the cavity.

BRE (from their or their consultant's surveys of 83 houses) identified a number of defect types, such as cracked secondary beams due to expansive reinforcement corrosion, cracked and poor quality High-alumina cement (HAC) stitches and cracking and spalling of other precast concrete components i.e. cladding blocks, window frames, door canopies and supports, and roof soffit units. The BRE also identified variable and high chloride contents and carbonation depths within the precast frame elements, particularly the secondary beams. The BRE report partly concludes that no structurally unsafe conditions were found but in some cases early remedial action was desirable.

The 'Orlit' house type was declared a defective property type under the 1985 Housing Act.

It is understood that the Client's Engineers (Tully De'Ath Consultants) are carrying out a structural engineering appraisal of the existing Orlit Houses on the Ravensbury Estate, and as such, there was a requirement to carry out a

structural condition survey of four Orlit houses in order to inform this appraisal. The four properties are indicated on Fig. R1 below.

Fig. R1: Aerial view of the Ravensbury Estate showing the position of the four properties investigated

1.4. Purpose of Investigation

The purpose of the investigation was to carry out a structural condition survey of four Orlit houses.

A summary of the scope of the site works for each of the four properties is presented below:

- Visually assess the condition of all accessible portions of the structure and record the locations and extents of any significant defects recorded.

- Extract up to 15 No. concrete dust samples from the concrete elements of each structure for laboratory testing to determine the chloride contents of the concretes.
- Determine the localised minimum depth of concrete cover to the reinforcement and corresponding depth of carbonation at each sample location.
- Carry out 4 No. intrusive inspections to assess the condition of the reinforcement generally. Carry out further inspections, targeted to specifically investigate the construction and condition of the joints, with an emphasis of identifying if High-alumina cement (HAC) concrete has been used in the in-situ stiches.
- Extract two lump samples from each structure to determine the cement content of the concretes and examine one sample petrographically to identify the constituent parts and identify signs of any deleterious reactions.
- Survey up to 4 No. c.2 x 2m areas of the cavity walls per property, in order to establish the position and density of the cavity ties for comparison with the recommendations outlined in current British Standards.
- At each survey area inspect the type and condition of representative cavity ties by inserting an endoscope into the cavities and where permitted, carry out localised and targeted exposures to allow us to inspect the portion of the ties embedded within the wall.

2.0 THE SURVEY

2.1. General

Survey Dates: 22nd to 25th September 2014 – four weekday survey sessions (4 x c.7-11 hours duration)

Personnel: 3 person survey team

2.2. Methodology

The main investigative techniques used were visual inspection, covermeter surveying, metal/wall tie detection and impulse radar surveying, accompanied by traditional intrusive inspections and breakouts, concrete dust and lump sampling and in-situ carbonation testing, enabling both on site interpretation as well as a more detailed analysis of the data and laboratory testing off site.

Visual Inspection

A visual inspection was carried out to identify the general form and condition of the accessible parts of each structure, recording the locations and extents of any significant defects noted. The visual inspections were also carried out to assist in identifying suitable sample and test locations.

Covermeter Surveys

Covermeters were primarily used to locate the near surface reinforcement within the structural elements and measure the localised minimum depth of concrete cover to the reinforcement at each of the sample locations.

Metal/Wall Tie Surveys

A combination of metal detectors and wall tie detectors were used to locate and plot the cavity wall ties at representative locations. The cavity wall ties were also inspected through exposures carried out to the internal blockwork walls.

Impulse Radar Surveys

Used primarily for assisting in the location of wall ties, the data was collected from a series of profiles set typically at varying centres to suit the survey, using a transducer with centre frequency of 1.5GHz. Recovered signals were recorded digitally, allowing more detailed analysis of the data off site.

Calibration (Radar)

Our quality standard calls wherever possible for a calibration of wave velocities in the surveyed materials on site: otherwise less reliable comparative methods with other materials surveyed elsewhere must be used. These are probably accurate to about +/-5-8%, excluding the effects of varying moisture and variations in compaction.

Traditional Intrusive Inspections and Breakouts

Exposures were formed within ceilings and the internal blockwork walls at permitted locations in order to facilitate the inspection, sampling and testing of the hidden structural elements. Localised breakouts were carried out using 110V powered electrical drills/breakers to selected elements in order to size and inspect the embedded reinforcement and to inspect the embedded portions of the wall ties.

Concrete Dust/Lump Sampling

Samples of the concrete were extracted from the various internal reinforced concrete elements as dust or Lumps for laboratory testing. The samples were extracted using a battery or 110V powered rotary drill/breaker. At each dust sample location the outer 5mm of concrete were discarded to avoid contamination. The samples were taken as a single gradient sample at a depth between 5mm and 30mm from the surface of the concrete.

Carbonation Testing

The depth of carbonation was determined at each sample location by spraying the freshly fractured concrete surface (usually on the edge of the drilled hole/breakout) with a phenolphthalein indicator solution.

Reinstatement

On completion of the works, all test sites/holes were made good with a proprietary cementitious repair mortar, trowelled to a flush finish. The internal blockwork wall was reinstated prior to reinstatement of the finishes and redecoration by others at a later date. The ceiling exposures were temporarily covered prior to reinstatement of the ceiling by others at a later date.

2.3. Access, Areas Surveyed and Site Relocation

The properties were occupied at the time of the surveys. Access was generally available throughout the roof spaces of each property, although the presence of roof insulation prevented complete inspection of the structural elements. Floorboards were lifted locally at 1st Floor Level in order to inspect the hidden structure.

The extent of the intrusive works was tailored in each property to those areas where intrusive works were permitted by the individual property owner or tenant.

The sample and test locations are referenced to the layouts provided to GBG by the Client's Engineers, Tully De'Ath Consultants. All property plans have been presented on the drawings in the same orientation for consistency, irrespective of the true orientation. The true North is however, indicated on each plan for reference. For the purpose of orientation within this report the front of each property has been taken as the elevation facing the respective road.

3.0 FINDINGS

3.1. Presentation of Results

The main findings of this investigation are discussed below under the headings **Structure**, **Condition** and **Material Sampling and Testing.**

The sample and test locations and the results of the survey are presented on the following drawings, which are attached.

Property No. 241 Morden Road, CR4 4DJ – Drawings 3905A-1 to 2
Property No. 193 Morden Road, CR4 4DJ – Drawings 3905B-1 to 4
Property No. 1 Rutter Gardens, CR4 4DS – Drawings 3905C-1 to 3
Property No. 20 Hatfield Close, CR4 4DJ – Drawings 3905D-1 to 5

A reduced scale print of each of the drawings is presented in Appendix 1.

The results of the laboratory and site tests are presented in Appendix 2 and the petrographic examination certificates are presented in Appendix 3. A selection of photographs of interest is presented within this report and on the attached drawings.

3.2. Observations

Structure

General

The two-storey structures forming the four properties investigated are very similar in construction, each comprising a structural frame clad in precast reinforced concrete panels with timber pitched roofs. All the properties are semi-detached.

The primary load bearing structures are two bay, two-storey precast reinforced concrete portal frames with cast in-situ joints in the beams and bolted connections in the precast columns. The floor structures comprise precast concrete primary beams spanning approximately 3.8m front to back between precast reinforced concrete columns, with precast reinforced concrete secondary beams at approximately 1.2m centres spanning approximately 3m between the primary beams. The beams and columns were found to be conventionally reinforced with plain round steel bars and links.

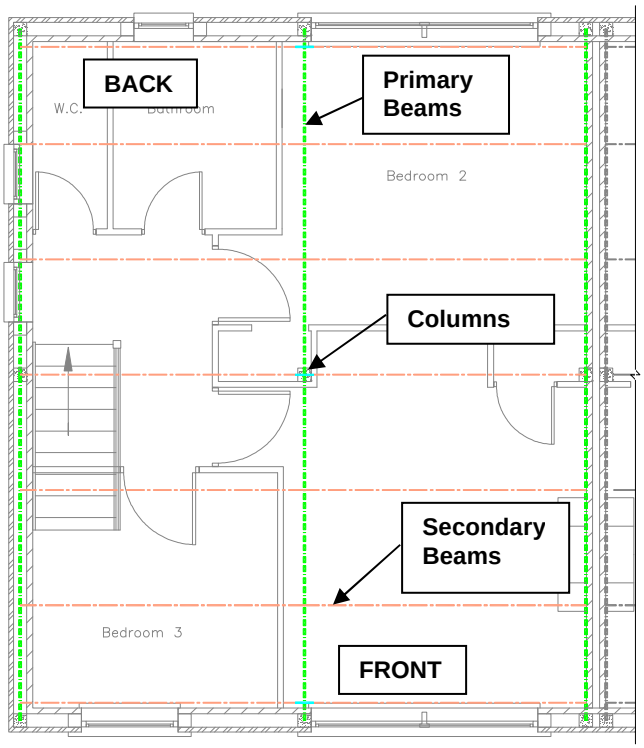


Fig. R2: Typical plan of Orlit House investigated showing the column layout and suspended floor structure

Details of the four structures investigated, including typical elements sizes, typical reinforcement bar sizes and wall tie details are presented on the attached survey drawings. The findings are summarised below.

The central primary beams were found to comprise a series of precast reinforced concrete inverted 'T' sections connected with in-situ reinforced concrete stitches. The primary edge beams generally comprise of 'L' sections, again with in-situ stiches. The precast reinforced concrete secondary beams are 'H' sections along the majority of their length, but solid in section towards their ends. The ends of the secondary beams are notched so that they bear onto the bottom flange of the central primary beams or the bottom leg of the primary edge beams. Stability is provided to the secondary beams in places by in-situ mortar haunches at their bearing ends.

The tops of the secondary beams have pre-formed slots in their ends in order to accommodate continuity bars at the connections with the primary beams. Continuity bars have generally been provided to the central beam connections over the three columns (front, central and back columns). In-situ mortar has been used to cover the continuity bars and fill the remainder of the slots at these locations.

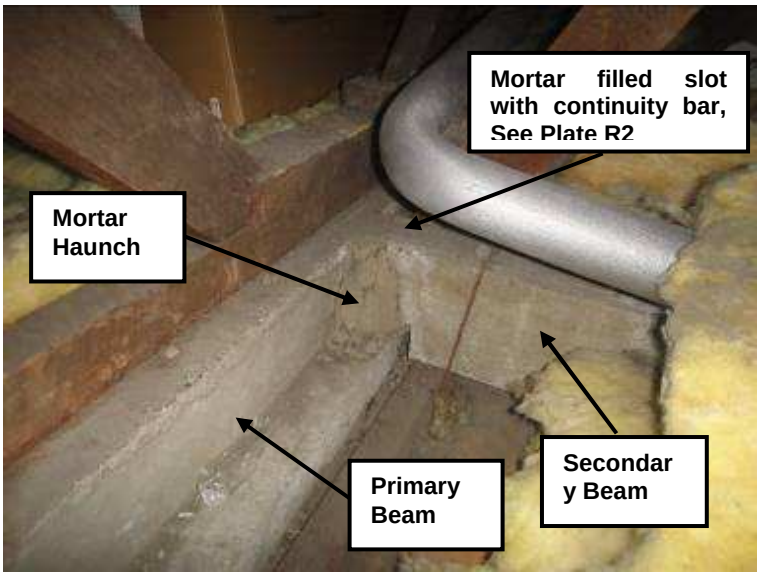


Plate R1: View of roof secondary beam bearing onto central roof primary beam over central column at No.193 Morden Road. Note mortar haunch and mortar filled slot with continuity bar

Plate R2: View of Breakout C1 to continuity bar at roof secondary beam to roof primary beam connection over central column at No. 1 Rutter Gardens.

Each of the four properties were found to have a pitched timber roof structure and a suspended 1st floor structure, typically comprising timber floorboards supported on a series of timber joists spanning front to back between the secondary beams.

Plate R3: View of typical 1st Floor structure at No. 20 Hatfield Close

The ground floor structures were not surveyed as part of this investigation.

The reinforced concrete column sections are typically one storey high, with bolted plate connections between each section at ground floor and 1st floor level.

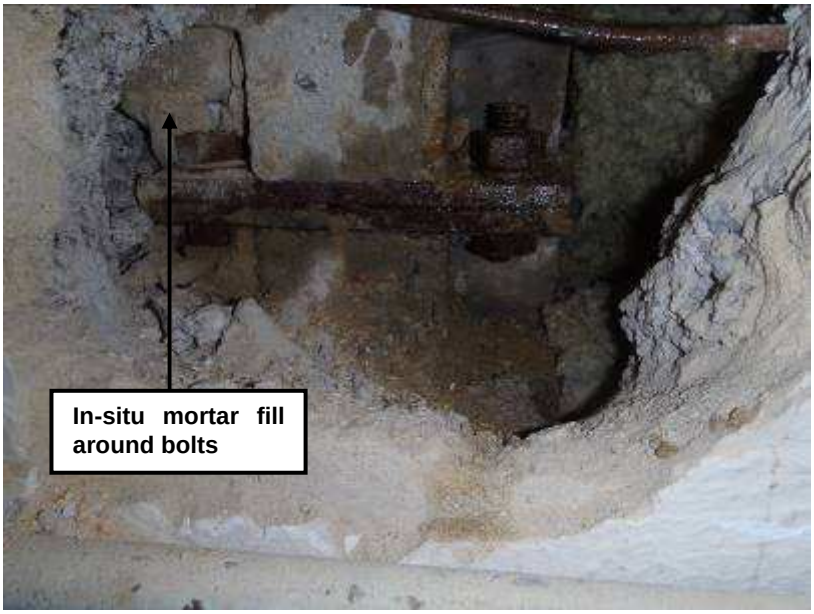


Plate R4: View of Ground Floor to 1st Floor column connection at No. 1 Rutter Gardens. Note in-situ mortar fill around bolts partially removed for inspection.

The external cavity wall construction to each of the four properties comprises 50mm (2") thick precast reinforced concrete panels with a 90mm (3 ½") thick internal blockwork skin. The cavity width was typically 150mm (6") with the cladding panels and blockwork skins connected via galvanised steel fishtail ties.

The external end of the wall ties were found to be embedded by approximately 15mm into the cladding panels at their horizontal joints and the internal ends of the ties were found to be embedded by approximately 35mm into the horizontal mortar joints of the internal blockwork skin where inspected.

Fig. R5: View of Breakout B3 to tie embedment within external cladding panel at No. 193 Morden Road.

The wall ties have a drip grove which was generally well positioned near the centre of the cavities where inspected.

Plate R6: View looking up towards cavity wall ties above Breakout B3 at No. 193 Morden Road.

Where surveyed using non-destructive testing (NDT) methods or inspected within the cavities, the wall ties were found to be spaced between 250mm and 900mm horizontally and 400 to 420mm vertically (vertical spacing between cladding panel horizontal joints).

The cavities to No. 241 and 193 Morden Road were open whilst the cavities to No. 1 Rutter Gardens and No. 20 Hatfield Close have been filled with a foam

insulation. The presence of a series of mortar filled holes within the external cladding panels of No. 1 Rutter Gardens suggests the insulation has been installed post construction.

Condition

The precast reinforced concrete frame elements and in-situ concrete stitches within the beams generally appeared to be in reasonable condition, with no obvious signs of significant cracking or spalling of the concrete noted where the elements could be inspected in each of the four properties.

A total of eighteen localised breakouts were carried out to the various precast concrete elements forming the structures in order to size and inspect the reinforcement. The reinforcement was generally observed to be in good condition, generally exhibiting light surface corrosion only.

Plate R7: View of column Breakout A2 at No. 241 Morden Road.

At each property a single continuity bar was exposed at the central roof secondary beam to primary beam connection (over the central column). At each location the continuity bars was observed to be in good condition, exhibiting light surface corrosion only.

The mortar cover to the continuity bar exposed within No. 193 Morden Road and 1 Rutter Gardens exhibited cracking, elsewhere the mortar was observed to be in reasonable condition.

Plate R8: View of Breakout D2 to roof secondary beam continuity bar over central column at No. 20 Hatfield Close.

The steel column connection plates and bolts exhibited light to moderate surface corrosion where inspected, however, no significant section loss was noted. See Plate R4 above.

Plate R9: View of tie fishtail end embedded within internal blockwork skin at Breakout D6 to No. 20 Hatfield Close.

The galvanised wall ties were observed to be in good condition where inspected during this investigation.

Details of the breakouts carried out during this investigation are presented in full on the attached drawings.

The external cladding panels were generally observed to be in reasonable condition, however, cracking and spalling of the corner panels was noted at each property, particularly at low level. There was also some cracking and spalling noted to the front porch frames.

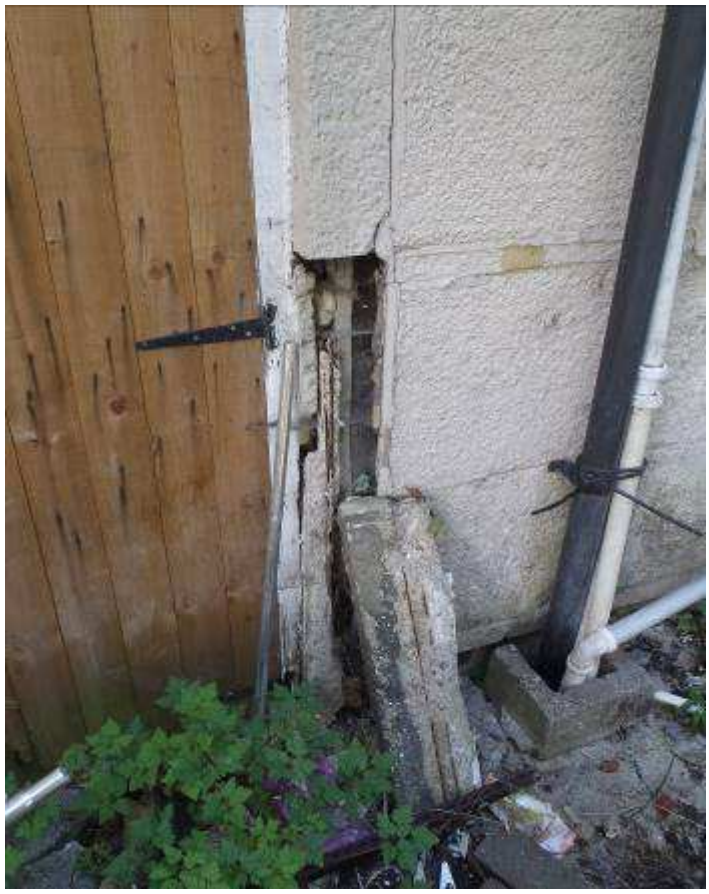


Plate R10: View of spalled corner panel at ground floor level to No. 1 Rutter Gardens

Material Sampling and Testing

A total of forty eight concrete dust or lump samples were removed from the various precast reinforced concrete elements or in-situ stitches forming the four structures for inspection and/or laboratory testing, and a further seven mortar samples were also extracted for laboratory testing (fifty five samples in total).

A total of two representative precast concrete lump samples from each of the four properties (L1A, L2A, L2B, L5B, L3C, L5C, L2D and L4D) were selected for inspection and laboratory testing to determine the cement content of the concretes.

The lump concretes generally contained approximately 45% to 55% mixed flint-gravel as the coarse aggregate, which was sub-rounded to sub-angular and equant to elongate in shape, and generally reasonably well graded and evenly distributed. The maximum nominal aggregate size was typically 10mm.

The cement pastes were apparently of good quality and compaction, with excess surface voidage generally judged at 0.5%. The cement pastes of two of the samples (L3C from a column and L2D from a secondary beam) were light grey in colour, whilst the cement pastes of the remaining six samples were off-white to light grey in colour.

Plate R11: View of concrete lump sample L2D from a 1st Floor secondary beam at No. 20 Hatfield Close.

The cement contents of samples L3C (a column at 1 Rutter Gardens) and L2D (a secondary beam at 20 Hatfield Close) were 18.2% and 18.7% respectively whilst the cement content of the remaining six samples ranged between 10.3% and 14.7% with an average cement content of 12.7%.

A single precast concrete lump sample from each of the four properties (L1A, L2B, L4C and L2D) was dispatched for petrographic examination of the concrete in order to identify the constituent parts and identify any signs of deleterious reactions which may have occurred.

The petrographic examination certificates are presented in Appendix 3. In summary; all four lump samples were found to contain natural flint coarse and sand fine aggregates set within a hardened Portland type cement matrix. The constituents of all four samples appeared to be well mixed with good compaction. The concretes appeared to be sound with no obvious evidence of significant distress or deterioration.

All fifty five dust or lump samples were tested to determine the chloride concrete of the concretes or mortars. All chloride contents are presented by mass of cement based on the average calculated cement contents for each property.

The chloride contents of the five samples extracted from the precast concrete secondary beams at No. 193 Morden Road ranged between <0.06% and 0.22% with an average of 0.12%. The chloride contents of the three samples extracted from the precast concrete columns at No. 20 Hatfield Close ranged between 0.16% and 1.33% with an average of 0.58%. The single sample extracted from a precast roof primary beam at No. 20 Hatfield Close had a chloride content of 0.34%.

The chloride contents of the remaining thirty nine concrete sample or lump samples were low at 0.07% or less. The chloride contents of the seven mortar samples were all low at 0.15% or less.

A total of twenty four representative dust or lump samples extracted from the various precast concrete, in-situ concrete or mortar elements (six samples per property) were further screened to detect the presence or otherwise of High-alumina cement (HAC). None of the twenty four samples contained HAC.

At each of the forty eight concrete sample locations the localised minimum depth of cover to the reinforcement was determined along with the corresponding depth of carbonation.

The results of these tests are presented in full on Figure A2.1 to A2.4 of Appendix 2 and are summarised in Tables R1 and R8 below and overleaf.

Element	Number of tests	Maximum (mm)	Minimum (mm)	Average (mm)
Columns	6	76	3	24
Primary Beams	4	36	25	30
Secondary Beams	5	35	20	26
In-situ Concrete Stitches	1	34	34	34

Table R1: Summary of concrete cover readings at No. 241 Morden Road

Element	Number of tests	Maximum (mm)	Minimum (mm)	Average (mm)
Columns	6	20	6	13
Primary Beams	4	22	4	10
Secondary Beams	5	20	4	13
In-situ Concrete Stitches	1	3	3	3

Table R2: Summary of carbonation values at No. 241 Morden Road

Element	Number of tests	Maximum (mm)	Minimum (mm)	Average (mm)
Columns	2	20	20	20
Primary Beams	3	35	20	29
Secondary Beams	5	33	2	25

Table R3: Summary of concrete cover readings at No. 193 Morden Road

Element	Number of tests	Maximum (mm)	Minimum (mm)	Average (mm)
Columns	2	5	1	3
Primary Beams	3	25	3	11
Secondary Beams	5	18	2	6

Table R4: Summary of carbonation values at No. 193 Morden Road

Element	Number of tests	Maximum (mm)	Minimum (mm)	Average (mm)
Columns	2	14	14	14
Primary Beams	4	58	19	34
Secondary Beams	3	35	9	25
In-situ Concrete Stitches	2	23	30	37

Table R : Summary of concrete cover readings at No. 1 Rutter Gardens

Element	Number of tests	Maximum (mm)	Minimum (mm)	Average (mm)
Columns	2	10	10	10
Primary Beams	4	20	4	16
Secondary Beams	3	10	3	6
In-situ Concrete Stitches	2	2	1	2

Table R!: Summary of carbonation values at No. 1 Rutter Gardens

Element	Number of tests	Maximum (mm)	Minimum (mm)	Average (mm)
Columns	3	20	15	17
Primary Beams	1	20	20	20
Secondary Beams	5	36	20	29
In-situ Concrete Stitches	2	31	26	29

Table R": Summary of concrete cover readings at No. 2 !atfield "lose

Element	Number of tests	Maximum (mm)	Minimum (mm)	Average (mm)
Columns	3	22	20	21
Primary Beams	1	18	18	18
Secondary Beams	5	40	10	21
In-situ Concrete Stitches	2	35	30	33

Table R#: Summary of carbonation values at No. 2 !atfield "lose

At eight out of the forty eight sample locations the depth of carbonation had reached or exceeded the depth of concrete cover to the reinforcement. At a further six concrete sample locations the depth of carbonation was within 5mm of the depth of concrete cover to the reinforcement. At the remaining thirty four sample locations there appears to be a reasonable margin of un-carbonated concrete around the reinforcement. A summary of the locations where the depth of carbonation had reached, exceeded or was within 5mm of the reinforcement is presented in Table R9 below.

Element	241 Morden Road	193 Morden Road	1 Rutter Gardens	20 Hatfield Close
Columns	2 & 1 / 6	0 / 2	2 / 2	3 / 3
Primary Beams	1 / 4	0 / 3	1 / 4	1 / 1
Secondary Beams	0 / 5	0 / 5	0 / 3	1 / 5
In-situ Concrete Stitches	0 / 1	-	0 / 2	2 / 2

Table R$: No. of locations #$ere carbonation $ad reac$ed or e%ceeded t$e de&t$ of concrete cover 'indicated by red value(or #as #it$in)mm of t$e de&t$ of concrete cover 'indicated by green value(

The mortar cover to continuity bars at the four continuity bar breakout locations (one per property) was low, ranging between 2mm and 10mm with an average cover of 6mm.

3.3. Discussion and Conclusions

The precast reinforced concrete frame elements and in-situ concrete stitches forming the four structures investigated appear to be in reasonable condition, with no obvious visible signs of significant deterioration where inspected. At the concrete breakout locations the embedded reinforcement was generally observed to be in good condition where locally exposed, exhibiting light surface corrosion only. Nonetheless the presence of visible light corrosion indicates that corrosion has occurred since construction.

The quality of the in-situ mortar cover/fill to the continuity bars varied and the mortar cover to the bars was low (2 to 10mm) where inspected. The mortar appeared to be a simple sand/cement mix, as would be expected. In its current condition, the protection provided to the continuity bars by the mortar is inadequate. Nonetheless, the condition of the bars where inspected was reasonable. Consideration should be given to the adequacy of the bond between the bars and the components they are intended to restrain

The galvanised steel wall ties were observed to be in good condition where inspected and appeared to be well positioned, with the drip groove at or near the centre of the cavity. Where surveyed during these investigations, the spacings of the wall ties would generally comply with the requirements set out in current British Standards, however, there do not appear to be sufficient ties within 150mm of the openings in some instances. The depth of wall tie embedment within the internal blockwork skin (typically 35mm) and within the external precast concrete cladding panels (typically 15mm) is below the minimum embedment of 50mm outlined in current British Standards for cavity walls. The effectiveness of the wall ties may therefore be reduced. Bearing in mind that the outer panel is only 50mm thick it is clear that the BS recommendation of 50mm minimum embedment is not achievable.

The appears to be frequent cracking and spalling of the corner cladding panels, particularly at low level and cracking and spalling of some of the concrete elements forming the front porch frames. Remedial action is required to address these issues.

No HAC was detected in the twenty four dust/lump samples tested and is considered unlikely that HAC would have been used during the construction of similar elements elsewhere within the four properties investigated.

The visual appearance of the eight precast concrete lump samples inspected and their cement contents (10.3% to 18.7%) are indicative of a reasonable to good quality precast concrete. The variability in the cement contents is not uncommon for a structure of this age.

The constituents of all four lump samples examined petrographically (L1A, L2B, L4C and L2D) appeared to be well mixed with good compaction. The concretes appeared to be sound with no obvious evidence of significant distress or deterioration.

The minimum depth of concrete cover to the reinforcement at the sample locations was generally in line with the minimum requirements at the time of construction at or above 20mm, however, in localised instances very low covers were identified to the links. The corresponding depths of carbonation at the sample locations were variable, an indication of localised variations in the compaction and quality of the concrete.

At eight out of the forty eight sample locations the depth of carbonation had reached or exceeded the depth of concrete cover to the reinforcement. At these locations the alkaline protection normally afforded to the steel by the concrete has been lost, making the steel more susceptible to corrosion in the near future.

At a further six concrete sample locations the depth of carbonation was within 5mm of the depth of concrete cover to the reinforcement, and should be expected to reach the reinforcement in the near future.

At the remaining thirty four sample locations there appears to be a reasonable margin of un-carbonated concrete around the reinforcement.

When chlorides are present in the concrete, whether naturally or by addition, in the wet concrete they become partially bound into the cement matrix and are not available to cause corrosion.

Approximately 0.2% chloride by mass of cement may be bound up in this way. A further 0.2% is generally accepted as being required to instigate corrosion.

The corrosion trigger levels for in-built chlorides are therefore 0.4% but for chlorides ingressing post hardening the trigger level is only 0.2%. Further, the bound in chlorides can be released by carbonation of the paste so that the trigger level in carbonated concrete for in-built chlorides is reduced to 0.2%.

The chloride contents of the mortar and concrete samples were generally low and would be considered insufficient to contribute to corrosion of the embedded reinforcement. However, samples extracted from the precast concrete secondary beams at No. 193 Morden Road ranged between 0.06% and 0.22% (average chloride content of 0.12%), samples extracted from the precast concrete columns at No. 20 Hatfield Close (chloride content ranging between 0.16% and 1.33% with an average of 0.58%) and the single sample extracted from a precast roof primary beam at No. 20 Hatfield Close (chloride content of 0.34%), suggests contamination of these concretes at the time of construction. The contamination is possibly by the use of poorly washed marine aggregates or, more likely, the deliberate addition of chloride containing admixtures at times of cold weather.

The chloride contents of one out of the forty eight samples (S1D) was well in excess of the trigger level of 0.4% for the instigation of chloride-induced corrosion when the chlorides were present at the time of construction. It is unlikely that there is or has been any source of chlorides ingressing post-construction to the locations sampled in these structures.

Providing the elements are kept dry and the reinforcement remains in an un-carbonated environment, the residual risk of corrosion occurring to the concrete elements as a result of the effects of the presence of chlorides is considered to generally be low, but the risk will be increased in areas where high chlorides exist and in areas susceptible to moisture ingress (such as at roof level or in the vicinity of kitchens and bathrooms), and in instances where the depth of carbonation has reached or exceeded the depth of concrete cover to reinforcement.

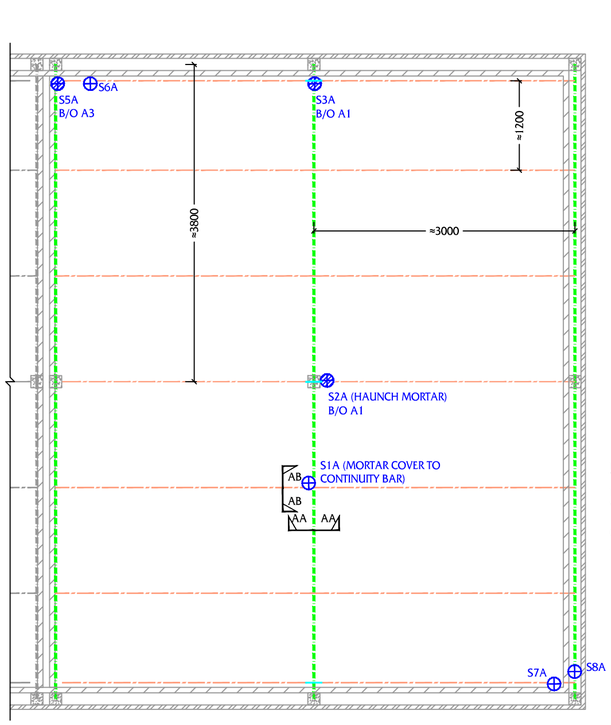
It should be noted that it is unlikely that the areas of highest or lowest chloride contamination or the areas with the highest and lowest carbonation depths have been sampled and tested during these investigations.

As with any structure it is imperative to keep the elements dry to increase the durability of the reinforced concrete.

APPENDIX 1
DRAWINGS

DETAILS OF ROOF SURVEYS AND BREAKOUTS
RAVENSBURY ESTATE - 241 MORDEN ROAD

FIG.A1: ROOF PLAN SHOWING LOCATIONS OF SAMPLES AND BREAKOUTS NOT TO SCALE



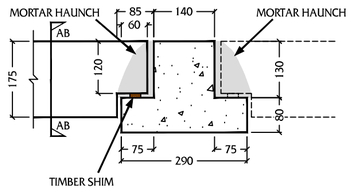
MORDEN ROAD

NOTES

NO SIGNIFICANT DEFECTS NOTED TO BEAMS WHERE INSPECTED.

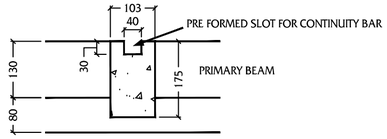
CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

FIG.A2: SECTION AA-AA THROUGH PRIMARY BEAM SCALE 1:10



PA2a: VIEW OF SECONDARY BEAMS SPANNING ONTO NORTHERN PRIMARY BEAM

FIG.A3: SECTION AB-AB THROUGH ROOF SECONDARY BEAM SCALE 1:10



PA3a: VIEW OF SECONDARY BEAM BEARING ONTO PRIMARY BEAM AT SECTION AA-AA POST REMOVAL OF MORTAR HAUNCH

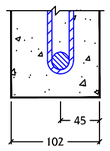
FIG.A4: DETAILS OF B/O A5 TO CONTINUITY BAR WITHIN TOP OF ROOF SECONDARY BEAM

DETAILS OF B/O A5 TO CONTINUITY BAR

10mmØ PLAIN ROUND CONTINUITY BAR EMBEDDED WITHIN INSITU MORTAR FILLED PRE-FORMED SLOT. TOP COVER TO BAR 2mm.
BAR OBSERVED TO BE IN GOOD CONDITION WITH LIGHT SURFACE CORROSION ONLY.
INSITU MORTAR APPEARS TO BE IN REASONABLE CONDITION.

PA4a: VIEW OF B/O A5 TO CONTINUITY BAR WITHIN TOP OF SECONDARY BEAM

FIG.A5: B/O A1 TO SOFFIT OF ROOF SECONDARY BEAM SCALE 1:5



DETAILS OF B/O A1

20mmØ PLAIN ROUND LONGITUDINAL BAR AT 32mm SOFFIT COVER.
5mmØ PLAN ROUND VERTICAL LINK AT 27mm COVER.

BOTH BARS IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY.
CARBONATION DEPTH: 20mm

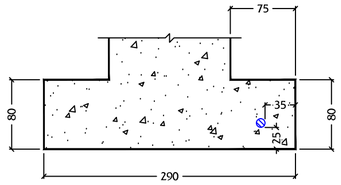
NOTES

GALVANISED STEEL WALL TIES WITHIN CAVITY ON EASTERN SIDE OF SECONDARY BEAM.
TIES SPACED TYPICALLY AT 400mm c/c VERTICALLY AND 250-350mm c/c HORIZONTALLY.
TIES OBSERVED TO BE IN GOOD CONDITION.

PA5a: VIEW OF B/O A1 TO SOFFIT OF ROOF SECONDARY BEAM

PA5b: VIEW LOOKING DOWN CAVITY ON EASTERN SIDE OF SECONDARY BEAM

FIG.A6: DETAILS OF B/O A3 TO SOFFIT OF ROOF PRIMARY BEAM SCALE 1:5



DETAILS OF B/O A3

10mmØ PLAIN ROUND LONGITUDINAL BAR AT 25mm SOFFIT COVER AND 35mm SIDE COVER.
BAR OBSERVED TO BE IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY.

CARBONATION DEPTH: 22mm

NOTES

GALVANISED STEEL WALL TIES PRESENT WITHIN CAVITY IN VICINITY OF B/O A3.
TIES SPACED TYPICALLY AT 400mm c/c VERTICALLY AND 250-350mm c/c HORIZONTALLY.
TIES OBSERVED TO BE IN GOOD CONDITION.

PA6a: GENERAL VIEW OF B/O A3 TO SOFFIT OF PRIMARY BEAM

PA6b: VIEW LOOKING UP AT B/O A3 TO SOFFIT OF PRIMARY ROOF BEAM

LOCATION PLAN

SYMBOLS USED

PLAN EXTENT OF AREA SURVEYED
PRIMARY BEAM
SECONDARY BEAM
CONTINUITY BAR
DUST SAMPLE LOCATION
DUST SAMPLE AND BREAKOUT LOCATION
DUST SAMPLE AND LUMP SAMPLE LOCATION

MATERIAL TYPES

CONCRETE
STEEL

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 2 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905A-1 TO -2.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	241 MORDEN ROAD, MITCHAM CR4 4DJ
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 241 MORDEN ROAD

Client: CIRCLE HOUSING

Title: DETAILS OF ROOF SURVEYS AND BREAKOUTS

Drawn	Date	Scale
HW	OCT 14	AS SHOWN
CAD	PM	APP

Dwg. No. 3905A-1

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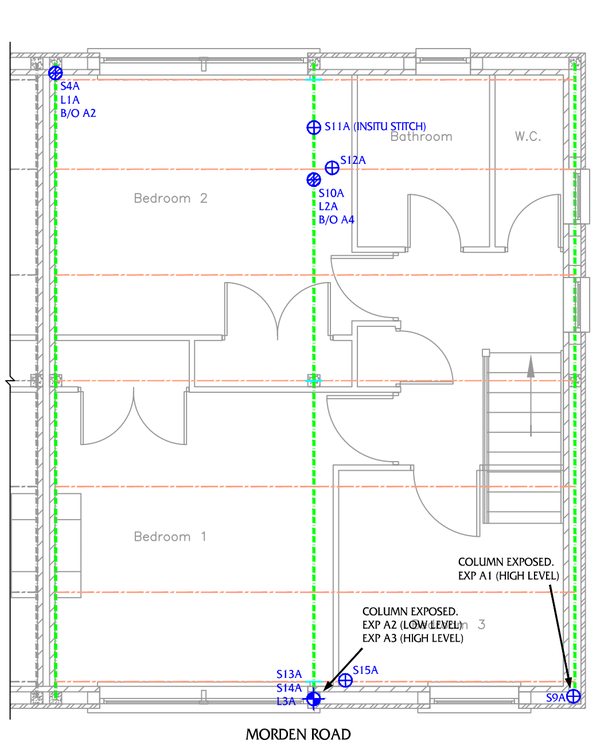
GBG

DETAILS OF 1ST FLOOR SURVEYS AND BREAKOUTS
RAVENSBURY ESTATE - 241 MORDEN ROAD

FIG.A7: 1ST FLOOR PLAN SHOWING LOCATIONS OF SAMPLES AND BREAKOUTS NOT TO SCALE

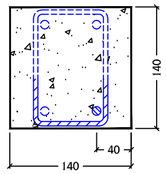


NOTES

NO SIGNIFICANT DEFECTS NOTED TO BEAMS AND COLUMNS WHERE INSPECTED.

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

FIG.A8: DETAILS OF B/O A2 TO 1ST FLOOR COLUMN AT HIGH LEVEL SCALE 1:5



DETAILS OF B/O A2

10mmØ PLAIN ROUND VERTICAL BAR AT 15mm COVER
5mmØ PLAIN ROUND HORIZONTAL LINK AT 2-3mm MINIMUM COVER

BOTH BARS IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY.
CARBONATION DEPTH: 15mm

PA8a: VIEW OF B/O A2 TO 1ST FLOOR COLUMN WITHIN CAVITY

FIG.A9: DETAILS OF ROOF CEILING AND INTERNAL BLOCKWORK SKIN EXPOSURE A1 AT 1ST FLOOR LEVEL IN SOUTH WESTERN CORNER OF PROPERTY

NOTES

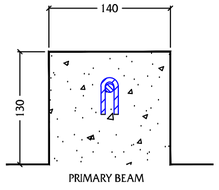
GALVANISED WALL TIES PRESENT WITHIN CAVITY IN VICINITY OF EXPOSURE EXP A1.
TIES SPACED TYPICALLY AT 400mm c/c VERTICALLY AND 250-350mm c/c HORIZONTALLY.
TIES OBSERVED TO BE IN GOOD CONDITION.

PA9a: GENERAL VIEW OF EXPOSURE EXP A1 IN SOUTH WESTERN CORNER OF PROPERTY

PA9b: CLOSER VIEW OF COLUMN HEAD AND SOFFIT OF ROOF PRIMARY BEAM AT EXPOSURE EXP A1

PA9c: VIEW LOOKING DOWN CAVITY ADJACENT TO 1ST FLOOR COLUMN AT EXPOSURE EXP A1

FIG.A10: DETAILS OF B/O A4 TO TOP OF 1ST FLOOR PRIMARY BEAM SCALE 1:5

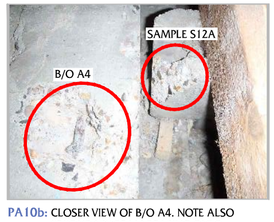


DETAILS OF B/O 4

10mmØ PLAIN ROUND LONGITUDINAL BAR AT 37mm TOP COVER.
5mmØ PLAIN ROUND VERTICAL LINK AT TOP 30mm COVER.

BOTH BARS IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY.
CARBONATION DEPTH: 3-4mm

PA10a: GENERAL VIEW OF 1ST FLOOR EXPOSURE AT B/O A4



PA10b: CLOSER VIEW OF B/O A4. NOTE ALSO SECONDARY BEAM BEARING ONTO PRIMARY BEAM

FIG.A11: PHOTOGRAPHS OF 1ST FLOOR EXPOSURES EXP A2 (LOW LEVEL) AND EXP A3 (HIGH LEVEL)

PA11a: GENERAL VIEW OF EXPOSURE EXP A2

PA11b: VIEW OF COLUMN CONNECTION AT 1ST FLOOR LEVEL

PA11c: VIEW LOOKING SOUTH FROM EXPOSURE EXP A2 WITHIN CAVITY

PA11d: VIEW LOOKING UP AT PRIMARY ROOF BEAM BEARING ONTO COLUMN HEAD AT EXPOSURE EXP A3

LOCATION PLAN

SYMBOLS USED

PLAN EXTENT OF AREA SURVEYED
PRIMARY BEAM
SECONDARY BEAM
CONTINUITY BAR
DUST SAMPLE LOCATION
DUST SAMPLE AND BREAKOUT LOCATION
DUST SAMPLE AND LUMP SAMPLE LOCATION

MATERIAL TYPES
CONCRETE
STEEL

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 2 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905A-1 TO -2.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	241 MORDEN ROAD, MITCHAM CR4 4DJ
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 241 MORDEN ROAD

Client: CIRCLE HOUSING

Title: DETAILS OF 1ST FLOOR SURVEYS AND BREAKOUTS

Drawn	Date	Scale	Dwg. No. 3905A-2
HW	OCT 14	AS SHOWN	
CAD	PM	APP	

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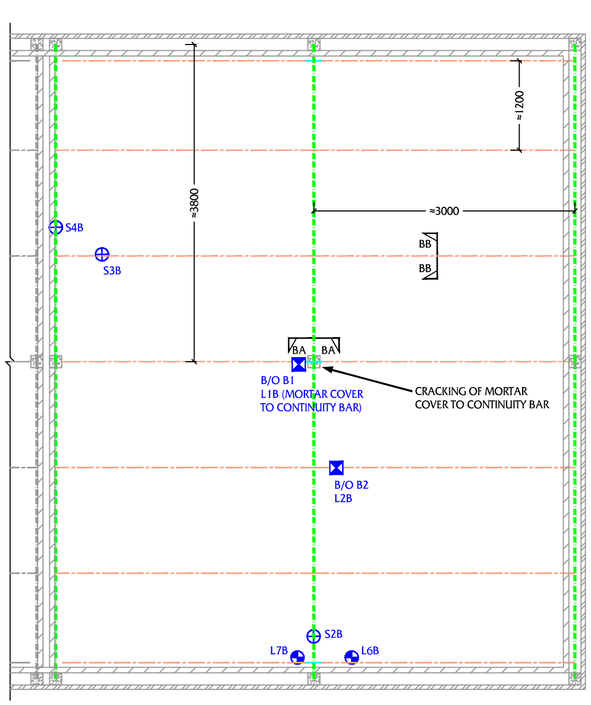
DETAILS OF ROOF SURVEYS AND BREAKOUTS
RAVENSBURY ESTATE - 193 MORDEN ROAD

FIG.B1: ROOF PLAN SHOWING LOCATIONS OF SAMPLES AND BREAKOUTS NOT TO SCALE



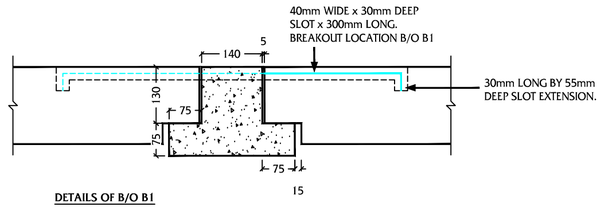
MORDEN ROAD

NOTES

NO SIGNIFICANT DEFECTS NOTED TO BEAMS WHERE INSPECTED.

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

FIG.B2: SECTION BA-BA THROUGH ROOF PRIMARY BEAM SHOWING DETAILS OF BREAKOUT B/O B1 SCALE 1:10



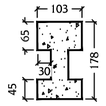
DETAILS OF B/O B1

10mmØ PLAIN ROUND CONTINUITY BAR EMBEDDED WITHIN INSITU MORTAR FILLED PRE-FORMED SLOT. TOP COVER TO BAR 5mm. BAR OBSERVED TO BE IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY.
INSITU MORTAR EXHIBITS CRACKING.

PB2a: VIEW OF INSITU MORTAR PRIOR TO BREAKOUT B/O B1

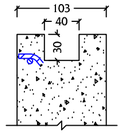
PB2b: VIEW LOOKING DOWN AT BREAKOUT B/O B1

FIG.B3: SECTION BB-BB THROUGH ROOF SECONDARY BEAM AT MID-SPAN SCALE 1:10



PB3b: SECONDARY BEAM BEARING ONTO EASTERN PRIMARY BEAM. NOTE CHANGE IN BEAM SECTION. PREFORMED SLOT WITH NO CONTINUITY BAR AND MORTAR HAUNCH AT BEAM BEARING.

FIG.B4: DETAILS OF BREAKOUT B/O B2 TO TOP OF SECONDARY BEAM SCALE 1:5



DETAILS OF B/O B2

6mmØ PLAIN ROUND LONGITUDINAL BAR AT 12mm MINIMUM COVER.
5mmØ PLAIN ROUND LINK AT 2mm MINIMUM COVER.

BOTH BARS EXHIBIT LIGHT TO MODERATE SURFACE CORROSION.
CARBONATION DEPTH: 2-3mm

PB4a: VIEW OF BREAKOUT B/O B2 TO TOP OF SECONDARY BEAM

LOCATION PLAN

SYMBOLS USED

- PLAN EXTENT OF AREA SURVEYED
- PRIMARY BEAM
- SECONDARY BEAM
- CONTINUITY BAR
- DUST SAMPLE LOCATION
- LUMP SAMPLE LOCATION
- LUMP SAMPLE AND BREAKOUT LOCATION
- EXTENT OF BREAKOUT

MATERIAL TYPES

- CONCRETE
- STEEL
- PLASTER
- BRICKWORK
- TIMBER
- BLOCKWORK

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 4 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905B-1 TO -4.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	193 MORDEN ROAD, MITCHAM CR4 4DJ
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 193 MORDEN ROAD

Client: CIRCLE HOUSING

Title: DETAILS OF ROOF SURVEYS AND BREAKOUTS

Drawn	Date	Scale	
HW	OCT 14	AS SHOWN	Dwg. No. 3905B-1
CAD	PM	APP	

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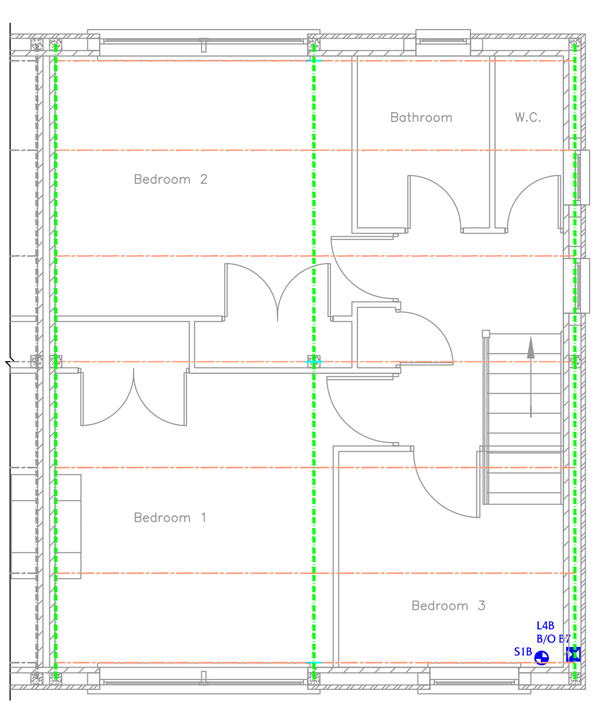
DETAILS OF 1ST FLOOR SURVEY AND BREAKOUTS
RAVENSBURY ESTATE - 193 MORDEN ROAD

FIG.B5: 1ST FLOOR PLAN SHOWING LOCATIONS OF SAMPLES AND BREAKOUTS NOT TO SCALE

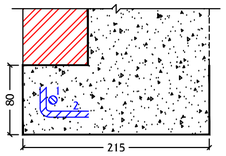


NOTES

NO SIGNIFICANT DEFECTS NOTED TO BEAMS AND COLUMNS WHERE INSPECTED.

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

FIG.B6: DETAILS OF B/O B7 TO SOFFIT OF 1ST FLOOR PRIMARY BEAM SCALE 1:5



DETAILS OF REINFORCEMENT

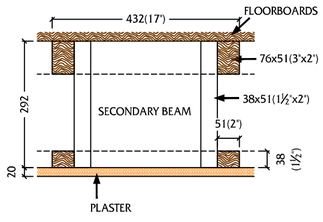
1. 10mmØ PLAIN ROUND BAR AT 30mm SIDE COVER AND 35mm SOFFIT COVER.
2. 8mmØ PLAIN ROUND LINK BAR AT 20mm SIDE AND SOFFIT COVER.

BARS EXHIBIT LIGHT TO MODERATE SURFACE CORROSION.
CARBONATION DEPTH: 2-3mm

PB6a: GENERAL VIEW OF B/O B7 TO 1ST FLOOR PRIMARY BEAM

PB6b: CLOSER VIEW OF B/O B7

FIG.B7: SECTION LOOKING SOUTH THROUGH 1ST FLOOR STRUCTURE ADJACENT TO B/O B7 SCALE 1:5



PB7a: VIEW LOOKING SOUTH THROUGH 1ST FLOOR STRUCTURE ADJACENT TO B/O B7

LOCATION PLAN

SYMBOLS USED

- PLAN EXTENT OF AREA SURVEYED
- PRIMARY BEAM
- SECONDARY BEAM
- CONTINUITY BAR
- DUST SAMPLE LOCATION
- LUMP SAMPLE LOCATION
- LUMP SAMPLE AND BREAKOUT LOCATION
- EXTENT OF BREAKOUT

MATERIAL TYPES

- CONCRETE
- STEEL
- PLASTER
- BRICKWORK
- TIMBER
- BLOCKWORK

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 4 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905B-1 TO -4.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	193 MORDEN ROAD, MITCHAM CR4 4DJ
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 193 MORDEN ROAD

Client: CIRCLE HOUSING

Title: DETAILS OF 1ST FLOOR SURVEY AND BREAKOUTS

Drawn	Date	Scale
HW	OCT 14	AS SHOWN
CAD	PM	APP

Dwg. No. 3905B-2

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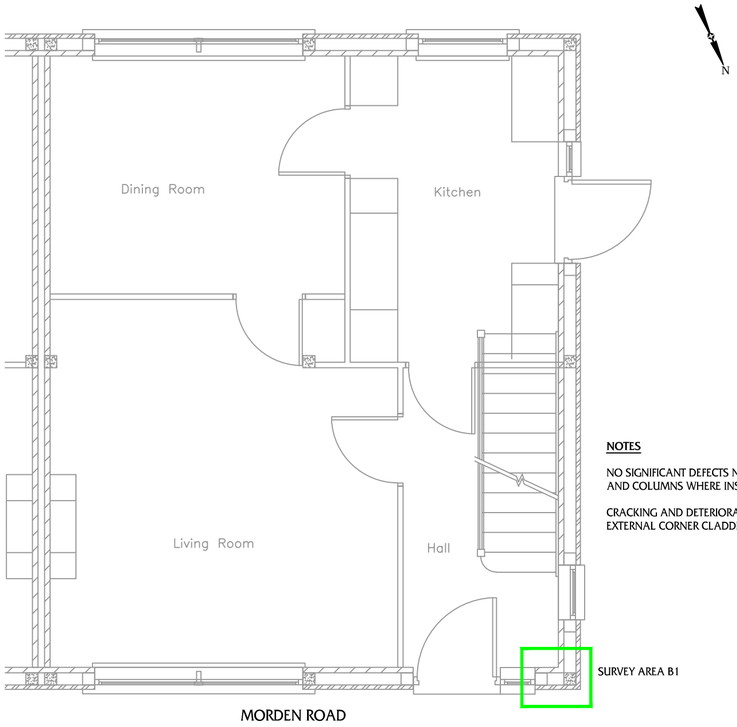
DETAILS OF INTERNAL GROUND FLOOR SURVEYS AND BREAKOUTS
RAVENSBURY ESTATE - 193 MORDEN ROAD

FIG.B8: GROUND FLOOR PLAN SHOWING LOCATIONS OF SAMPLES AND BREAKOUTS NOT TO SCALE



NOTES

NO SIGNIFICANT DEFECTS NOTED TO BEAMS AND COLUMNS WHERE INSPECTED.

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

FIG.B9: PART GROUND FLOOR PLAN SHOWING LOCATIONS OF SAMPLES AND BREAKOUTS SCALE 1:10

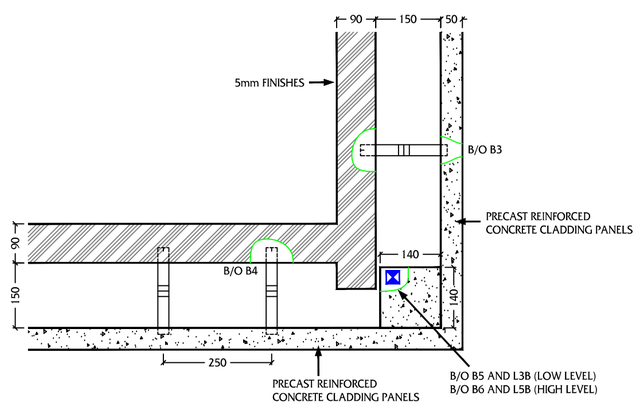


FIG.B10: DETAILS OF WALL TIES AT B/O B3 AND B/O B4 SCALE 1:2

FIG.B10a: PLAN

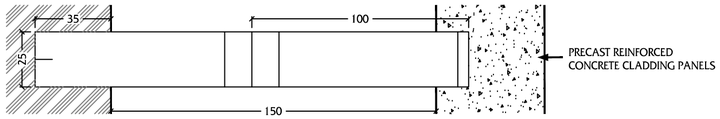
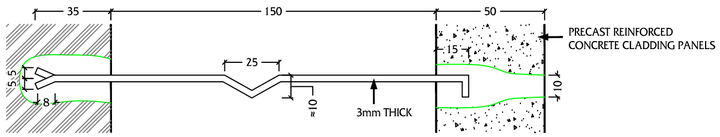


FIG.B10a: ELEVATION



NOTES

DIMENSIONS HERE MEASURED AT B/O B3 AND B/O B4

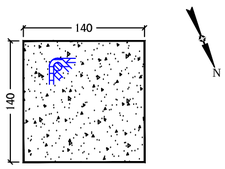
NOTES

DIMENSIONS HERE MEASURED AT B/O B3

NOTES

GALVANISED STEEL WALL TIES OBSERVED TO BE IN SOUND CONDITION.

FIG.B11: DETAILS OF GROUND FLOOR COLUMN AT B/O B5 (LOW LEVEL) SCALE 1:5

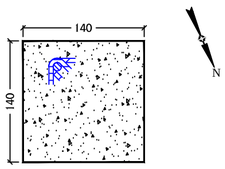


DETAILS OF BREAKOUT

10mmØ PLAIN ROUND VERTICAL BAR AT 25mm MINIMUM COVER.
5mmØ PLAIN ROUND LINK BAR AT 20mm MINIMUM COVER.

BOTH BARS EXHIBIT LIGHT SURFACE CORROSION ONLY.
CARBONATION DEPTH: 1mm

FIG.B12: DETAILS OF GROUND FLOOR COLUMN AT B/O B6 (HIGH LEVEL) SCALE 1:5



DETAILS OF BREAKOUT

10mmØ PLAIN ROUND VERTICAL BAR AT 25mm MINIMUM COVER.
5mmØ PLAIN ROUND LINK BAR AT 20mm MINIMUM COVER.

BOTH BARS EXHIBIT LIGHT SURFACE CORROSION ONLY.
CARBONATION DEPTH: 2-5mm

PB11a: VIEW OF B/O B5 TO GROUND FLOOR COLUMN AT LOW LEVEL

PB11b: VIEW LOOKING DOWN TOWARDS COLUMN BASEPLATE CONNECTION BELOW B/O B5

PB12a: VIEW OF B/O B6 TO GROUND FLOOR COLUMN AT HIGH LEVEL. NOTE ALSO EXPOSED WALL TIES

PB10a: VIEW OF B/O B3 TO WALL TIE EMBEDMENT WITHIN CLADDING

PB10b: VIEW OF B/O B4 TO WALL TIE EMBEDMENT WITHIN INTERNAL BLOCKWORK SKIN

PB10c: VIEW LOOKING UP WITHIN CAVITY WALL ON EASTERN SIDE OF COLUMN AT B/O B4

LOCATION PLAN

SYMBOLS USED

- PLAN EXTENT OF AREA SURVEYED
- PRIMARY BEAM
- SECONDARY BEAM
- CONTINUITY BAR
- DUST SAMPLE LOCATION
- LUMP SAMPLE LOCATION
- LUMP SAMPLE AND BREAKOUT LOCATION
- EXTENT OF BREAKOUT

MATERIAL TYPES

- CONCRETE
- STEEL
- PLASTER
- BRICKWORK
- TIMBER
- BLOCKWORK

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 4 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905B-1 TO -4.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	193 MORDEN ROAD, MITCHAM CR4 4DJ
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 193 MORDEN ROAD

Client: CIRCLE HOUSING

Title: DETAILS OF INTERNAL GROUND FLOOR SURVEYS AND BREAKOUTS

Drawn	Date	Scale	Dwg. No. 3905B-3
HW	OCT 14	AS SHOWN	
CAD	PM	APP	

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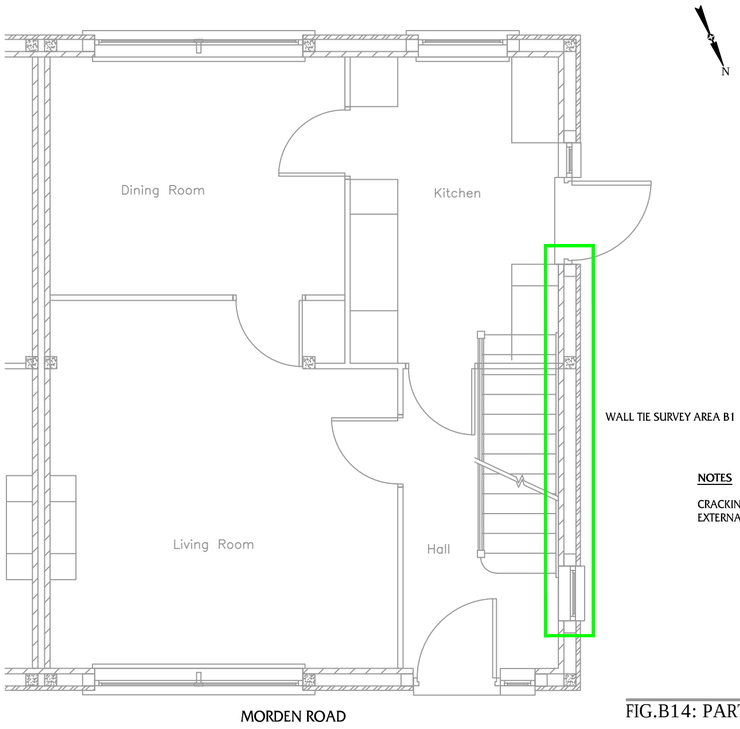
ISO 9001 Registered

File 3905B

GBG

DETAILS OF WALL TIE SURVEY
RAVENSBURY ESTATE - 193 MORDEN ROAD

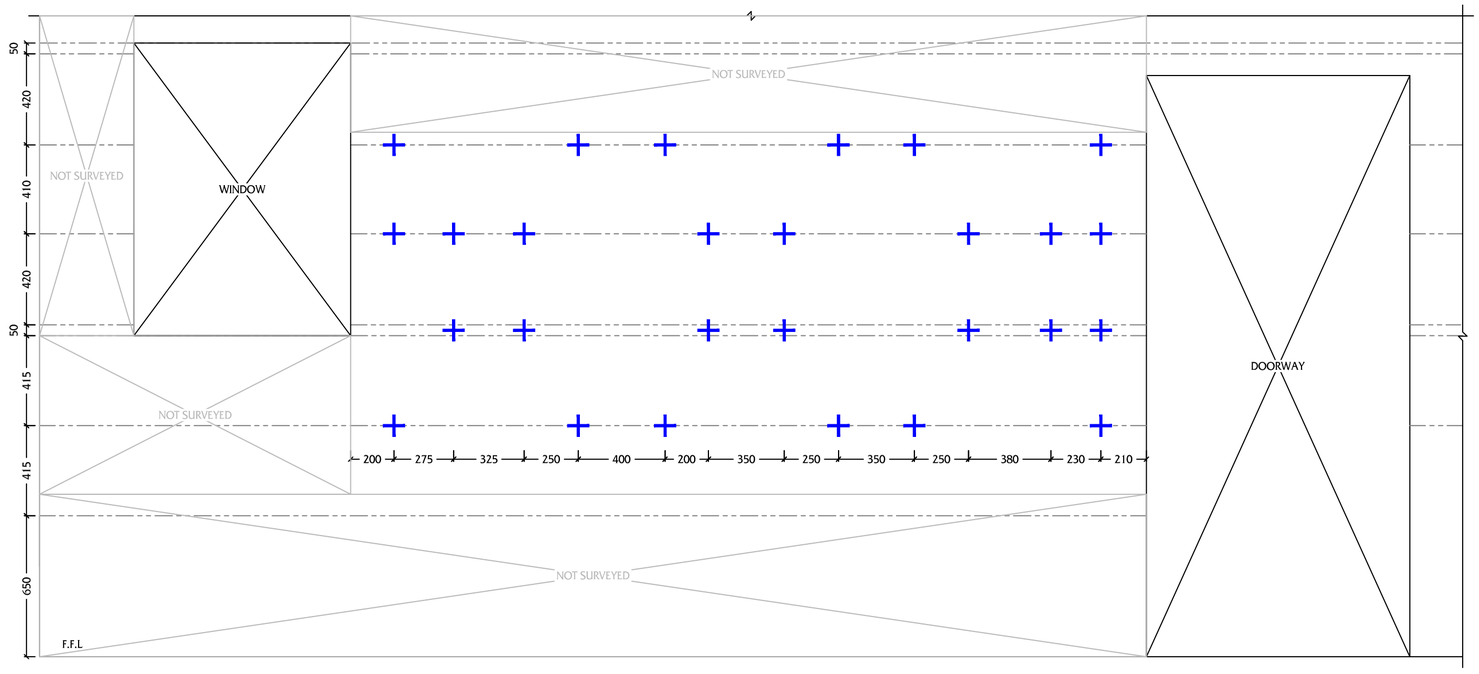
FIG.B13: GROUND FLOOR PLAN SHOWING LOCATION OF WALL TIE SURVEY NOT TO SCALE



NOTES

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

FIG.B14: PART WESTERN GROUND FLOOR ELEVATION SHOWING RESULTS OF WALL TIE SURVEY B1 SCALE 1:20



PB14a: VIEW OF WALL TIE SURVEY AREA B1 ON WESTERN SIDE OF PROPERTY AT GROUND FLOOR LEVEL

NOTES

VERTICAL JOINTS BETWEEN PRECAST CLADDING PANELS OMITTED FROM SKETCH

LOCATION PLAN

SYMBOLS USED

- PLAN EXTENT OF AREA SURVEYED
- \+ LOCATION OF TIE
- HORIZONTAL JOINT BETWEEN PRECAST CLADDING PANELS

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 4 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905B-1 TO -4.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	193 MORDEN ROAD, MITCHAM CR4 4DJ
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 193 MORDEN ROAD

Client: CIRCLE HOUSING

Title: DETAILS OF WALL TIE SURVEY

Drawn	Date	Scale	Dwg. No. 3905B-4
HW	OCT 14	AS SHOWN	
CAD	PM	APP	

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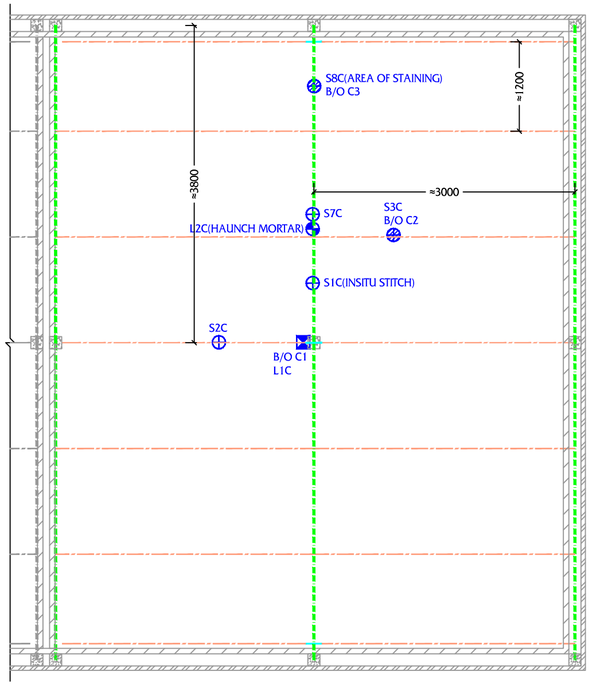
DETAILS OF ROOF SURVEYS AND BREAKOUTS
RAVENSBURY ESTATE - 1 RUTTER GARDENS

FIG.C1: ROOF PLAN SHOWING LOCATIONS OF SAMPLES AND BREAKOUTS NOT TO SCALE

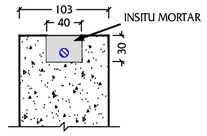


NOTES

NO SIGNIFICANT DEFECTS NOTED TO BEAMS WHERE INSPECTED.

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

FIG.C2: DETAILS OF BREAKOUT B/O C1 TO TOP OF ROOF SECONDARY BEAM SCALE 1:5

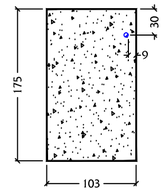


DETAILS OF B/O C1

10mmØ PLAIN ROUND CONTINUITY BAR EMBEDDED WITHIN INSITU MORTAR FILLED PRE-FORMED SLOT. TOP COVER TO BAR 10mm. BAR OBSERVED TO BE IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY. INSITU MORTAR APPEARS TO BE IN REASONABLE CONDITION WITH THE EXCEPTION OF SOME CRACKING.

PC2a: VIEW OF B/O C1 TO TOP OF ROOF SECONDARY BEAM

FIG.C3: DETAILS OF B/O C2 TO TOP OF SECONDARY BEAM SCALE 1:5



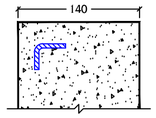
DETAILS OF B/O C2

5mmØ PLAIN ROUND HORIZONTAL BAR AT 9mm MINIMUM COVER.

BAR OBSERVED TO BE IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY
CARBONATION DEPTH: 2-3mm.

PC3a: VIEW OF B/O C2 TO SECONDARY BEAM

FIG.C4: DETAILS OF B/O C3 TO TO ROOF PRIMARY BEAM SCALE 1:5



DETAILS OF B/O C3

5mmØ PLAIN ROUND LINK AT 19mm MINIMUM COVER.

BAR IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY.
CARBONATION DEPTH: 17mm

PC4a: VIEW OF B/O C3 TO ROOF PRIMARY BEAM

LOCATION PLAN

SYMBOLS USED

- PLAN EXTENT OF AREA SURVEYED
- PRIMARY BEAM
- SECONDARY BEAM
- CONTINUITY BAR
- DUST SAMPLE LOCATION
- LUMP SAMPLE LOCATION
- DUST SAMPLE AND BREAKOUT LOCATION
- LUMP SAMPLE AND BREAKOUT LOCATION
- EXTENT OF BREAKOUT

MATERIAL TYPES

- CONCRETE
- STEEL
- PLASTER
- BRICKWORK
- TIMBER
- TIMBER

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 2 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905C-1 TO -3.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	1 RUTTER GARDENS, MITCHAM CR4 4DS
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 1 RUTTER GARDENS

Client: CIRCLE HOUSING

Title: DETAILS OF ROOF SURVEYS AND BREAKOUTS

Drawn	Date	Scale	
HW	OCT 14	AS SHOWN	Dwg. No. 3905C-1
CAD	PM	APP	

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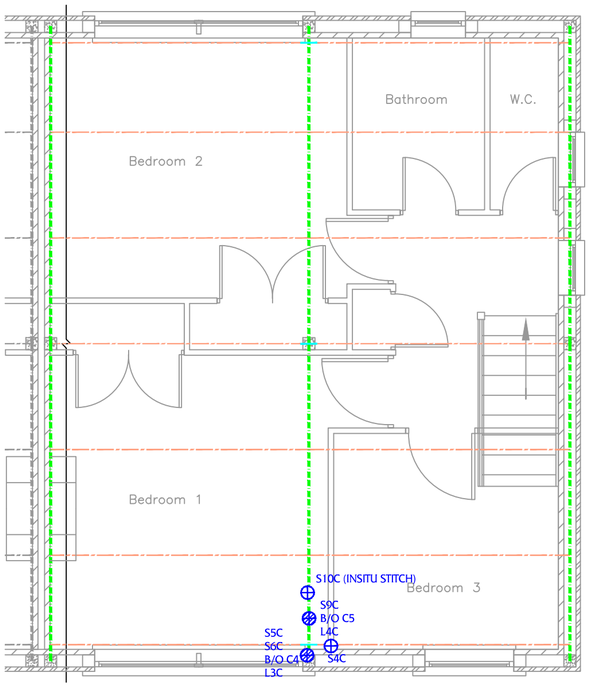
DETAILS OF 1ST FLOOR SURVEYS AND BREAKOUTS
RAVENSBURY ESTATE - 1 RUTTER GARDENS

FIG.C5: 1ST FLOOR PLAN SHOWING LOCATIONS OF SAMPLES AND BREAKOUTS

NOT TO SCALE



RUTTER GARDENS

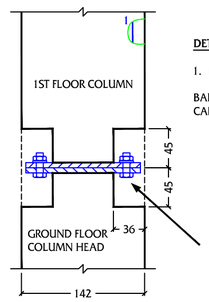
NOTES

NO SIGNIFICANT DEFECTS NOTED TO BEAMS WHERE INSPECTED.

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

FIG.C6: DETAILS OF BREAKOUT B/O C4 TO 1ST FLOOR COLUMN AND 1ST FLOOR TO GROUND FLOOR COLUMN CONNECTION

SCALE 1:5



DETAILS OF B/O C41

1. 10mmØ PLAIN ROUND VERTICAL BAR AT 14mm COVER.

BAR IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY.
CARBONATION DEPTH: 10mm

NOTES

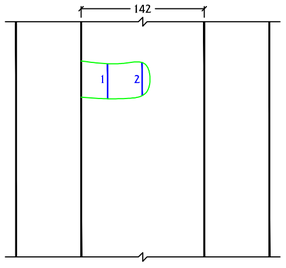
CAVITY WALLS FILLED WITH INSULATION. UNABLE TO INSPECT WALL TIES.

PC6a: VIEW OF B/O C4 TO 1ST FLOOR COLUMN

PC6b: VIEW OF 1ST FLOOR TO GROUND FLOOR COLUMN CONNECTION DETAIL

FIG.C7: DETAILS OF B/O C5 TO TOP OF 1ST FLOOR PRIMARY BEAM - PLAN VIEW

SCALE 1:5



PC7a: GENERAL VIEW OF 1ST FLOOR EXPOSURE TO B/O C5

PC7b: VIEW OF B/O C5 TO TOP OF PRIMARY BEAM

DETAILS OF B/O C5

1. 13mmØ PLAIN ROUND BAR AT 30mm COVER.
2. 10mmØ PLAIN ROUND BAR AT 30mm COVER.

BOTH BARS IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY.
CARBONATION DEPTH: 20mm

LOCATION PLAN

SYMBOLS USED

- PLAN EXTENT OF AREA SURVEYED
- PRIMARY BEAM
- SECONDARY BEAM
- CONTINUITY BAR
- DUST SAMPLE LOCATION
- LUMP SAMPLE LOCATION
- DUST SAMPLE AND BREAKOUT LOCATION
- LUMP SAMPLE AND BREAKOUT LOCATION
- EXTENT OF BREAKOUT

MATERIAL TYPES

- CONCRETE
- STEEL
- PLASTER
- BRICKWORK
- TIMBER
- TIMBER

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 2 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905C-1 TO -3.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	1 RUTTER GARDENS, MITCHAM CR4 4DS
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 1 RUTTER GARDENS

Client: CIRCLE HOUSING

Title: DETAILS OF 1ST FLOOR SURVEYS AND BREAKOUTS

Drawn	Date	Scale	Dwg. No. 3905C-2
HW	OCT 14	AS SHOWN	
CAD	PM	APP	

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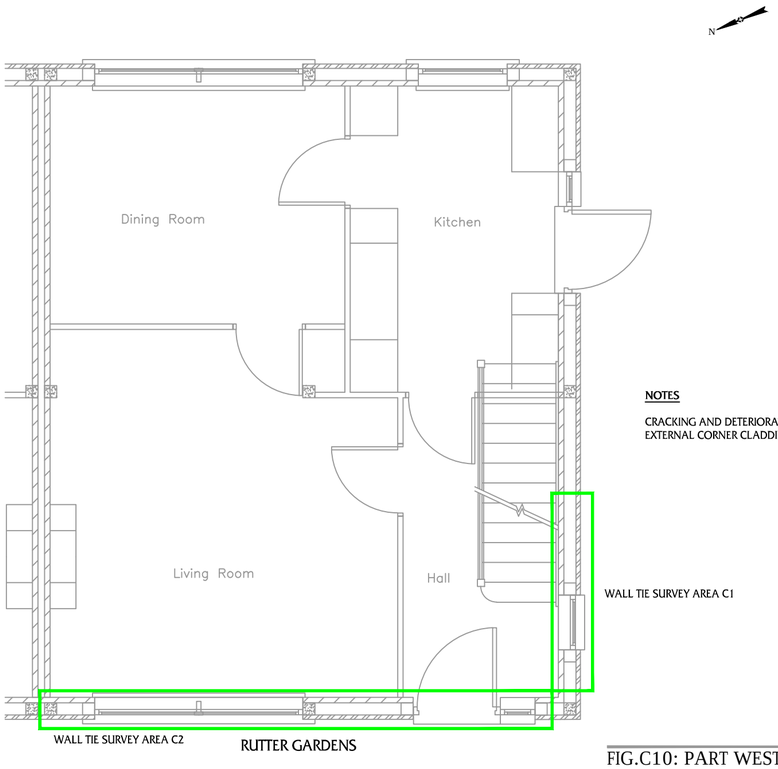
GBG

DETAILS OF WALL TIE SURVEYS
RAVENSBURY ESTATE - 1 RUTTER GARDENS

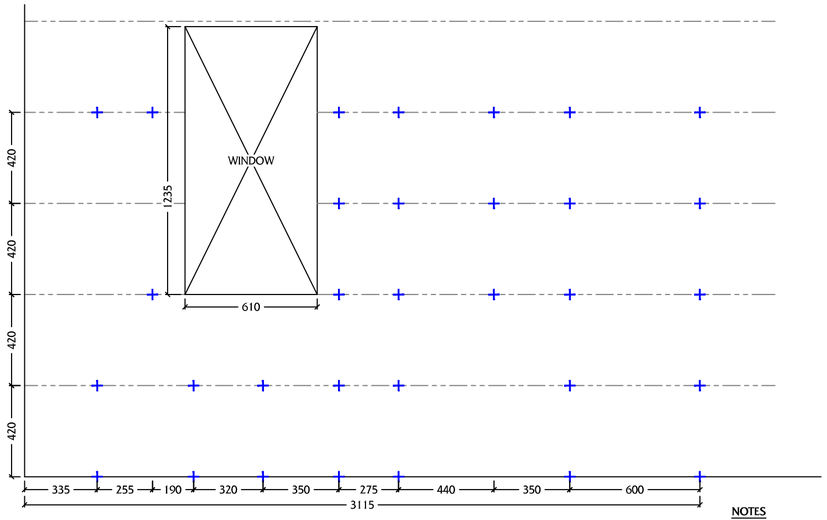
FIG.C8: GROUND PLAN SHOWING LOCATIONS OF WALL TIE SURVEYS NOT TO SCALE



NOTES

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

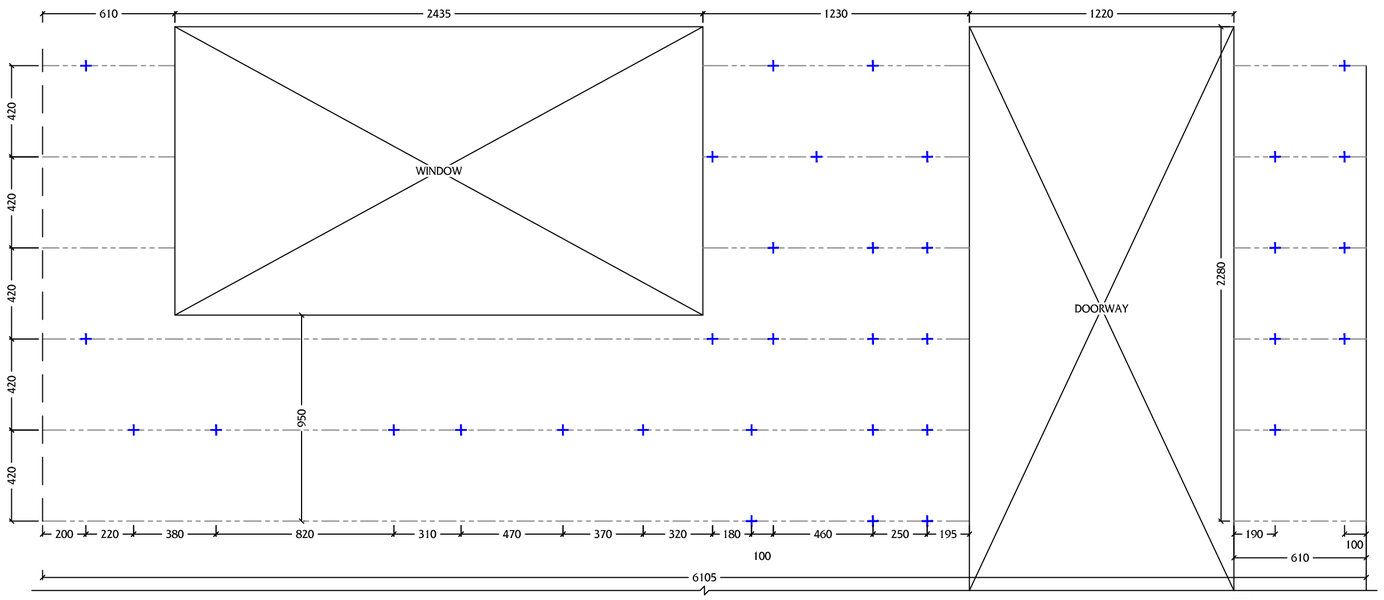
FIG.C9: PART SOUTHERN GROUND FLOOR ELEVATION SHOWING RESULTS OF WALL TIE SURVEY C1 SCALE 1:20



NOTES

VERTICAL JOINTS BETWEEN PRECAST CLADDING PANELS OMITTED FROM SKETCH

FIG.C10: PART WESTERN (FRONT) GROUND FLOOR ELEVATION SHOWING RESULTS OF WALL TIE SURVEY C2 SCALE 1:20



NOTES

VERTICAL JOINTS BETWEEN PRECAST CLADDING PANELS OMITTED FROM SKETCH

LOCATION PLAN

SYMBOLS USED

- PLAN EXTENT OF AREA SURVEYED
- LOCATION OF TIE
- HORIZONTAL JOINT BETWEEN PRECAST CLADDING PANELS

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 2 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905C-1 TO -3.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	1 RUTTER GARDENS, MITCHAM CR4 4DS
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

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0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 1 RUTTER GARDENS

Client: CIRCLE HOUSING

Title: DETAILS OF WALL TIE SURVEYS

Drawn	Date	Scale	Dwg. No.
HW	OCT 14	AS SHOWN	3905C-3
CAD	PM	APP	

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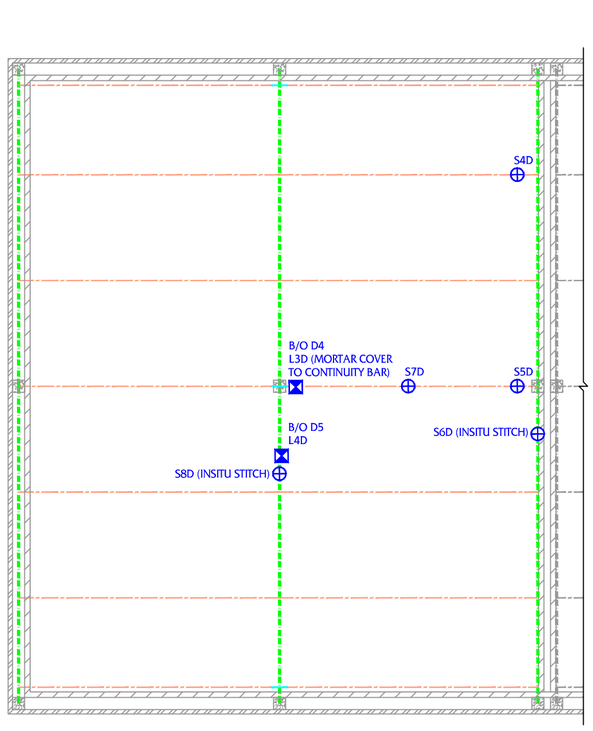
DETAILS OF ROOF SURVEYS AND BREAKOUTS
RAVENSBURY ESTATE - 20 HATFIELD CLOSE

FIG.D1: ROOF PLAN SHOWING LOCATIONS OF SAMPLES AND BREAKOUTS NOT TO SCALE



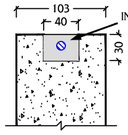
HATFIELD CLOSE

NOTES

NO SIGNIFICANT DEFECTS NOTED TO BEAMS WHERE INSPECTED.

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

FIG.D2: DETAILS OF BREAKOUT B/O D4 TO TOP OF ROOF SECONDARY BEAM SCALE 1:5

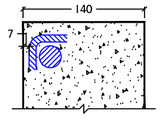


DETAILS OF B/O D4

12.5mmØ PLAIN ROUND CONTINUITY BAR EMBEDDED WITHIN INSITU MORTAR FILLED PRE-FORMED SLOT. TOP COVER TO BAR 8mm. BAR OBSERVED TO BE IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY. INSITU MORTAR APPEARS TO BE IN REASONABLE CONDITION.

PD2a: VIEW OF B/O D4 TO TOP OF ROOF SECONDARY BEAM

FIG.D3: DETAILS OF B/O D5 TO TO ROOF PRIMARY BEAM SCALE 1:5



DETAILS OF B/O D5

25mmØ PLAIN ROUND LONGITUDINAL BAR AT 19mm MINIMUM COVER.
8mmØ PLAIN ROUND LINK AT 15mm MINIMUM COVER.

BOTH BARS OBSERVED TO BE IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY.
CARBONATION DEPTH: 18mm

PD3a: VIEW OF B/O D5 TO ROOF PRIMARY BEAM

LOCATION PLAN

SYMBOLS USED

PLAN EXTENT OF AREA SURVEYED
PRIMARY BEAM
SECONDARY BEAM
CONTINUITY BAR
DUST SAMPLE LOCATION
BREAKOUT LOCATION
LUMP SAMPLE AND BREAKOUT LOCATION
EXTENT OF BREAKOUT

MATERIAL TYPES

CONCRETE
STEEL

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 5 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905D-1 TO -5.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	20 HATFIELD CLOSE, MITCHAM CR4 4DJ
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 20 HATFIELD CLOSE

Client: CIRCLE HOUSING

Title: DETAILS OF ROOF SURVEYS AND BREAKOUTS

Drawn	Date	Scale	Dwg. No. 3905D-1
HW	OCT 14	AS SHOWN	
CAD	PM	APP	

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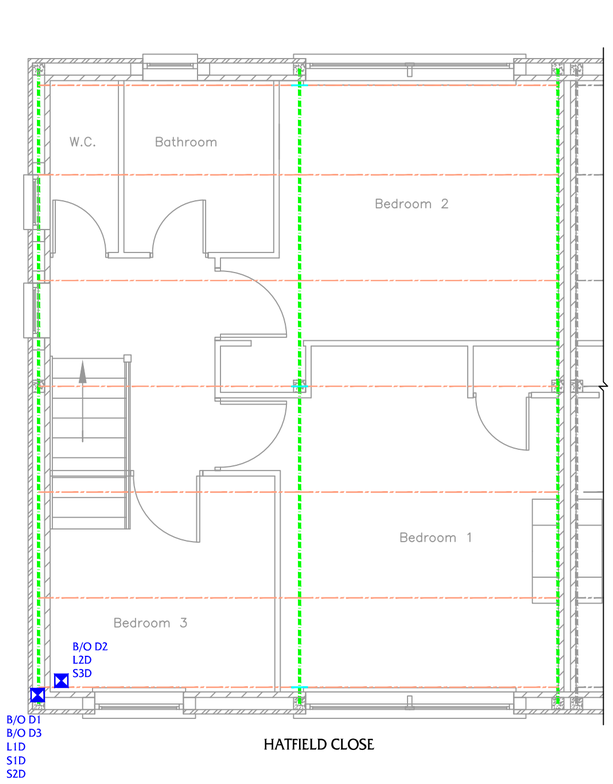
ISO 9001 Registered

File 3905D

DETAILS OF 1ST FLOOR SURVEYS AND BREAKOUTS
RAVENSBURY ESTATE - 20 HATFIELD CLOSE

FIG.D4: 1ST PLAN SHOWING LOCATIONS OF SAMPLES AND BREAKOUTS NOT TO SCALE



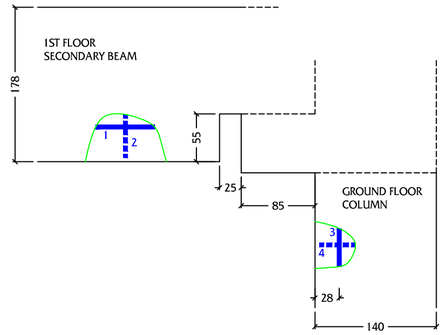
HATFIELD CLOSE

NOTES

NO SIGNIFICANT DEFECTS NOTED TO BEAMS WHERE INSPECTED.

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

FIG.D5: PART ELEVATION ON WESTERN SIDE OF 1ST FLOOR SECONDARY BEAM TO GROUND FLOOR COLUMN CONNECTION AT B/O D1 AND B/O D3 SCALE 1:5



DETAILS OF REINFORCEMENT

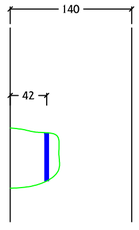
1. 20mmØ PLAIN LONGITUDINAL ROUND BAR AT 25 MINIMUM COVER.
2. 5mmØ PLAIN ROUND LINK AT 20 MINIMUM COVER.
3. 10mmØ PLAIN VERTICAL ROUND BAR AT 22 MINIMUM COVER.
4. 5mmØ PLAIN ROUND LINK AT 17 MINIMUM COVER.

ALL BARS OBSERVED TO BE IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY.
CARBONATION DEPTH: 22mm AT B/O D1 AND 15mm AT B/O D2.

PD5a: VIEW OF B/O D1 TO GROUND FLOOR COLUMN. NOTE INSULATION WITHIN CAVITIES.

PD5b: VIEW LOOKING SOUTH FROM B/O D1 WITHIN 1ST FLOOR CEILING VOID

FIG.D6: DETAILS OF B/O D3 TO 1ST FLOOR COLUMN AT HIGH LEVEL - PART VIEW ON EASTERN FACE OF COLUMN SCALE 1:5



DETAILS OF B/O D3

10mmØ PLAIN ROUND VERTICAL BAR AT 15mm MINIMUM COVER.

BAR OBSERVED TO BE IN GOOD CONDITION EXHIBITING LIGHT SURFACE CORROSION ONLY.
CARBONATION: 25mm.

PD6a: VIEW OF 1ST FLOOR COLUMN. NOTE PHOTO TAKEN POST REINSTATEMENT OF B/O D1

LOCATION PLAN

SYMBOLS USED

- PLAN EXTENT OF AREA SURVEYED
- PRIMARY BEAM
- SECONDARY BEAM
- CONTINUITY BAR
- DUST SAMPLE LOCATION
- BREAKOUT LOCATION
- LUMP SAMPLE AND BREAKOUT LOCATION
- EXTENT OF BREAKOUT

MATERIAL TYPES

- CONCRETE
- STEEL

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 5 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905D-1 TO -5.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	20 HATFIELD CLOSE, MITCHAM CR4 4DJ
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 20 HATFIELD CLOSE

Client: CIRCLE HOUSING

Title: DETAILS OF 1ST FLOOR SURVEYS AND BREAKOUTS

Drawn	Date	Scale	Dwg. No. 3905D-2
HW	OCT 14	AS SHOWN	
CAD	PM	APP	

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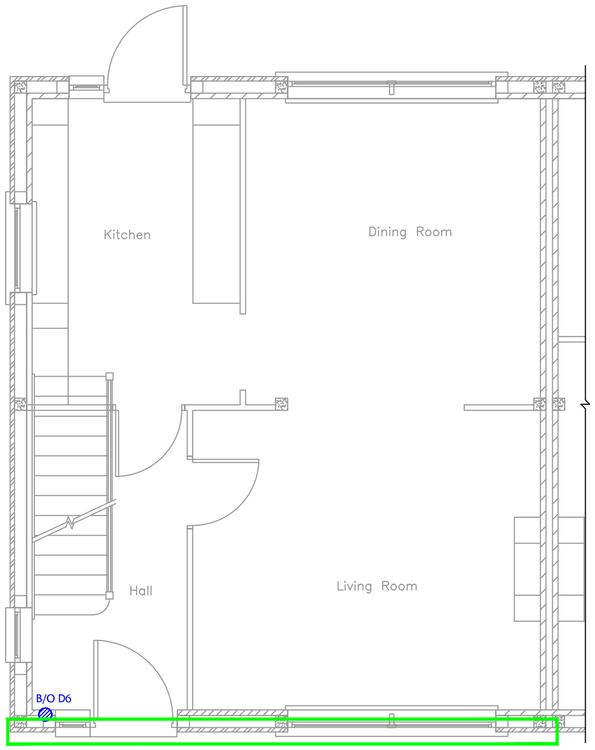
Website: www.gbg.co.uk

DETAILS OF GROUND FLOOR WALL TIE SURVEY AND BREAKOUT TO WESTERN ELEVATION
RAVENSBURY ESTATE - 20 HATFIELD CLOSE

FIG.D7: GROUND FLOOR PLAN SHOWING LOCATIONS OF BREAKOUT AND WALL TIE SURVEY AREA D1 NOT TO SCALE



NOTES

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

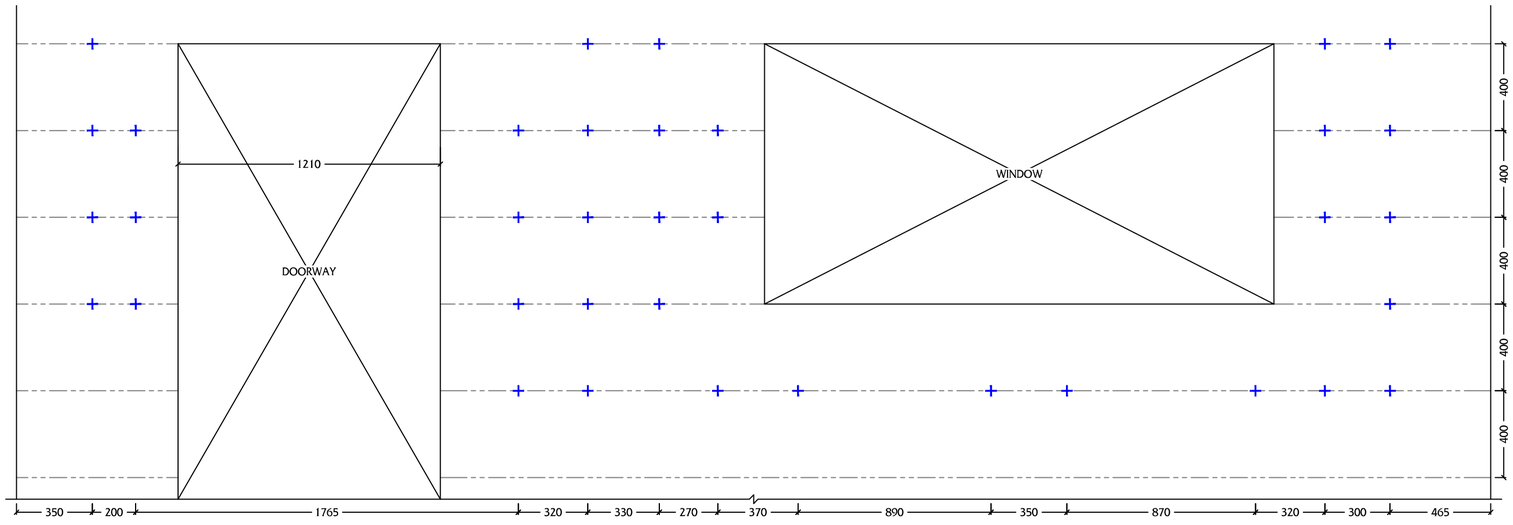
FIG.D8: DETAILS OF B/O D6 TO INTERNAL BLOCKWORK WALL AT GROUND FLOOR LEVEL

DETAILS OF B/O D6

GALVANISED STEEL WALL TIE EXPOSED AND FOUND TO BE IN GOOD CONDITION.
DEPTH OF TIE EMBEDMENT WITHIN INTERNAL BLOCKWORK SKIN: 35mm.
NOTE CAVITY FILLED WITH INSULATION.

PD8a: VIEW OF B/O D6 AND EXPOSED WALL TIE

FIG.D9: PART WESTERN (FRONT) GROUND FLOOR ELEVATION SHOWING RESULTS OF WALL TIE SURVEY D1 SCALE 1:20



PD9a: PART VIEW OF SOUTHERN SIDE OF WALL TIE SURVEY AREA D1

NOTES

VERTICAL JOINTS BETWEEN PRECAST PANELS OMITTED FROM SKETCH

LOCATION PLAN

SYMBOLS USED

- PLAN EXTENT OF AREA SURVEYED
- \+ LOCATION OF TIE
- HORIZONTAL JOINT BETWEEN PRECAST CLADDING PANELS

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 5 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905D-1 TO -5.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	20 HATFIELD CLOSE, MITCHAM CR4 4DJ
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 20 HATFIELD CLOSE

Client: CIRCLE HOUSING

Title: DETAILS OF GROUND FLOOR WALL TIE SURVEY AND BREAKOUT TO WESTERN ELEVATION

Drawn	Date	Scale
HW	OCT 14	AS SHOWN
CAD	PM	APP

Dwg. No. 3905D-3

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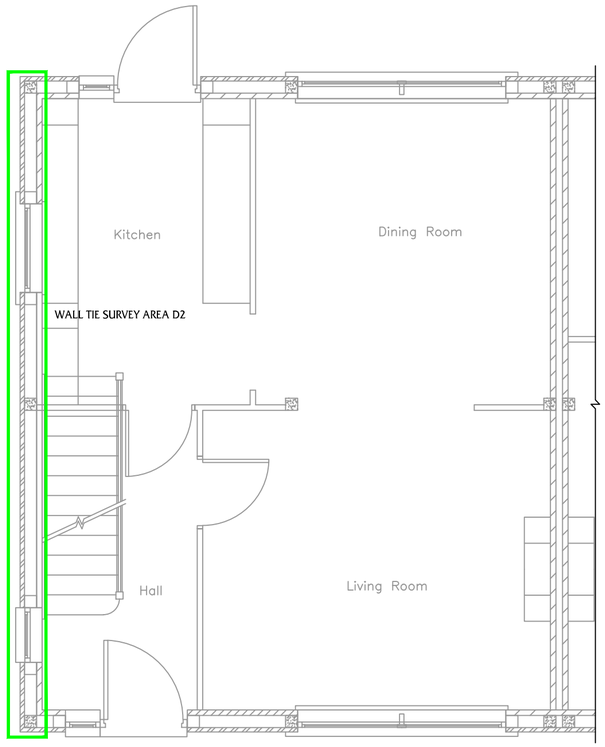
DETAILS OF WALL TIE SURVEY TO NORTHERN ELEVATION
RAVENSBURY ESTATE - 20 HATFIELD CLOSE

FIG.D10: GROUND FLOOR PLAN SHOWING LOCATION OF WALL TIE SURVEY AREA D2 NOT TO SCALE

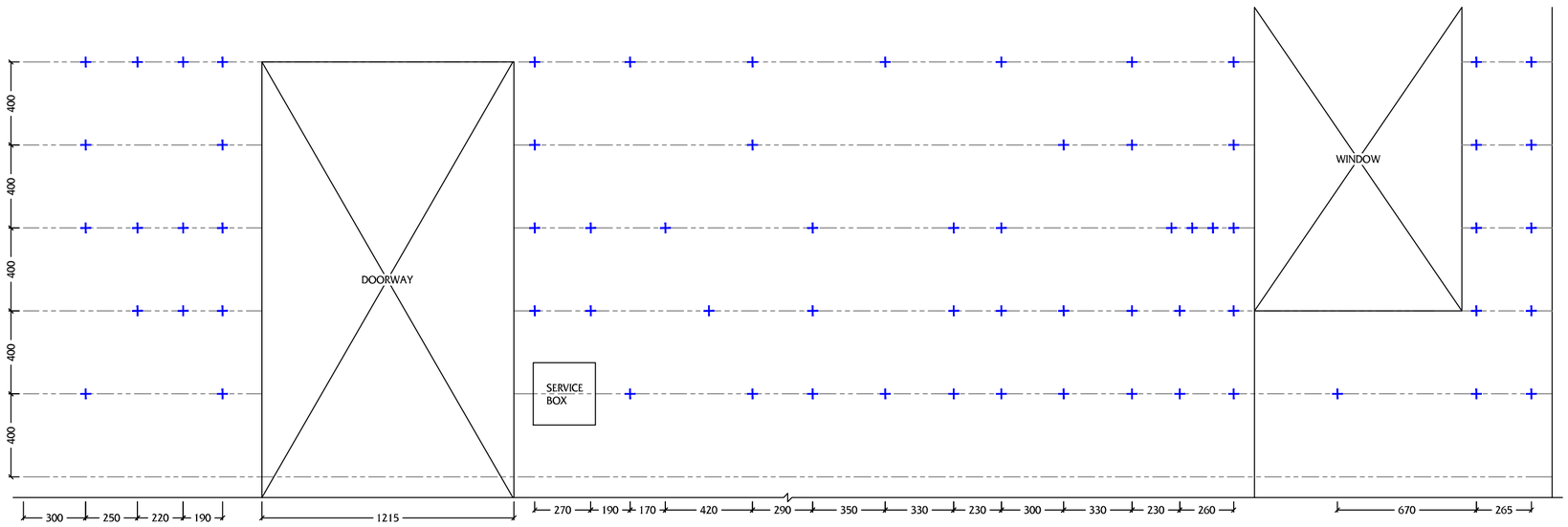


HATFIELD CLOSE

NOTES

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

FIG.D11: PART NORTHERN GROUND FLOOR ELEVATION SHOWING RESULTS OF WALL TIE SURVEY D2 SCALE 1:20



PD11a: PART VIEW OF EASTERN SIDE OF WALL TIE SURVEY AREA D2

NOTES

VERTICAL JOINTS BETWEEN PRECAST PANELS OMITTED FROM SKETCH

LOCATION PLAN

SYMBOLS USED

PLAN EXTENT OF AREA SURVEYED

LOCATION OF TIE

HORIZONTAL JOINT BETWEEN PRECAST CLADDING PANELS

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 5 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905D-1 TO -5.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	20 HATFIELD CLOSE, MITCHAM CR4 4DJ
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 20 HATFIELD CLOSE

Client: CIRCLE HOUSING

Title: DETAILS OF WALL TIE SURVEY TO NORTHERN ELEVATION

Drawn	Date	Scale
HW	OCT 14	AS SHOWN
CAD	PM	APP

Dwg. No. 3905D-4

GBG INNOVATION IN STRUCTURAL INVESTIGATION

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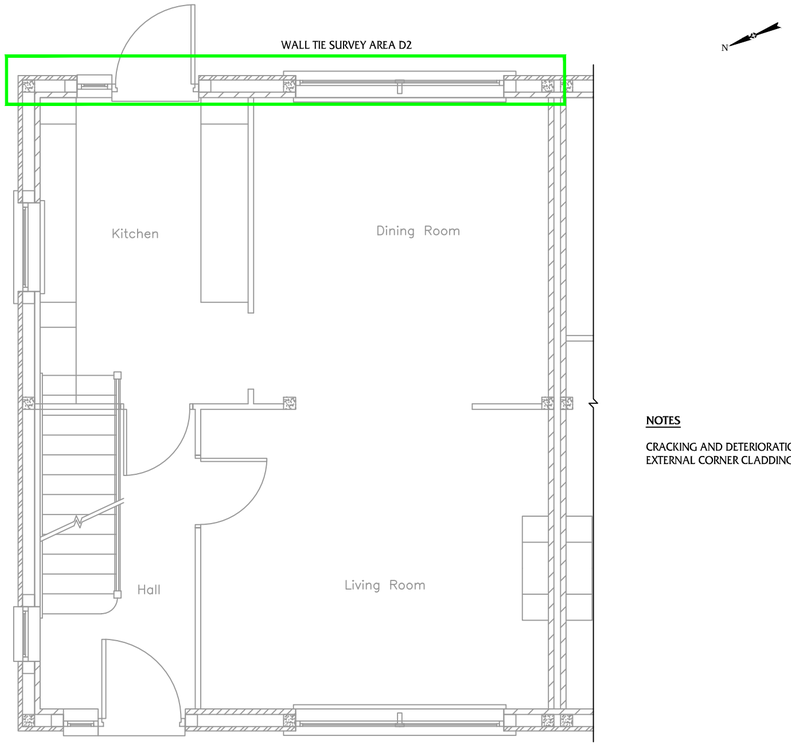
GBG

DETAILS OF WALL TIE SURVEY TO EASTERN ELEVATION
RAVENSBURY ESTATE - 20 HATFIELD CLOSE

FIG.D12: GROUND FLOOR PLAN SHOWING LOCATION OF WALL TIE SURVEY AREA D3 NOT TO SCALE

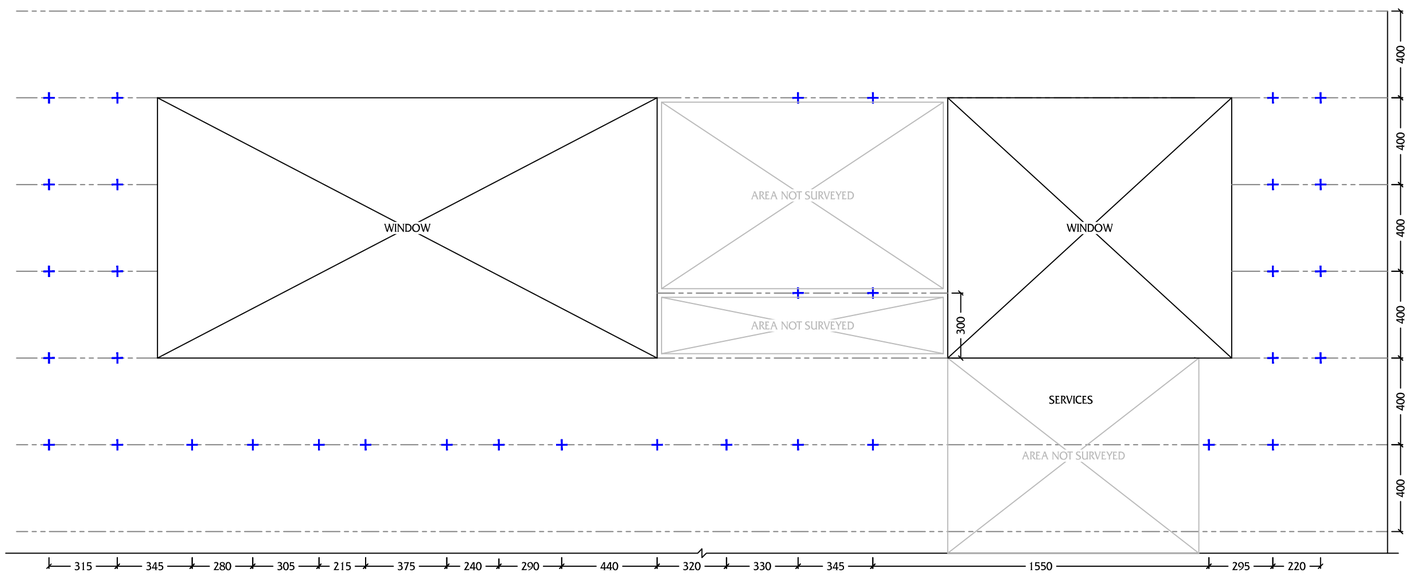


HATFIELD CLOSE

NOTES

CRACKING AND DETERIORATION NOTED TO EXTERNAL CORNER CLADDING PANELS.

FIG.D13: PART EASTERN GROUND FLOOR ELEVATION SHOWING RESULTS OF WALL TIE SURVEY D3 SCALE 1:20



PD13a: PART VIEW OF WALL TIE SURVEY AREA D3

NOTES

VERTICAL JOINTS BETWEEN PRECAST PANELS OMITTED FROM SKETCH

LOCATION PLAN

SYMBOLS USED

- PLAN EXTENT OF AREA SURVEYED
- \+ LOCATION OF TIE
- HORIZONTAL JOINT BETWEEN PRECAST CLADDING PANELS

PROJECT DETAILS

GBG REPORT No. 3905 ACCOMPANIES THIS DRAWING.
A TOTAL OF 5 DRAWINGS FOR THIS PROPERTY ARE INCLUDED WITH THIS REPORT, Dwg. No's 3905D-1 TO -5.

STRUCTURE INVESTIGATED	ORLIT HOUSE
LOCATION	20 HATFIELD CLOSE, MITCHAM CR4 4DJ
PURPOSE OF INVESTIGATION	TO CARRY OUT A STRUCTURAL CONDITION SURVEY OF 4 ORLIT HOUSES

THIS DRAWING HAS BEEN PREPARED USING EXISTING DRAWINGS AND/OR PRINTS OF DRAWINGS AS SUPPLIED BY THE CLIENT AND SUPPLEMENTED BY MEASUREMENTS TAKEN ON SITE. ALL DIMENSIONS THEREFORE ARE TO BE CHECKED ON SITE PRIOR TO PREPARING DRAWINGS OR COMMENCING ANY WORK.

0 METRES 5

AT A SCALE OF 1:100 - ORIGINAL DWG SIZE A2 (420mm x 594mm)

REF.	REVISION	DATE

ALL ORIGINAL DRAWINGS ARE PRODUCED IN COLOUR

Project: RAVENSBURY ESTATE - 20 HATFIELD CLOSE

Client: CIRCLE HOUSING

Title: DETAILS OF WALL TIE SURVEY TO EASTERN ELEVATION

Drawn	Date	Scale	
HW	OCT 14	AS SHOWN	Dwg. No. 3905D-5
CAD	PM	APP	

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 File 3905D

APPENDIX 2
LABORATORY AND SITE TEST RESULTS SUMMARY

GBG

Site Ref.	Location	Cement Content	Chloride Content*	Depth of Carb'n	Depth of Conc. Cover	HAC
		%	%	mm	mm	
	Precast Concrete Columns					
S4A	1st Floor		<0.06	**15**	3	
S9A	1st Floor		<0.06	**14**	16	**N**
S13A	1st Floor		<0.06	6	23	
S14A	1st Floor		<0.06	20	76	
L1A	1st Floor	12.8	<0.06	**15**	3	
L3A	1st Floor		<0.06	6	23	**N**
	Max		*<0.06*	*20*	*76*	
	Min		*<0.06*	*6*	*3*	
	Avge		*<0.06*	*13*	*24*	
	Precast Concrete Primary Beams					
S5A	Roof		<0.06	**22**	25	
S8A	1st Floor		<0.06	10	36	
S10A	1st Floor		<0.06	4	30	**N**
L2A	1st Floor	11.9	<0.06	4	30	
	Max		*<0.06*	*22*	*36*	
	Min		*<0.06*	*4*	*25*	
	Avge		*<0.06*	*10*	*30*	
	Precast Concrete Secondary Beams					
S3A	Roof		<0.06	20	27	
S6A	Roof		<0.06	20	26	
S7A	1st Floor		<0.06	5	20	
S12A	1st Floor		<0.06	4	20	
S15A	1st Floor		<0.06	15	35	
	Max		*<0.06*	*20*	*35*	
	Min		*<0.06*	*4*	*20*	
	Avge		*<0.06*	*13*	*26*	
	In-situ Concrete Stitches (Beams)					
S11A	1st Floor primary beam		<0.06	3	34	**N**
	Mortar Cover to Continuity Bars					
S2A	Roof secondary beam		0.15	-	2	**N**
	Mortar Haunch					
S1A	Roof secondary beam		<0.06	-	-	**N**

*Chloride contents are expressed by mass of cement based on the calculated average cement content of 12.4%.

N – HAC Not Present.

20 Indicates depth of carbonation has exceeded depth of concrete cover.

20 Indicates depth of carbonation is within 5mm of depth of concrete cover.

Site Ref.	Location	Cement Content	Chloride Content*	Depth of Carb'n	Depth of Conc. Cover	HAC
		%	%	mm	mm	
	Precast Concrete Columns					
L3B	Ground Floor		<0.06	1	20	**N**
L5B	Ground Floor	14.7	<0.06	5	20	
	Avge		*<0.06*	*3*	*20*	
	Precast Concrete Primary Beams					
S2B	Roof		0.07	25	33	**N**
S4B	Roof		<0.06	6	35	
L4B	1st Floor		<0.06	3	20	**N**
	Max		*0.07*	*25*	*35*	
	Min		*<0.06*	*3*	*20*	
	Avge		*<0.06*	*11*	*29*	
	Precast Concrete Secondary Beams					
S3B	Roof		0.06	5	32	
L2B	Roof	12.4	0.22	3	2	
L6B	Roof		0.20	4	29	**N**
L7B	Roof		<0.06	18	33	**N**
S1B	1st Floor		<0.06	2	30	
	Max		*0.22*	*18*	*33*	
	Min		*<0.06*	*2*	*2*	
	Avge		*0.12*	*6*	*25*	
	Mortar Cover to Continuity Bars					
L1B	Roof secondary beam		0.11	-	5	**N**

*Chloride contents are expressed by mass of cement based on the calculated average cement content of 13.6%.

N – HAC Not Present.

Site Ref.	Location	Cement Content	Chloride Content*	Depth of Carb'n	Depth of Conc. Cover	HAC
		%	%	mm	mm	
	Precast Concrete Columns					
S5C	1st Floor		<0.06	**10**	14	**N**
L3C	1st Floor	18.2	<0.06	**10**	14	
	Precast Concrete Primary Beams					
S7C	Roof		0.06	4	58	
S8C	Roof		<0.06	**17**	19	**N**
S9C	1st Floor		0.06	20	30	
L4C	1st Floor	10.3	0.06	20	30	
	Max		*<0.06*	*20*	*58*	
	Min		*<0.06*	*4*	*19*	
	Avge		*<0.06*	*16*	*34*	
	Precast Concrete Secondary Beams					
S2C	Roof		<0.06	4	35	**N**
S3C	Roof		<0.06	3	9	
S4C	1st Floor		<0.06	10	30	
	Max		*<0.06*	*10*	*35*	
	Min		*<0.06*	*3*	*9*	
	Avge		*<0.06*	*6*	*25*	
	In-situ Concrete Stitches (Beams)					
S1C	Roof		<0.06	2	23	
S10C	Roof		<0.06	1	30	
	Avge			*2*	*27*	
	Mortar Cover to Continuity Bars					
L1C	Roof secondary beam		0.09	-	10	**N**
	Mortar Haunch					
L2C	1st Floor secondary beam		<0.06	-	-	**N**
	Mortar at Column Connection					
S6C	1st Floor		<0.06	-	-	**N**

*Chloride contents are expressed by mass of cement based on the calculated average cement content of 14.3%.

N – HAC Not Present.

20 Indicates depth of carbonation is within 5mm of depth of concrete cover.

Site Ref.	Location	Cement Content	Chloride Content*	Depth of Carb'n	Depth of Conc. Cover	HAC
		%	%	mm	mm	
	Precast Concrete Columns					
S1D	1st Floor		1.33	**20**	15	**N**
S2D	1st Floor		0.16	**22**	20	
L1D	1st Floor		0.25	**20**	15	
	Max		*1.33*	*22*	*20*	
	Min		*0.16*	*20*	*15*	
	Avge		*0.58*	*21*	*17*	
	Precast Concrete Primary Beams					
L4D	Roof	14.0	0.34	**18**	20	**N**
	Precast Concrete Secondary Beams					
S4D	Roof		<0.06	20	34	
S5D	Roof		<0.06	20	36	
S7D	Roof		<0.06	**40**	20	**N**
S3D	1st Floor		<0.06	15	25	**N**
L2D	1st Floor	18.7	<0.06	10	30	
	Max		*<0.06*	*40*	*36*	
	Min		*<0.06*	*10*	*20*	
	Avge		*<0.06*	*21*	*29*	
	In-situ Concrete Stitches (Beams)					
S6D	Roof		<0.06	**35**	31	**N**
S8D	Roof		<0.06	**30**	26	
	Avge		*<0.06*	*33*	*29*	
	Mortar Cover to Continuity Bars					
L3D	Roof		0.09	-	8	**N**

*Chloride contents are expressed by mass of cement based on the calculated average cement content of 16.4%.

N – HAC Not Present.

20 Indicates depth of carbonation has exceeded depth of concrete cover.

20 Indicates depth of carbonation is within 5mm of depth of concrete cover.

APPENDIX 3
PETROGRAPHIC EXAMINATION CERTIFICATES

Certificate of Examination
Petrographic Examination of Concrete – ASTM C856-11

Client and Sample Details

Client	GBG Structural Services, Bucknalls Lane, Garston, Watford, WD25 9XX		
IBIS Ref. No	2317-C1	**Sample No**	3905 (L1A)
Sample Details	Job No. 3905		
Sampled by / Date	Client	**Date Received**	06.10.14
Exam by / Date	BJH / 09.03-24.04.12	**Condition**	Damp
Max. Length, mm	36	**Diameter, mm**	Not applicable
Min. Length, mm	31	**Orientation**	Not advised
Outer End Nature	As cast	**Inner End Nature**	Rough
Section Details	Thin-section taken from slice cut perpendicular to the apparent outer surface.		

Methods of Examination and Results

The detailed examination methods, including guidance for some of the terms used in the description, are given in Page 7 of this Certificate of Examination. The detailed petrographic examination results are given in Pages 2 to 3 and a summary is provided below. Record photographs and photomicrographs are given in Pages 4 to 6.

Summary Overview

Composition and Constituents	Natural flint coarse and sand fine aggregates set within a hardened Portland type cement matrix.
Mix Quality	The constituents appeared to be well mixed with good compaction. Matrix microporosity could not be determined as a consequence of matrix changes (carbonation).
Condition	The concrete appeared to be sound with no obvious evidence of significant distress or deterioration. Carbonation was present throughout the sample. Minor microcracking of the cement matrix.
Other Details	The total aggregate combination was considered to have a normal alkali-reaction potential.
Rating (See Page 7)	A2

Remarks

The results and comments given in this certificate relate only to the sample examined. How these results and comments relate to concrete elements represented by this sample is outside the scope of this certificate.

Issue Date: 25.10.14

Barry J Hunt
Director, IBIS Limited

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Aggregate Details		
Coarse Aggregate *(incl. type, nominal max. size, shape, grading, distribution and orientation)*	Natural flint gravel comprising particles of nominal 10 mm maximum size, angular to rounded shape, single-sized grading, uniform distribution and random orientation.	
Constituents (Coarse) *(incl. hardness, colour and approx. percent of lithological types present, alteration, weathering and general features of engineering significance)*	Major	CHERT: particles of microcrystalline and cryptocrystalline silica, including some fibrous quartz (chalcedony), that were sometimes microporous and/or fossiliferous. Some particles were partially discoloured by the presence of orange/brown compounds of iron.
	Minor	None observed.
	Trace	None observed.
Cement:Aggregate Bond	Good, relatively few partings visible.	
Additional Observations *(incl. evidence of deterioration etc)*	None observed.	
Fine Aggregate *(incl. type, nominal max. size, shape, grading, distribution and orientation)*	Natural sand comprising particles of nominal 5 mm maximum size, irregular to mostly rounded shape, continuous grading, uniform distribution and random orientation.	
Constituents (Fine) *(incl. hardness, colour and approx. percent of lithological types present, alteration, weathering and general features of engineering significance)*	Major	QUARTZ: particles of monocrystalline silica that appeared unstrained. CHERT: particles as described for the coarse aggregate, some of them probably derived from it.
	Minor	QUARTZITE: particles of polycrystalline silica, the individual crystal grains appearing to be unstrained.
	Trace	GLAUCONITE: occasional green or brown particulate agglomerations of the mineral glauconite. OPAQUES: deep-red and black particles rich in iron and often enclosing fine quartz. FELDSPAR: alkali and plagioclase types present.
Cement:Aggregate Bond	Good, relatively few partings visible.	
Additional Observations *(incl. evidence of deterioration etc)*	In combination with the coarse aggregate, the total aggregate combination was considered to exhibit a normal potential for alkali-reaction.	

Cement Type Determination – BS 1881 : Part 124 : 1988

Only carried out if requested.

Polished Specimen Details	N/A			
No. of Grains > 40µm	OPC Type	N/A	SRPC Type	N/A
No. of Grains 20-40µm	OPC Type	N/A	SRPC Type	N/A
No. of Grains < 20µm	OPC Type	N/A	SRPC Type	N/A
Apparent Cement Type	N/A			
Other Details	N/A			

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Concrete Features	
Apparent Cement Type† and Matrix Details *(Portland, High Alumina, White, PBC, etc and incl. hardness, colour, colour distribution and matrix distribution)*	Abundant small and frequent medium to large relict unhydrated and hemi-hydrated Portland type cement grains distributed throughout the matrix. The cement matrix appeared dark light grey, which was suggestive of the use of an Ordinary Portland Cement.
Mineral Additions• *(incl. type, size, relative abundance, distribution and shape)*	None observed.
Compaction *(incl. air void max. size, shape, distribution, orientation, excess voidage)*	Good compaction suggested by the general lack of large entrapped air voids. The largest visible voids reached up to 3 mm in diameter, most less than 1 mm. The excess voidage was estimated to be < 0.5 %.
Air Void Details and Water/Cement Ratio# *(incl. presence of entrainment, microporosity variations and relation to other features; assessment of original water/cement ratio)*	Impregnation of the thin-section was reasonably consistent due to the presence of the carbonation, which did not allow an assessment of the original water/cement ratio to be made.
Carbonation* *(incl. depths, variations and relation to surface cracking)*	Carbonation was present throughout the sample received and thus present to a depth of at least 36 mm. Patchy carbonation effects were visible at a depth of 33 mm.
Portlandite *(incl. size, shape, abundance and distribution of crystallites)*	Portlandite not observed within the sample, which was likely a consequence of the extensive and essentially complete carbonation effects.
Other Concrete Details *(incl. applied finishes, inclusions and impurities)*	None observed.
Reinforcement *(incl. types, sizes, depths, orientations, evidence of corrosion)*	None present in the sample though a possible 8 mm impression was visible 17 mm from one of the outer surfaces.
Evidence of Cracking *(incl. crack styles, abundance and relation to other features)*	Sporadic microcracking of the cement matrix apparent, this exploiting aggregate particle boundaries.
Presence of Deposits *(incl. gel, sulfates, carbonates, oxides, soot and their location, abundance and distribution)*	None observed.
Other Observations *(incl. sweaty patches, matrix alteration, bleeding, segregation, plastic settlement, loss of bond, embedded items)*	None observed.

† cement type by reflected light microscopy
• some mineral additions are not easily identified by optical microscopy (eg. microsilica, metakaolin)
* sometimes assisted by phenolphthalein indicator solution
# estimated by fluorescence microscopy

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Photographs and Photomicrographs

Photograph 1

General view of the as-received concrete sample with the apparent outer surface shown facing upwards and another surface facing the rule.

The brown and grey particles in this view are chert particles of apparent flint type.

Photomicrograph 2

Typical view of the concrete constituents with variably brown chert coarse and fine aggregate particles amongst much finer clear quartz and quartzite fine aggregate particles. The particles appeared to be packed together very well.

Plane Polarised Light

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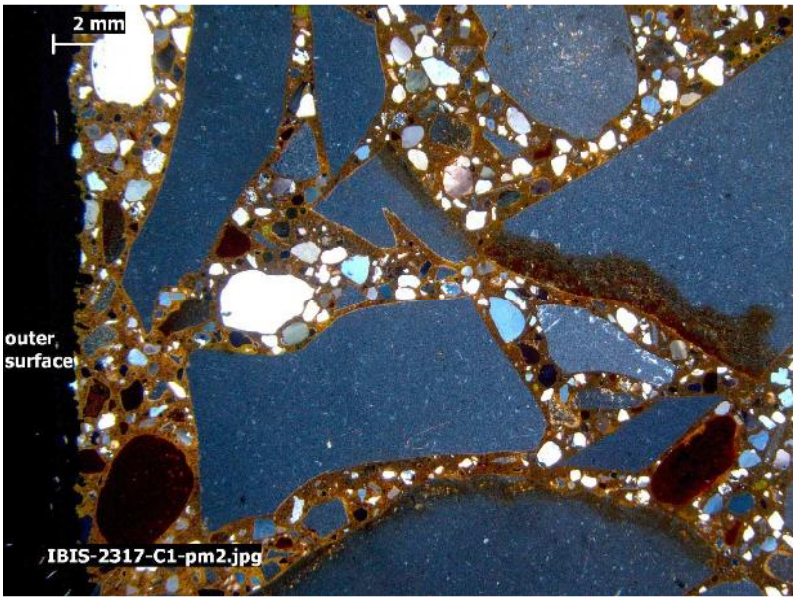
Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

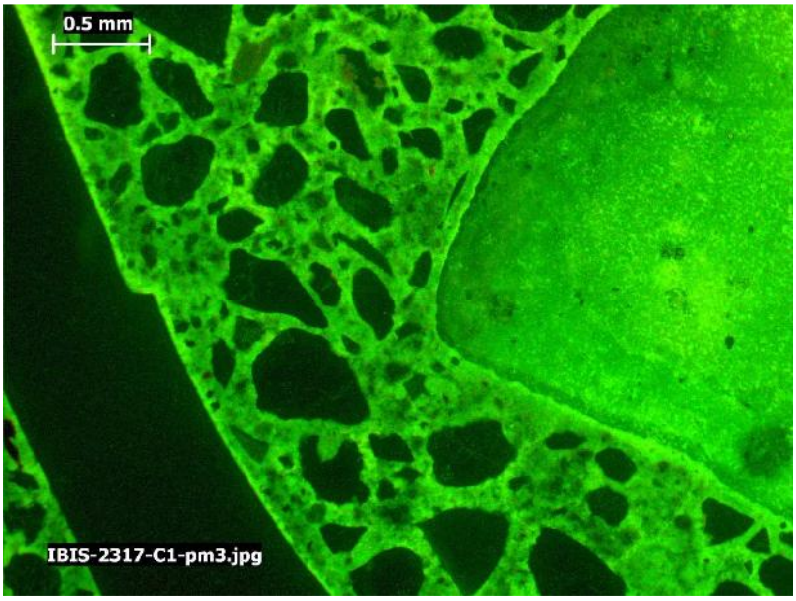
Photographs and Photomicrographs



Photomicrograph 3

The outer surface is indicated to the left in this view and the matrix is completely carbonated, the matrix having lightened in colour from the change in crystallinity.

Cross Polarised Light



Photomicrograph 4

Typical view of the concrete matrix and the apparent microporosity that was exhibited due to the carbonation effects.

A microporous chert particle is visible to the right.

Reflected Ultraviolet Light

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Photographs and Photomicrographs

Photomicrograph 5

Typical view of the carbonation effects at the deepest part of the sample, which were not complete but which resulted in a lack of portlandite.

Cross Polarised Light

Photomicrograph 6

Some of the typical Ordinary Portland type cement grains that were present throughout the sample, a particularly large grain being visible at the centre.

Plane Polarised Light

Petrographic Examination of Concrete – ASTM C856-11

Examination Methods

Submitted samples are subjected to petrographic examination following methods recommended by ASTM C856-11, Standard Practice for Petrographic Examination of Hardened Concrete. Examinations may be supplemented by the determination of the cement type following BS 1881: Part 124: 1988. If high alumina cement is suspected, the examination may take guidance from BRE Digest 392, Assessment of existing high alumina cement concrete construction in the UK, March 1994.

Samples are first visually and low-power microscopically examined using a Leica MZ16 binocular zoom microscope employing magnifications up to x160. Record photographs of samples are prepared with any features of interest highlighted. Low-power photomicrographs (photographs taken through the microscope) may be prepared to illustrate features of importance.

The initial examination is used to determine an appropriate location for thin-sections to be taken for further, more detailed microscopic examination. Thin-sections are prepared from diamond sawn slices which had been vacuum impregnated with a consolidating epoxy resin containing an ultraviolet light sensitive fluorescent dye. Highly polished specimens may sometimes be prepared for inspection of the matrix in reflected light and for the determination of cement type.

Thin-sections (and any polished specimens) are examined using a Leica DM RXP multi-functional microscope employing various magnifications up to x3000. Thin-sections are examined using transmitted plane-polarised, cross-polarised and reflected ultraviolet illuminations. Polished specimens are examined using reflected and brightfield illuminations. Record photomicrographs are prepared to illustrate microscopical features of importance. Highly polished specimens may be etched to assist with the identification of residual particles of unhydrated cement and any non-reacted mineral additions.

Glossary of Common Terms Used in the Descriptions

Cracks	Fine microcracks (<1µm wide); Microcracks (1-10µm wide); Fine cracks (10-100µm wide); Cracks (100µm-1mm wide); Large cracks (>1mm wide).
Voids	Entrapped: typically irregular in shape & >1mm in diameter; Entrained: typically round in shape and <100µm in diameter (taken to be all voids <1mm diameter when undertaking air content analyses).
Carbonation	Complete – no isotropic matrix with occasional unreacted relics; Partial – evidence of carbonate crystallites with isotropic matrix; Faint – occasional carbonate crystallites, <25% of the area.
Matrix portlandite	Small (<20µm); Medium (20-60µm); Large (60-100µm); Very large (>100µm). Sizes given are for the average measurement across the crystallites.
Relict cement	Small (<20µm); Medium (20-60µm); Large (60-100µm); Very large (>100µm). Sizes given are for the average measurement across the grains.
Water/cement ratio	Low (<0.35); Below normal (0.35-0.45); Normal (0.45-0.55); Above normal (0.55-0.65); High (>0.65).
Frequency	Increasing Frequency ↓ Rare - only found by thorough searching Sporadic - only occasionally observed during normal examination Common - easily observed during normal examination Frequent - easily observed with minimal examination Abundant - immediately apparent to initial examination
Hardness	Very soft: can be penetrated using a finger; Soft: scores with a fingernail; Moderately soft: scores using a copper coin or nail; Moderately hard: scores with a penknife; Hard: difficult to score with a penknife; Very hard: cannot be scored with a steel point or knife.

Concrete Condition Rating

Microscopic Damage Only	A1	Well made homogeneous concrete with minimal evidence of issues. Rare microcracks but generally paste, voids and other features appear normal for the apparent mix design.
	A2	Very low deterioration: possibly including sporadic microcracking, uneven paste composition, original drying shrinkage, low temperature curing, slightly lean mixture.
	A3	Low deterioration: possibly common microcracking, excessive paste porosity, minor leaching, minor secondary alteration, lean mixture. possibly with enhanced voidage.
Macroscopic and Microscopic Damage	B1	Low to Moderate deterioration: sporadic macrocracking or fine cracking, enhanced microporosity, high voidage, abundant microcracking, moderate leaching, moderate secondary alteration, significant secondary deposition.
	B2	Moderate deterioration, frequent fine cracking and some macrocracking, abundant microcracks, high excess voidage, evidence of paste recrystallisation, excessive microporosity, deep carbonation, significant secondary deposition, reaction sites.
	B3	As for B2, but with a high level of deterioration whilst the concrete remains intact.
Incoherent, Friable and Decomposed	C1	Concrete exhibits obvious deterioration and may be partly decomposed and/or friable. Samples may be difficult to cut and to polish.
	C2	As C1, but increased friability and tending to break into fragments. Aggregate particles may be loose and the matrix honeycombed.
	C3	As C2, but enhanced deterioration. Much cracking and fragmentation.
	D	Completely disintegrated or exhibiting no coherence.

Certificate of Examination
Petrographic Examination of Concrete – ASTM C856-11

Client and Sample Details

Client	GBG Structural Services, Bucknalls Lane, Garston, Watford, WD25 9XX		
IBIS Ref. No	2317-C2	**Sample No**	3905 (L2B)
Sample Details	Job No. 3905		
Sampled by / Date	Client	**Date Received**	06.10.14
Exam by / Date	BJH / 06-25.10.14	**Condition**	Damp
Max. Length, mm	37	**Diameter, mm**	Not applicable
Min. Length, mm	30	**Orientation**	Not advised
Outer End Nature	As cast	**Inner End Nature**	Rough
Section Details	Thin-section taken from slice cut perpendicular to the apparent outer surface.		

Methods of Examination and Results

The detailed examination methods, including guidance for some of the terms used in the description, are given in Page 7 of this Certificate of Examination. The detailed petrographic examination results are given in Pages 2 to 3 and a summary is provided below. Record photographs and photomicrographs are given in Pages 4 to 6.

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Composition and Constituents	Natural flint coarse and sand fine aggregates set within a hardened Portland type cement matrix.
Mix Quality	The constituents appeared to be well mixed with good compaction. Matrix microporosity could not be determined as a consequence of matrix changes (carbonation).
Condition	The concrete appeared to be sound with no obvious evidence of significant distress or deterioration. Carbonation was present throughout the sample. Minor microcracking of the cement matrix.
Other Details	The total aggregate combination was considered to have a normal alkali-reaction potential.
Rating (See Page 7)	A2

Remarks

The results and comments given in this certificate relate only to the sample examined. How these results and comments relate to concrete elements represented by this sample is outside the scope of this certificate.

Issue Date: 25.10.14

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Aggregate Details		
Coarse Aggregate *(incl. type, nominal max. size, shape, grading, distribution and orientation)*	Natural flint gravel comprising particles of nominal 10 mm maximum size, angular to rounded shape, single-sized grading, uniform distribution and random orientation.	
Constituents (Coarse) *(incl. hardness, colour and approx. percent of lithological types present, alteration, weathering and general features of engineering significance)*	Major	CHERT: particles of microcrystalline and cryptocrystalline silica, including some fibrous quartz (chalcedony), that were sometimes microporous and/or fossiliferous. Some particles were partially discoloured by the presence of orange/brown compounds of iron.
	Minor	None observed.
	Trace	None observed.
Cement:Aggregate Bond	Good, relatively few partings visible.	
Additional Observations *(incl. evidence of deterioration etc)*	None observed.	
Fine Aggregate *(incl. type, nominal max. size, shape, grading, distribution and orientation)*	Natural sand comprising particles of nominal 5 mm maximum size, irregular to mostly rounded shape, continuous grading, uniform distribution and random orientation.	
Constituents (Fine) *(incl. hardness, colour and approx. percent of lithological types present, alteration, weathering and general features of engineering significance)*	Major	QUARTZ: particles of monocrystalline silica that appeared unstrained. CHERT: particles as described for the coarse aggregate, some of them probably derived from it.
	Minor	QUARTZITE: particles of polycrystalline silica, the individual crystal grains appearing to be unstrained.
	Trace	GLAUCONITE: occasional green or brown particulate agglomerations of the mineral glauconite. OPAQUES: deep-red and black particles rich in iron and often enclosing fine quartz. FELDSPAR: alkali and plagioclase types present.
Cement:Aggregate Bond	Good, relatively few partings visible.	
Additional Observations *(incl. evidence of deterioration etc)*	In combination with the coarse aggregate, the total aggregate combination was considered to exhibit a normal potential for alkali-reaction.	

Cement Type Determination – BS 1881 : Part 124 : 1988

Only carried out if requested.

Polished Specimen Details	N/A			
No. of Grains > 40µm	OPC Type	N/A	SRPC Type	N/A
No. of Grains 20-40µm	OPC Type	N/A	SRPC Type	N/A
No. of Grains < 20µm	OPC Type	N/A	SRPC Type	N/A
Apparent Cement Type	N/A			
Other Details	N/A			

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Concrete Features	
Apparent Cement Type† and Matrix Details *(Portland, High Alumina, White, PBC, etc and incl. hardness, colour, colour distribution and matrix distribution)*	Abundant small and frequent medium to large relict unhydrated and hemi-hydrated Portland type cement grains distributed throughout the matrix. The cement matrix appeared dark light grey, which was suggestive of the use of an Ordinary Portland Cement.
Mineral Additions• *(incl. type, size, relative abundance, distribution and shape)*	None observed.
Compaction *(incl. air void max. size, shape, distribution, orientation, excess voidage)*	Good compaction suggested by the general lack of large entrapped air voids. The largest visible voids reached up to 2 mm in diameter, most less than 1 mm. The excess voidage was estimated to be < 0.5 %.
Air Void Details and Water/Cement Ratio# *(incl. presence of entrainment, microporosity variations and relation to other features; assessment of original water/cement ratio)*	Impregnation of the thin-section was reasonably consistent due to the presence of the carbonation, which did not allow an assessment of the original water/cement ratio to be made.
Carbonation* *(incl. depths, variations and relation to surface cracking)*	Carbonation was present throughout the sample received and thus present to a depth of at least 37 mm. Patchy carbonation effects were visible at a depth of 32 mm.
Portlandite *(incl. size, shape, abundance and distribution of crystallites)*	Portlandite not observed within the sample, which was likely a consequence of the extensive and essentially complete carbonation effects.
Other Concrete Details *(incl. applied finishes, inclusions and impurities)*	None observed.
Reinforcement *(incl. types, sizes, depths, orientations, evidence of corrosion)*	None present in the sample.
Evidence of Cracking *(incl. crack styles, abundance and relation to other features)*	Sporadic microcracking of the cement matrix apparent, this exploiting aggregate particle boundaries.
Presence of Deposits *(incl. gel, sulfates, carbonates, oxides, soot and their location, abundance and distribution)*	None observed.
Other Observations *(incl. sweaty patches, matrix alteration, bleeding, segregation, plastic settlement, loss of bond, embedded items)*	None observed.

† cement type by reflected light microscopy
• some mineral additions are not easily identified by optical microscopy (eg. microsilica, metakaolin)
* sometimes assisted by phenolphthalein indicator solution
# estimated by fluorescence microscopy

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Photographs and Photomicrographs

Photograph 1

General view of the as-received concrete sample, which exhibited top, side and soffit surfaces. The top surface has been oriented to the top in this view.

Photomicrograph 2

Typical view of the concrete constituents with variably brown chert coarse and fine aggregate particles amongst much finer clear quartz and quartzite fine aggregate particles. The particles appeared to be packed together very well. The yellow particle to the left is also chert and is highly microporous.

Plane Polarised Light

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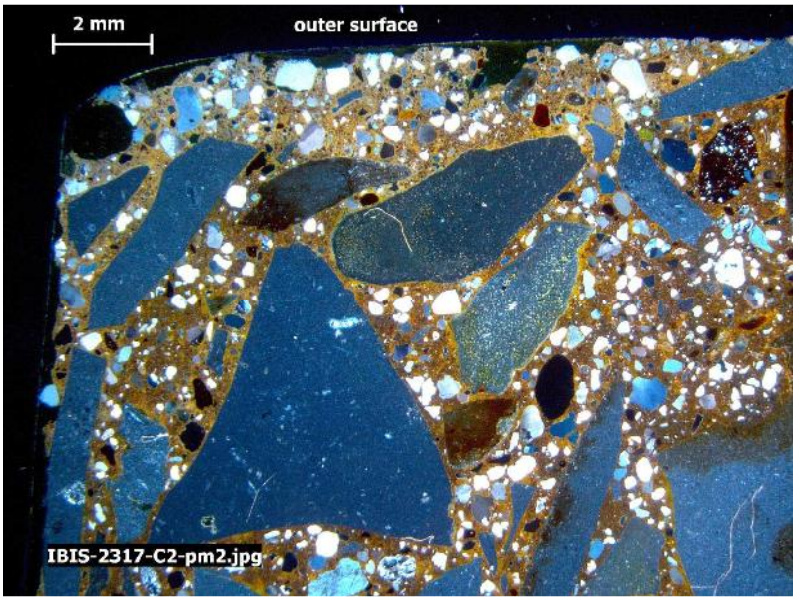
Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

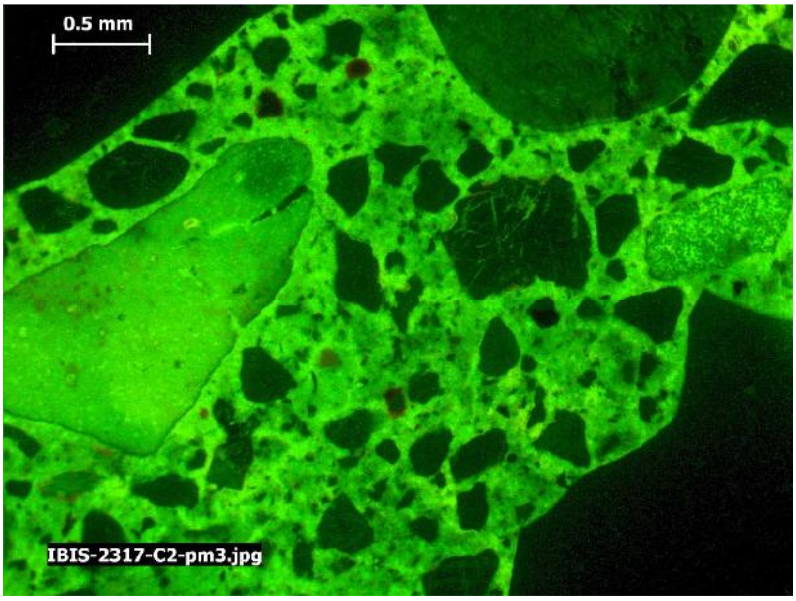
Photographs and Photomicrographs



Photomicrograph 3

The outer surface is indicated to the top and is also present to the left in this view. The matrix is completely carbonated, it having lightened in colour from the change in crystallinity.

Cross Polarised Light



Photomicrograph 4

Typical view of the concrete matrix and the apparent microporosity that was exhibited due to the carbonation effects.

A microporous chert particle is visible to the left.

Reflected Ultraviolet Light

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Photographs and Photomicrographs

Photomicrograph 5

Typical view of the carbonation effects at the deepest part of the sample, which were not complete but which resulted in a lack of portlandite.

Cross Polarised Light

Photomicrograph 6

Some of the typical Ordinary Portland type cement grains that were present throughout the sample, a particularly large grain being visible below right of centre.

Plane Polarised Light

Petrographic Examination of Concrete – ASTM C856-11

Examination Methods

Submitted samples are subjected to petrographic examination following methods recommended by ASTM C856-11, Standard Practice for Petrographic Examination of Hardened Concrete. Examinations may be supplemented by the determination of the cement type following BS 1881: Part 124: 1988. If high alumina cement is suspected, the examination may take guidance from BRE Digest 392, Assessment of existing high alumina cement concrete construction in the UK, March 1994.

Samples are first visually and low-power microscopically examined using a Leica MZ16 binocular zoom microscope employing magnifications up to x160. Record photographs of samples are prepared with any features of interest highlighted. Low-power photomicrographs (photographs taken through the microscope) may be prepared to illustrate features of importance.

The initial examination is used to determine an appropriate location for thin-sections to be taken for further, more detailed microscopic examination. Thin-sections are prepared from diamond sawn slices which had been vacuum impregnated with a consolidating epoxy resin containing an ultraviolet light sensitive fluorescent dye. Highly polished specimens may sometimes be prepared for inspection of the matrix in reflected light and for the determination of cement type.

Thin-sections (and any polished specimens) are examined using a Leica DM RXP multi-functional microscope employing various magnifications up to x3000. Thin-sections are examined using transmitted plane-polarised, cross-polarised and reflected ultraviolet illuminations. Polished specimens are examined using reflected and brightfield illuminations. Record photomicrographs are prepared to illustrate microscopical features of importance. Highly polished specimens may be etched to assist with the identification of residual particles of unhydrated cement and any non-reacted mineral additions.

Glossary of Common Terms Used in the Descriptions

Cracks	Fine microcracks (<1µm wide); Microcracks (1-10µm wide); Fine cracks (10-100µm wide); Cracks (100µm-1mm wide); Large cracks (>1mm wide).
Voids	Entrapped: typically irregular in shape & >1mm in diameter; Entrained: typically round in shape and <100µm in diameter (taken to be all voids <1mm diameter when undertaking air content analyses).
Carbonation	Complete – no isotropic matrix with occasional unreacted relics; Partial – evidence of carbonate crystallites with isotropic matrix; Faint – occasional carbonate crystallites, <25% of the area.
Matrix portlandite	Small (<20µm); Medium (20-60µm); Large (60-100µm); Very large (>100µm). Sizes given are for the average measurement across the crystallites.
Relict cement	Small (<20µm); Medium (20-60µm); Large (60-100µm); Very large (>100µm). Sizes given are for the average measurement across the grains.
Water/cement ratio	Low (<0.35); Below normal (0.35-0.45); Normal (0.45-0.55); Above normal (0.55-0.65); High (>0.65).
Frequency	Increasing Frequency ↓ Rare - only found by thorough searching Sporadic - only occasionally observed during normal examination Common - easily observed during normal examination Frequent - easily observed with minimal examination Abundant - immediately apparent to initial examination
Hardness	Very soft: can be penetrated using a finger; Soft: scores with a fingernail; Moderately soft: scores using a copper coin or nail; Moderately hard: scores with a penknife; Hard: difficult to score with a penknife; Very hard: cannot be scored with a steel point or knife.

Concrete Condition Rating

Microscopic Damage Only	A1	Well made homogeneous concrete with minimal evidence of issues. Rare microcracks but generally paste, voids and other features appear normal for the apparent mix design.
	A2	Very low deterioration: possibly including sporadic microcracking, uneven paste composition, original drying shrinkage, low temperature curing, slightly lean mixture.
	A3	Low deterioration: possibly common microcracking, excessive paste porosity, minor leaching, minor secondary alteration, lean mixture. possibly with enhanced voidage.
Macroscopic and Microscopic Damage	B1	Low to Moderate deterioration: sporadic macrocracking or fine cracking, enhanced microporosity, high voidage, abundant microcracking, moderate leaching, moderate secondary alteration, significant secondary deposition.
	B2	Moderate deterioration, frequent fine cracking and some macrocracking, abundant microcracks, high excess voidage, evidence of paste recrystallisation, excessive microporosity, deep carbonation, significant secondary deposition, reaction sites.
	B3	As for B2, but with a high level of deterioration whilst the concrete remains intact.
Incoherent, Friable and Decomposed	C1	Concrete exhibits obvious deterioration and may be partly decomposed and/or friable. Samples may be difficult to cut and to polish.
	C2	As C1, but increased friability and tending to break into fragments. Aggregate particles may be loose and the matrix honeycombed.
	C3	As C2, but enhanced deterioration. Much cracking and fragmentation.
	D	Completely disintegrated or exhibiting no coherence.

Certificate of Examination
Petrographic Examination of Concrete – ASTM C856-11

Client and Sample Details

Client	GBG Structural Services, Bucknalls Lane, Garston, Watford, WD25 9XX		
IBIS Ref. No	2317-C3	**Sample No**	3905 (L4C)
Sample Details	Job No. 3905		
Sampled by / Date	Client	**Date Received**	06.10.14
Exam by / Date	BJH / 06-25.10.14	**Condition**	Damp
Max. Length, mm	35	**Diameter, mm**	Not applicable
Min. Length, mm	24	**Orientation**	Not advised
Outer End Nature	As cast	**Inner End Nature**	Rough
Section Details	Thin-section taken from slice cut perpendicular to the apparent outer surface.		

Methods of Examination and Results

The detailed examination methods, including guidance for some of the terms used in the description, are given in Page 7 of this Certificate of Examination. The detailed petrographic examination results are given in Pages 2 to 3 and a summary is provided below. Record photographs and photomicrographs are given in Pages 4 to 6.

Summary Overview

Composition and Constituents	Natural flint coarse and sand fine aggregates set within a hardened Portland type cement matrix.
Mix Quality	The constituents appeared to be well mixed with good compaction. Matrix microporosity could not be determined as a consequence of matrix changes (carbonation).
Condition	The concrete appeared to be sound with no obvious evidence of significant distress or deterioration. Carbonation was present throughout the sample. Minor microcracking of the cement matrix.
Other Details	The total aggregate combination was considered to have a normal alkali-reaction potential.
Rating (See Page 7)	A2 / A3

Remarks

The results and comments given in this certificate relate only to the sample examined. How these results and comments relate to concrete elements represented by this sample is outside the scope of this certificate.

Issue Date: 25.10.14

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Aggregate Details		
Coarse Aggregate *(incl. type, nominal max. size, shape, grading, distribution and orientation)*	Natural flint gravel comprising particles of nominal 10 mm maximum size, angular to rounded shape, single-sized grading, uniform distribution and random orientation.	
Constituents (Coarse) *(incl. hardness, colour and approx. percent of lithological types present, alteration, weathering and general features of engineering significance)*	Major	CHERT: particles of microcrystalline and cryptocrystalline silica, including some fibrous quartz (chalcedony), that were sometimes microporous and/or fossiliferous. Some particles were partially discoloured by the presence of orange/brown compounds of iron.
	Minor	None observed.
	Trace	None observed.
Cement:Aggregate Bond	Good, relatively few partings visible.	
Additional Observations *(incl. evidence of deterioration etc)*	None observed.	
Fine Aggregate *(incl. type, nominal max. size, shape, grading, distribution and orientation)*	Natural sand comprising particles of nominal 5 mm maximum size, irregular to mostly rounded shape, continuous grading, uniform distribution and random orientation.	
Constituents (Fine) *(incl. hardness, colour and approx. percent of lithological types present, alteration, weathering and general features of engineering significance)*	Major	QUARTZ: particles of monocrystalline silica that appeared unstrained. CHERT: particles as described for the coarse aggregate, some of them probably derived from it.
	Minor	QUARTZITE: particles of polycrystalline silica, the individual crystal grains appearing to be unstrained.
	Trace	GLAUCONITE: occasional green or brown particulate agglomerations of the mineral glauconite. OPAQUES: deep-red and black particles rich in iron and often enclosing fine quartz. FELDSPAR: alkali and plagioclase types present. LIMESTONE: particles of variable form but mostly comprising apparent chalk, biosparite, biomicrite and pelsparite.
Cement:Aggregate Bond	Good, relatively few partings visible.	
Additional Observations *(incl. evidence of deterioration etc)*	In combination with the coarse aggregate, the total aggregate combination was considered to exhibit a normal potential for alkali-reaction.	

Cement Type Determination – BS 1881 : Part 124 : 1988

Only carried out if requested.

Polished Specimen Details	N/A			
No. of Grains > 40µm	OPC Type	N/A	SRPC Type	N/A
No. of Grains 20-40µm	OPC Type	N/A	SRPC Type	N/A
No. of Grains < 20µm	OPC Type	N/A	SRPC Type	N/A
Apparent Cement Type	N/A			
Other Details	N/A			

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Concrete Features	
Apparent Cement Type† and Matrix Details *(Portland, High Alumina, White, PBC, etc and incl. hardness, colour, colour distribution and matrix distribution)*	Abundant small and frequent medium to large relict unhydrated and hemi-hydrated Portland type cement grains distributed throughout the matrix. The cement matrix appeared dark light grey, which was suggestive of the use of an Ordinary Portland Cement.
Mineral Additions• *(incl. type, size, relative abundance, distribution and shape)*	None observed.
Compaction *(incl. air void max. size, shape, distribution, orientation, excess voidage)*	Good compaction suggested by the general lack of large entrapped air voids. The largest visible voids reached up to 4 mm in diameter, most less than 1 mm. The excess voidage was estimated to be < 0.5 %.
Air Void Details and Water/Cement Ratio# *(incl. presence of entrainment, microporosity variations and relation to other features; assessment of original water/cement ratio)*	Impregnation of the thin-section was reasonably consistent due to the presence of the carbonation, which did not allow an assessment of the original water/cement ratio to be made.
Carbonation* *(incl. depths, variations and relation to surface cracking)*	Carbonation was present throughout the sample received and thus present to a depth of at least 35 mm.
Portlandite *(incl. size, shape, abundance and distribution of crystallites)*	Portlandite not observed within the sample, which was likely a consequence of the extensive and essentially complete carbonation effects.
Other Concrete Details *(incl. applied finishes, inclusions and impurities)*	None observed.
Reinforcement *(incl. types, sizes, depths, orientations, evidence of corrosion)*	None present in the sample though an impression of an apparent 12 mm bar was present 26 mm from Side A and 24 mm from Side B.
Evidence of Cracking *(incl. crack styles, abundance and relation to other features)*	Fine microcracking of the cement matrix apparent, this exploiting aggregate particle boundaries and visible throughout the sample.
Presence of Deposits *(incl. gel, sulfates, carbonates, oxides, soot and their location, abundance and distribution)*	None observed.
Other Observations *(incl. sweaty patches, matrix alteration, bleeding, segregation, plastic settlement, loss of bond, embedded items)*	None observed.

† cement type by reflected light microscopy
• some mineral additions are not easily identified by optical microscopy (eg. microsilica, metakaolin)
* sometimes assisted by phenolphthalein indicator solution
# estimated by fluorescence microscopy

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Photographs and Photomicrographs

Photograph 1

General view of the as-received concrete sample with “Side A” of the apparent outer surface shown and “Side B” to the bottom.

Photomicrograph 2

Typical view of the concrete constituents with variably brown chert coarse and fine aggregate particles amongst much finer clear quartz and quartzite fine aggregate particles. The particles appeared to be packed together very well.

Plane Polarised Light

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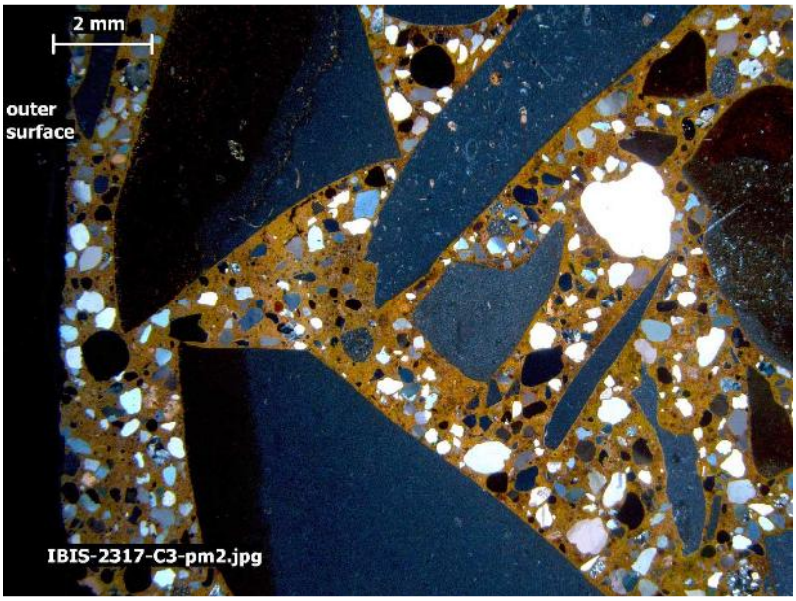
Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

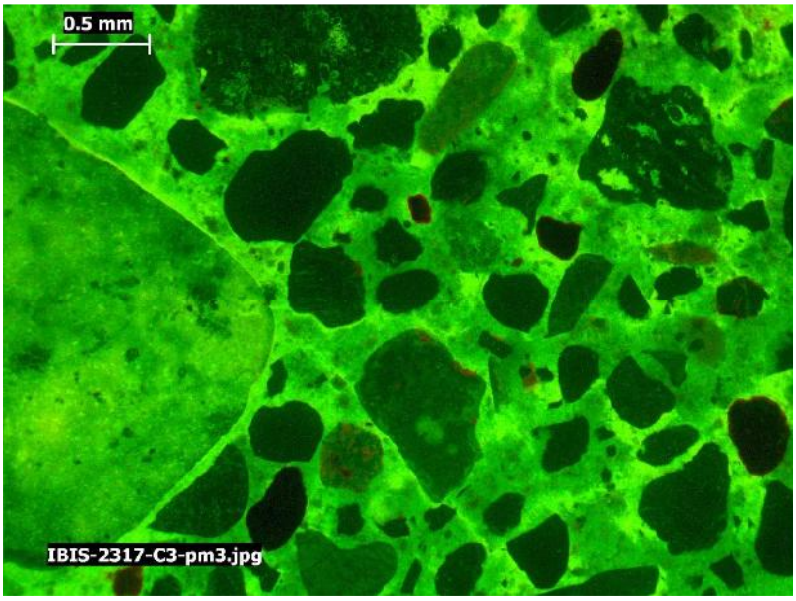
Photographs and Photomicrographs



Photomicrograph 3

The outer surface is indicated to the left in this view and the matrix is completely carbonated, the matrix having lightened in colour from the change in crystallinity.

Cross Polarised Light



Photomicrograph 4

Typical view of the concrete matrix and the apparent microporosity that was exhibited due to the carbonation effects.

Fine microcracking is visible in this view, these present throughout the concrete.

A microporous chert particle is visible to the left.

Reflected Ultraviolet Light

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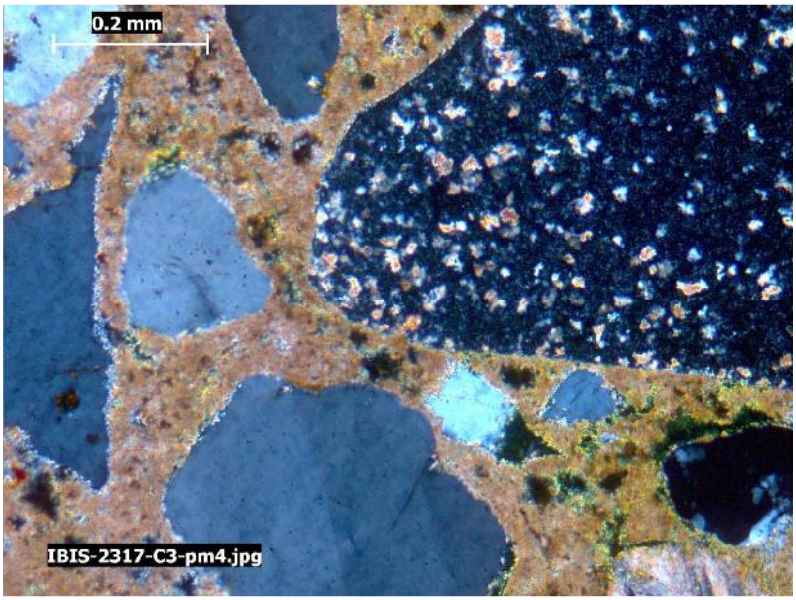
Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Photographs and Photomicrographs



Photomicrograph 5

Typical view of the carbonation effects at the deepest part of the sample, which resulted in a lack of portlandite. Some carbonate has grown within a porous chert particle to the top right.

Cross Polarised Light

Photomicrograph 6

Some of the typical Ordinary Portland type cement grains that were present throughout the sample, a particularly large grain being visible below centre.

Plane Polarised Light

Petrographic Examination of Concrete – ASTM C856-11

Examination Methods

Submitted samples are subjected to petrographic examination following methods recommended by ASTM C856-11, Standard Practice for Petrographic Examination of Hardened Concrete. Examinations may be supplemented by the determination of the cement type following BS 1881: Part 124: 1988. If high alumina cement is suspected, the examination may take guidance from BRE Digest 392, Assessment of existing high alumina cement concrete construction in the UK, March 1994.

Samples are first visually and low-power microscopically examined using a Leica MZ16 binocular zoom microscope employing magnifications up to x160. Record photographs of samples are prepared with any features of interest highlighted. Low-power photomicrographs (photographs taken through the microscope) may be prepared to illustrate features of importance.

The initial examination is used to determine an appropriate location for thin-sections to be taken for further, more detailed microscopic examination. Thin-sections are prepared from diamond sawn slices which had been vacuum impregnated with a consolidating epoxy resin containing an ultraviolet light sensitive fluorescent dye. Highly polished specimens may sometimes be prepared for inspection of the matrix in reflected light and for the determination of cement type.

Thin-sections (and any polished specimens) are examined using a Leica DM RXP multi-functional microscope employing various magnifications up to x3000. Thin-sections are examined using transmitted plane-polarised, cross-polarised and reflected ultraviolet illuminations. Polished specimens are examined using reflected and brightfield illuminations. Record photomicrographs are prepared to illustrate microscopical features of importance. Highly polished specimens may be etched to assist with the identification of residual particles of unhydrated cement and any non-reacted mineral additions.

Glossary of Common Terms Used in the Descriptions

Cracks	Fine microcracks (<1µm wide); Microcracks (1-10µm wide); Fine cracks (10-100µm wide); Cracks (100µm-1mm wide); Large cracks (>1mm wide).
Voids	Entrapped: typically irregular in shape & >1mm in diameter; Entrained: typically round in shape and <100µm in diameter (taken to be all voids <1mm diameter when undertaking air content analyses).
Carbonation	Complete – no isotropic matrix with occasional unreacted relics; Partial – evidence of carbonate crystallites with isotropic matrix; Faint – occasional carbonate crystallites, <25% of the area.
Matrix portlandite	Small (<20µm); Medium (20-60µm); Large (60-100µm); Very large (>100µm). Sizes given are for the average measurement across the crystallites.
Relict cement	Small (<20µm); Medium (20-60µm); Large (60-100µm); Very large (>100µm). Sizes given are for the average measurement across the grains.
Water/cement ratio	Low (<0.35); Below normal (0.35-0.45); Normal (0.45-0.55); Above normal (0.55-0.65); High (>0.65).
Frequency	Increasing Frequency ↓ Rare - only found by thorough searching Sporadic - only occasionally observed during normal examination Common - easily observed during normal examination Frequent - easily observed with minimal examination Abundant - immediately apparent to initial examination
Hardness	Very soft: can be penetrated using a finger; Soft: scores with a fingernail; Moderately soft: scores using a copper coin or nail; Moderately hard: scores with a penknife; Hard: difficult to score with a penknife; Very hard: cannot be scored with a steel point or knife.

Concrete Condition Rating

Microscopic Damage Only	A1	Well made homogeneous concrete with minimal evidence of issues. Rare microcracks but generally paste, voids and other features appear normal for the apparent mix design.
	A2	Very low deterioration: possibly including sporadic microcracking, uneven paste composition, original drying shrinkage, low temperature curing, slightly lean mixture.
	A3	Low deterioration: possibly common microcracking, excessive paste porosity, minor leaching, minor secondary alteration, lean mixture. possibly with enhanced voidage.
Macroscopic and Microscopic Damage	B1	Low to Moderate deterioration: sporadic macrocracking or fine cracking, enhanced microporosity, high voidage, abundant microcracking, moderate leaching, moderate secondary alteration, significant secondary deposition.
	B2	Moderate deterioration, frequent fine cracking and some macrocracking, abundant microcracks, high excess voidage, evidence of paste recrystallisation, excessive microporosity, deep carbonation, significant secondary deposition, reaction sites.
	B3	As for B2, but with a high level of deterioration whilst the concrete remains intact.
Incoherent, Friable and Decomposed	C1	Concrete exhibits obvious deterioration and may be partly decomposed and/or friable. Samples may be difficult to cut and to polish.
	C2	As C1, but increased friability and tending to break into fragments. Aggregate particles may be loose and the matrix honeycombed.
	C3	As C2, but enhanced deterioration. Much cracking and fragmentation.
	D	Completely disintegrated or exhibiting no coherence.

Certificate of Examination
Petrographic Examination of Concrete – ASTM C856-11

Client and Sample Details

Client	GBG Structural Services, Bucknalls Lane, Garston, Watford, WD25 9XX		
IBIS Ref. No	2317-C4	**Sample No**	3905 (L2D)
Sample Details	Job No. 3905		
Sampled by / Date	Client	**Date Received**	06.10.14
Exam by / Date	BJH / 06-25.10.14	**Condition**	Damp
Max. Length, mm	27	**Diameter, mm**	Not applicable
Min. Length, mm	19	**Orientation**	Not advised
Outer End Nature	As cast	**Inner End Nature**	Rough
Section Details	Thin-section taken from slice cut perpendicular to the apparent outer surface.		

Methods of Examination and Results

The detailed examination methods, including guidance for some of the terms used in the description, are given in Page 7 of this Certificate of Examination. The detailed petrographic examination results are given in Pages 2 to 3 and a summary is provided below. Record photographs and photomicrographs are given in Pages 4 to 6.

Summary Overview

Composition and Constituents	Natural flint coarse and marine dredged sand fine aggregates set within a hardened Portland type cement matrix.
Mix Quality	The constituents appeared to be well mixed with good compaction. Matrix microporosity could not be determined as a consequence of matrix changes (carbonation).
Condition	The concrete appeared to be sound with no obvious evidence of significant distress or deterioration. Carbonation was present throughout the sample. Microcracking of the cement matrix that formed a network.
Other Details	The total aggregate combination was considered to have a normal alkali-reaction potential.
Rating (See Page 7)	A3

Remarks

The results and comments given in this certificate relate only to the sample examined. How these results and comments relate to concrete elements represented by this sample is outside the scope of this certificate.

Issue Date: 25.10.14

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Aggregate Details		
Coarse Aggregate *(incl. type, nominal max. size, shape, grading, distribution and orientation)*	Natural flint gravel comprising particles of nominal 10 mm maximum size, angular to rounded shape, single-sized grading, uniform distribution and random orientation.	
Constituents (Coarse) *(incl. hardness, colour and approx. percent of lithological types present, alteration, weathering and general features of engineering significance)*	Major	CHERT: particles of microcrystalline and cryptocrystalline silica, including some fibrous quartz (chalcedony), that were sometimes microporous and/or fossiliferous. Some particles were partially discoloured by the presence of orange/brown compounds of iron.
	Minor	None observed.
	Trace	None observed.
Cement:Aggregate Bond	Good, relatively few partings visible.	
Additional Observations *(incl. evidence of deterioration etc)*	None observed.	
Fine Aggregate *(incl. type, nominal max. size, shape, grading, distribution and orientation)*	Natural marine dredged sand comprising particles of nominal 5 mm maximum size, irregular to mostly rounded shape, continuous grading, uniform distribution and random orientation.	
Constituents (Fine) *(incl. hardness, colour and approx. percent of lithological types present, alteration, weathering and general features of engineering significance)*	Major	QUARTZ: particles of monocrystalline silica that appeared unstrained. CHERT: particles as described for the coarse aggregate, some of them probably derived from it.
	Minor	QUARTZITE: particles of polycrystalline silica, the individual crystal grains appearing to be unstrained. LIMESTONE: particles of variable form but mostly comprising apparent chalk, biosparite, biomicrite and pelsparite. SHELL: unfossilised fragments of former marine organisms.
	Trace	GLAUCONITE: occasional green or brown particulate agglomerations of the mineral glauconite. OPAQUES: deep-red and black particles rich in iron and often enclosing fine quartz. FELDSPAR: alkali and plagioclase types present.
Cement:Aggregate Bond	Good, relatively few partings visible.	
Additional Observations *(incl. evidence of deterioration etc)*	In combination with the coarse aggregate, the total aggregate combination was considered to exhibit a normal potential for alkali-reaction.	

Cement Type Determination – BS 1881 : Part 124 : 1988

Only carried out if requested.

Polished Specimen Details	N/A			
No. of Grains > 40µm	OPC Type	N/A	SRPC Type	N/A
No. of Grains 20-40µm	OPC Type	N/A	SRPC Type	N/A
No. of Grains < 20µm	OPC Type	N/A	SRPC Type	N/A
Apparent Cement Type	N/A			
Other Details	N/A			

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Petrographic Examination of Concrete – ASTM C856-11

A full description of the examination methods is given in Page 7

Concrete Features	
Apparent Cement Type† and Matrix Details *(Portland, High Alumina, White, PBC, etc and incl. hardness, colour, colour distribution and matrix distribution)*	Abundant small and frequent medium to large relict unhydrated and hemi-hydrated Portland type cement grains distributed throughout the matrix. The cement matrix appeared dark light grey, which was suggestive of the use of an Ordinary Portland Cement.
Mineral Additions• *(incl. type, size, relative abundance, distribution and shape)*	None observed.
Compaction *(incl. air void max. size, shape, distribution, orientation, excess voidage)*	Good compaction suggested by the general lack of large entrapped air voids. The largest visible voids reached up to 2 mm in diameter, most less than 1 mm. The excess voidage was estimated to be < 0.5 %.
Air Void Details and Water/Cement Ratio# *(incl. presence of entrainment, microporosity variations and relation to other features; assessment of original water/cement ratio)*	Impregnation of the thin-section was reasonably consistent due to the presence of the carbonation, which did not allow an assessment of the original water/cement ratio to be made.
Carbonation* *(incl. depths, variations and relation to surface cracking)*	Carbonation was present throughout the sample received and thus present to a depth of at least 27 mm.
Portlandite *(incl. size, shape, abundance and distribution of crystallites)*	Portlandite not observed within the sample, which was likely a consequence of the extensive and essentially complete carbonation effects.
Other Concrete Details *(incl. applied finishes, inclusions and impurities)*	None observed.
Reinforcement *(incl. types, sizes, depths, orientations, evidence of corrosion)*	None present in the sample.
Evidence of Cracking *(incl. crack styles, abundance and relation to other features)*	Microcracking of the cement matrix apparent, this exploiting aggregate particle boundaries and forming a network.
Presence of Deposits *(incl. gel, sulfates, carbonates, oxides, soot and their location, abundance and distribution)*	None observed.
Other Observations *(incl. sweaty patches, matrix alteration, bleeding, segregation, plastic settlement, loss of bond, embedded items)*	None observed.

† cement type by reflected light microscopy
• some mineral additions are not easily identified by optical microscopy (eg. microsilica, metakaolin)
* sometimes assisted by phenolphthalein indicator solution
# estimated by fluorescence microscopy

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Photographs and Photomicrographs

Photograph 1

General view of the as-received concrete sample with the outer surface indicated by “NT Side”. The sample appeared to have been taken from the corner of a feature so that three surfaces were represented.

Photomicrograph 2

Typical view of the concrete constituents with variably brown chert coarse and fine aggregate particles amongst much finer clear quartz and quartzite fine aggregate particles. The particles appeared to be packed together very well.

Plane Polarised Light

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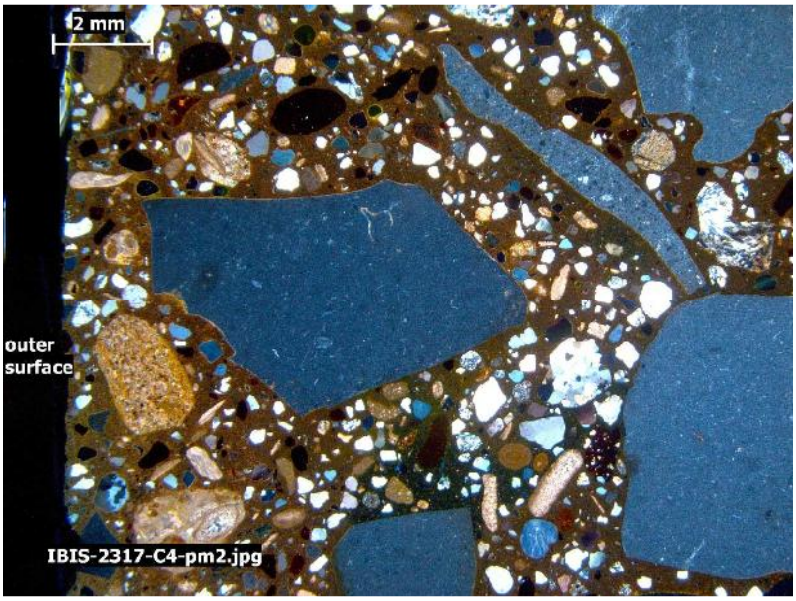
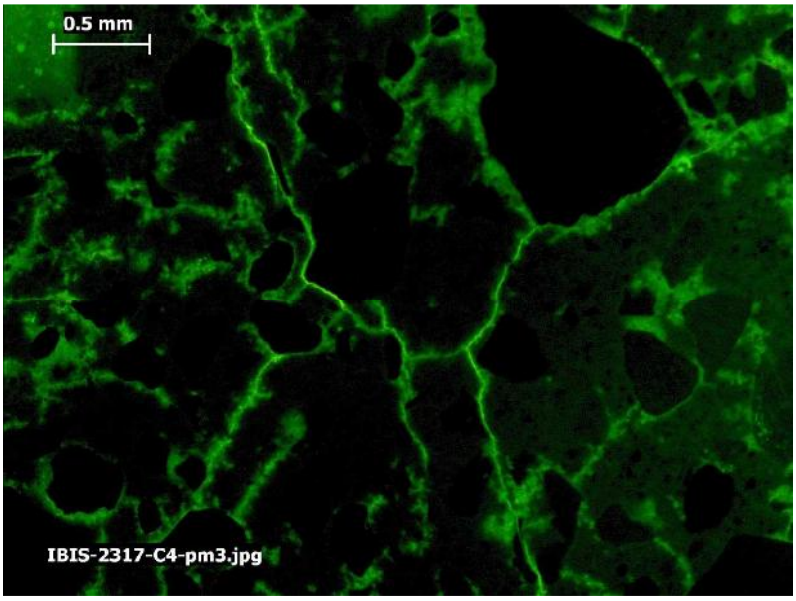
Photographs and Photomicrographs



Photomicrograph 3

The outer surface is indicated to the left in this view and the matrix is completely carbonated, the matrix having lightened in colour from the change in crystallinity.

Cross Polarised Light



Photomicrograph 4

Typical view of the concrete matrix, which was not correctly impregnated but revealed a number of microcracks. The microcracks extended throughout the concrete forming a network.

Reflected Ultraviolet Light

Petrographic Examination of Concrete – ASTM C856-11

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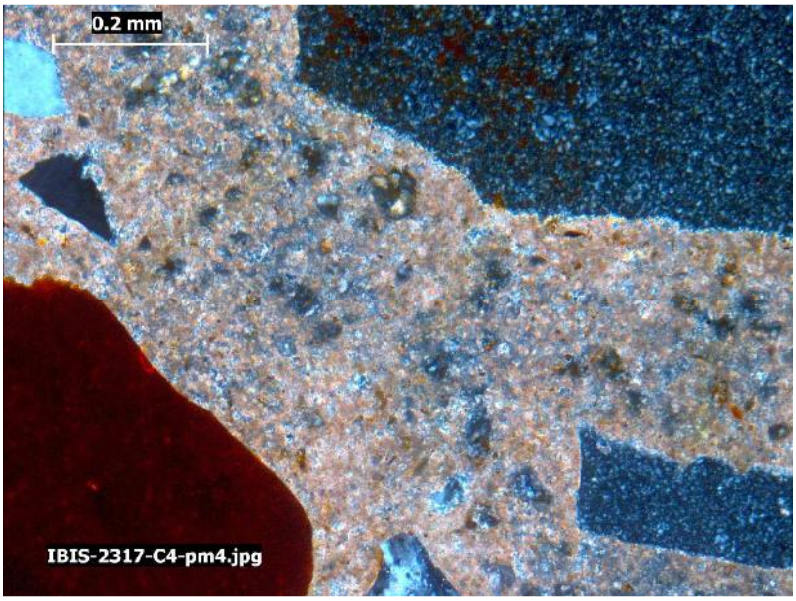
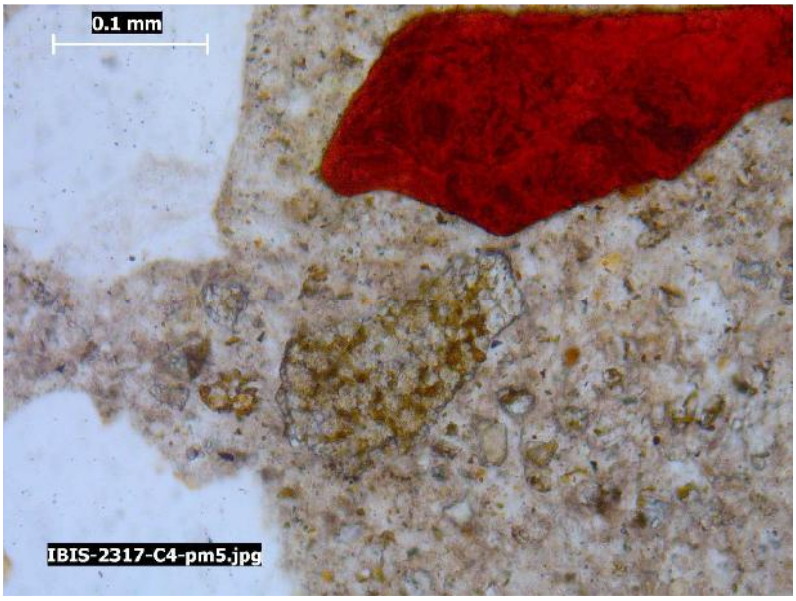
Photographs and Photomicrographs



Photomicrograph 5

Typical view of the carbonation effects at the deepest part of the sample, which resulted in a lack of portlandite.

Cross Polarised Light



Photomicrograph 6

Some of the typical Ordinary Portland type cement grains that were present throughout the sample, a particularly large grain being present at the centre.

Plane Polarised Light

Petrographic Examination of Concrete – ASTM C856-11

Examination Methods

Submitted samples are subjected to petrographic examination following methods recommended by ASTM C856-11, Standard Practice for Petrographic Examination of Hardened Concrete. Examinations may be supplemented by the determination of the cement type following BS 1881: Part 124: 1988. If high alumina cement is suspected, the examination may take guidance from BRE Digest 392, Assessment of existing high alumina cement concrete construction in the UK, March 1994.

Samples are first visually and low-power microscopically examined using a Leica MZ16 binocular zoom microscope employing magnifications up to x160. Record photographs of samples are prepared with any features of interest highlighted. Low-power photomicrographs (photographs taken through the microscope) may be prepared to illustrate features of importance.

The initial examination is used to determine an appropriate location for thin-sections to be taken for further, more detailed microscopic examination. Thin-sections are prepared from diamond sawn slices which had been vacuum impregnated with a consolidating epoxy resin containing an ultraviolet light sensitive fluorescent dye. Highly polished specimens may sometimes be prepared for inspection of the matrix in reflected light and for the determination of cement type.

Thin-sections (and any polished specimens) are examined using a Leica DM RXP multi-functional microscope employing various magnifications up to x3000. Thin-sections are examined using transmitted plane-polarised, cross-polarised and reflected ultraviolet illuminations. Polished specimens are examined using reflected and brightfield illuminations. Record photomicrographs are prepared to illustrate microscopical features of importance. Highly polished specimens may be etched to assist with the identification of residual particles of unhydrated cement and any non-reacted mineral additions.

Glossary of Common Terms Used in the Descriptions

Cracks	Fine microcracks (<1µm wide); Microcracks (1-10µm wide); Fine cracks (10-100µm wide); Cracks (100µm-1mm wide); Large cracks (>1mm wide).
Voids	Entrapped: typically irregular in shape & >1mm in diameter; Entrained: typically round in shape and <100µm in diameter (taken to be all voids <1mm diameter when undertaking air content analyses).
Carbonation	Complete – no isotropic matrix with occasional unreacted relics; Partial – evidence of carbonate crystallites with isotropic matrix; Faint – occasional carbonate crystallites, <25% of the area.
Matrix portlandite	Small (<20µm); Medium (20-60µm); Large (60-100µm); Very large (>100µm). Sizes given are for the average measurement across the crystallites.
Relict cement	Small (<20µm); Medium (20-60µm); Large (60-100µm); Very large (>100µm). Sizes given are for the average measurement across the grains.
Water/cement ratio	Low (<0.35); Below normal (0.35-0.45); Normal (0.45-0.55); Above normal (0.55-0.65); High (>0.65).
Frequency	Increasing Frequency ↓ Rare - only found by thorough searching Sporadic - only occasionally observed during normal examination Common - easily observed during normal examination Frequent - easily observed with minimal examination Abundant - immediately apparent to initial examination
Hardness	Very soft: can be penetrated using a finger; Soft: scores with a fingernail; Moderately soft: scores using a copper coin or nail; Moderately hard: scores with a penknife; Hard: difficult to score with a penknife; Very hard: cannot be scored with a steel point or knife.

Concrete Condition Rating

Microscopic Damage Only	A1	Well made homogeneous concrete with minimal evidence of issues. Rare microcracks but generally paste, voids and other features appear normal for the apparent mix design.
	A2	Very low deterioration: possibly including sporadic microcracking, uneven paste composition, original drying shrinkage, low temperature curing, slightly lean mixture.
	A3	Low deterioration: possibly common microcracking, excessive paste porosity, minor leaching, minor secondary alteration, lean mixture. possibly with enhanced voidage.
Macroscopic and Microscopic Damage	B1	Low to Moderate deterioration: sporadic macrocracking or fine cracking, enhanced microporosity, high voidage, abundant microcracking, moderate leaching, moderate secondary alteration, significant secondary deposition.
	B2	Moderate deterioration, frequent fine cracking and some macrocracking, abundant microcracks, high excess voidage, evidence of paste recrystallisation, excessive microporosity, deep carbonation, significant secondary deposition, reaction sites.
	B3	As for B2, but with a high level of deterioration whilst the concrete remains intact.
Incoherent, Friable and Decomposed	C1	Concrete exhibits obvious deterioration and may be partly decomposed and/or friable. Samples may be difficult to cut and to polish.
	C2	As C1, but increased friability and tending to break into fragments. Aggregate particles may be loose and the matrix honeycombed.
	C3	As C2, but enhanced deterioration. Much cracking and fragmentation.
	D	Completely disintegrated or exhibiting no coherence.

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