Exchequer Court
25-51 St.Mary Axe and
9 St.Helen's Place
London EC3

Appraisal and Testing of Retained Elements

Library of Documents
Volume 3

Ove Arup and Partners
Summary Report

EXCHEQUER COURT
25-51 ST MARY AXE
AND 9 ST HELEN'S PLACE,
LONDON EC3

INDEPENDENT STRUCTURAL ENGINEERS' SUMMARY REPORT

March 1995

Ove Arup & Partners
Consulting Engineers

EXCHEQUER COURT 25-51 ST MARY AXE AND 9 ST HELEN'S PLACE, LONDON EC3

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EXCHEQUER COURT
25-51 ST MARY AXE & 9 ST HELEN'S PLACE
LONDON EC3

Exchequer Court is a 7 storey building providing approximately 20,000m² of office and retail space with associated circulation, storage and plant areas. It was developed by Spaxe Properties Ltd (now in receivership) and is located on St Mary Axe to the east of Bishopsgate.

On the evening of 10 April 1992 a bomb exploded in St Mary Axe adjacent to Exchequer Court causing extensive damage to the building fabric and to parts of the structure. Most of the building's superstructure was demolished after the explosion and has now been rebuilt in essentially the same form. Certain original structural elements were retained and form part of the reconstructed building.

The developers and their insurers jointly engaged Ove Arup and Partners as Independent Structural Engineers to provide independent advice on the tests, inspections, analyses and remedial works proposed by the structural design engineers in order to ensure that the Retained Elements are fully able to perform their intended function in the completed building. On 24 April 1993 a further bomb explosion occurred in Bishopsgate. The initial investigation, including the role of the Independent Structural Engineers, was extended to include the effects of this second event on the Retained Elements. This is the Independent Structural Engineers' Summary Report.

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SUMMARY STATEMENT

Ove Arup and Partners, the Independent Structural Engineers engaged jointly by Spaxe Properties Ltd (now in administrative receivership) and its insurers, confirm they have sufficiently monitored the bomb damage assessments and testing regimes, analysed of test results, considered the structural analyses and have been involved in the remediation of the sub-structure existing following the detonation of the bomb on 10 April 1992 which supports the re-constructed scheme and the retained facade to St. Helen's Place (the "Retained Elements") of Exchequer Court, 25-51 St. Mary Axe and 9 St. Helen's Place, London EC3 ("Exchequer Court") to confirm that it is their professional opinion that the performance of the Retained Elements has not been impaired by the effects of the explosions so that they will provide proper and adequate support for Exchequer Court and will perform in all respects the functions for which they were incorporated in Exchequer Court as if the explosion had not occurred.

M J Glover

M.J. Glover
Director

Ove Arup and Partners
13 Fitzroy Street
London W1P 6BQ

Date: 12.5.95

1. INTRODUCTION

1.1 Description of the Project

Exchequer Court provides approximately 20,000m² of office and retail space in the City of London. Designed by architects Fitzroy Robinson Partnership with Waterman Partnership as structural engineers the building has 7 storeys above ground and two basement levels. The original developer was Spaxe Properties Ltd (now in receivership).

The building has a structural steel frame stabilised by braced cores with in situ concrete floor slabs cast on metal decking from ground level upwards. The basement, including the Level -1 slab, and piled foundations are in reinforced concrete. On the St Helen's Place elevation a retained masonry facade is stabilised by the steel frame behind it. External facades are generally clad with stone faced panels and aluminium framed windows.

On the evening of 10 April 1992, shortly before practical completion, a bomb exploded in St Mary Axe adjacent to the building causing extensive damage to the building fabric and to parts of the structure. Following the preparation of reports by the building design team comprising Fitzroy Robinson Partnership, Waterman Partnership and quantity surveyors Gardiner & Theobald a decision was taken to demolish and rebuild virtually all of the superstructure from Level -1 to roof. This decision and the extent of the demolition is described in Waterman Partnership's Final Report which forms Volume 2 of the Document Library.

The developers and their insurers jointly engaged Ove Arup and Partners as Independent Structural Engineers to provide independent advice on the tests, inspections, analyses and remedial works proposed by Waterman Partnership in order to ensure that the Retained Elements are fully able to perform their intended function in the completed building.

On 24 April 1993 a further bomb explosion occurred in Bishopsgate. The initial investigation, including the role of the Independent Structural Engineers, was extended to include the effects of this second event on the Retained Elements.

In addition to their role as Independent Structural Engineers, Ove Arup and Partners were subsequently appointed to organise and assemble the library of documents which describe the investigations and remedial works referred to above. This Summary Report forms Volume 3 of the Document Library.

1.2 Investigation Strategy

To establish the procedure by which they would investigate the condition of the Retained Elements Waterman Partnership drew up a Strategy Document, Assessment and Testing Retained Structures dated December 1992. This document, which forms Volume 5 of the Document Library, split the investigation into five Phases. A sixth Phase was subsequently introduced due to constraints on site access.

In addition to the narrative description of each Phase, flow charts included in the Strategy Document illustrate the process of data gathering and assessment by Waterman Partnership to be followed by Ove Arup and Partners' review, definition of remedial works, if necessary, and completion of each Phase Report.

As Independent Structural Engineers we reviewed and were involved in the development of this Strategy Document and consider that it established a logical and methodical framework within which the investigation could take place.

In addition to the Phase Reports we reviewed other documents by Waterman Partnership including their Executive Summary, Final Report and Supplementary Report. As in the case of the Phase Reports, on satisfactory completion of the reviews of each of these documents we issued to Waterman Partnership letters confirming our agreement with the conclusions drawn. Copies of these letters are included in the documents to which they refer.

1.3 Independent Structural Engineer's Brief

The role of Ove Arup and Partners as the Independent Structural Engineers is outlined in the preceding sections of this report. A more detailed description of the scope of our appointment is included here in Annex 1 together with a schedule, referred to as Appendix 2, which defines the Retained Elements.

1.4 Purpose of Report

The purpose of this Summary Report is to confirm the involvement and manner of working of Ove Arup and Partners as the Independent Structural Engineers and their professional opinion on the tests, inspections, analyses and remedial works carried out and specified by Waterman Partnership in relation to the Retained Elements at Exchequer Court.

2. INDEPENDENT STRUCTURAL ENGINEER'S OBJECTIVES AND MANNER OF WORKING

2.1 Tests and Inspections

Waterman Partnership's Strategy Document outlined their proposed programme of tests and inspections for each Phase. Our objectives with respect to these proposals were to ensure that:

- Tests and inspections appropriate to the elements under examination were undertaken.
- Meaningful conclusions could be drawn from the proposed tests and inspections.
- Data was obtained and recorded in a systematic manner which would allow valid interpretation.
- Valid conclusions were drawn from the tests and inspections carried out.

These objectives were addressed in the following manner:

- Our own visual inspections of the condition of the structure following the explosions.
- Review and discussion with Waterman Partnership of their detailed proposals.
- Attendance on site and at offsite testing facilities during key inspections, non-destructive testing and load tests. Inspections included entry to the heading constructed along the face of the basement retaining wall piles adjacent to the location of the St Mary Axe explosion.
- Detailed review and discussion with Waterman Partnership of the reports prepared by them and their testing and inspection subconsultants.

2.2 Structural Analyses

To complement their programme of tests and inspections Waterman Partnership commissioned and carried out various analytical studies to estimate the groundshock and airshock pressure time histories produced by the explosions and the resultant structural responses. Our objectives with respect to these studies were to ensure that:

- Realistic parameters and derivation methods were used to estimate blast pressures.
- Blast pressure estimates were reasonable and in a form which allowed them to be applied to analytical models of the structural elements.
- Reasonable structural models were assembled for the dynamic analyses to be undertaken.
- Valid interpretations were made of the results of these analyses and that the results were reasonable.

- Valid conclusions were drawn from the results of the analyses in relation to the observed physical condition of the elements under examination.

These objectives were addressed in the following manner:

- Discussion with Waterman Partnership and their specialist consultants on the calculation basis and validation of proposed software.
- Order of magnitude checks on estimated blast pressure values using established "free-field" equations.
- Review of member and connection properties in proposed structural models.
- Qualitative review of relative member forces within the various models, their displacements and overall dynamic properties.
- An evaluation of possible soil-structure interaction for the retaining wall elements adjacent to the St Mary Axe explosion using DYNA-3D software. This forms Volume 14.1 of the Document Library.
- An estimation of maximum possible forces in the stability cores and hence their foundations based on ultimate capacities of weakest elements and limits on lateral deflections imposed by adjacent buildings. This forms Volume 14.2 of the Document Library.
- Detailed review and discussion with Waterman Partnership of the reports on these analyses produced by them and their specialist consultants.

2.3 Remedial Works

Following assessment of the condition of the Retained Elements in each Phase Waterman Partnership produced Remedial Works Schedules. Our objectives in relation to these Schedules were to satisfy ourselves that:

- All necessary remedial works were identified.
- Appropriate remedial measures and materials were specified.
- Procedures for site control of the remedial works were in place which would ensure that they were implemented as specified.

These objectives were addressed in the following manner:

- Detailed review and discussion with Waterman Partnership of the conclusions drawn in their Phase reports and any recommendations for remedial works which they contained.
- Detailed review and discussion with Waterman Partnership of their Remedial Works Schedules.
- Discussion with Waterman Partnership on the procedures adopted by them and the Management Contractor for inspection and approval of the remedial works.

- Spot site inspections of remedial works in progress, particularly the reinstatement of the waterproofing systems to the retaining walls adjacent to the location of the St Mary Axe explosion.

2.4 Review Meetings

During the investigation and reconstruction works Ove Arup and Partners chaired regular Review Meetings with Waterman Partnership, Buro Four Project Services, the Loss Adjusters and other parties as appropriate. The minutes of these Review Meetings, which were generally held at fortnightly intervals, are compiled in Volume 13 of the Document Library.

The purpose of these meetings was to monitor progress on the investigations, remedial works and assembly of documents. They also served as a valuable forum at which to discuss and resolve technical aspects of the investigation and to decide on the direction of other inspections, tests and analyses to be carried out.

When necessary additional meetings between ourselves, Waterman Partnership and other relevant parties were convened to discuss particular issues in detail. Where appropriate notes of these discussions are appended to Review Meeting minutes.

2.5 Documentation

It is vital that a detailed investigation such as this one is documented in a way which enables it to be demonstrated that the Retained Elements were not impaired in performing their functions by the effects of the explosions. In addition to advising on documentation as Independent Structural Engineers, our appointment to assemble the Document Library enabled us to approach this task in the following manner:

- Establishment of a hierarchy of documents.
- Preparation of guidance, including explanatory graphics, for library users including flow charts for various types of enquiry (see Volume 1 of the Document Library).
- Indexing the library contents by topic and document originator to ease location of particular documents.
- Detailed review of the structure of individual reports and documents produced by others to check for accuracy of contents, references, indexes etc.
- Development with the Project Managers of proposals for the format in which the Document Library would be assembled and stored for reference, archiving and retrieval.

The process of detailed technical review of documents which formed much of our role as Independent Structural Engineers resulted in extensive correspondence between Waterman Partnership and ourselves. Numerous interim reports were produced during the investigation. The Document Library contains only final versions of reports, calculations etc. and only correspondence pertinent to the conclusions finally reached.

ANNEX 1

Spaxe Properties Limited

registered office

Osprey House Lower Square Old Isleworth
Middlesex TW7 6BN

Registered in England Number 2356651

5th March 1993

Ove Arup and Partners
13 Fitzroy Street
London
W1P 6BQ

Dear Sirs

Exchequer Court 25/51 St. Mary Axe London EC3

As you are aware we have been involved in the development of the site at 25/51 St. Mary Axe and 9 St. Helen's Place London EC3. The bomb detonated in St. Mary Axe on the evening of 10th April 1992 caused significant damage to the surrounding buildings. Initial investigations proved that it would not be economical to repair the damaged super-structure of Exchequer Court and as a consequence an order has been placed to demolish the whole building to one level below ground subject to one exception. Part of the site is within the St. Helen's conservation area and it is therefore necessary to retain a small facade at the end of St. Helen's Place together with the associated structure.

It is intended to rebuild the scheme in exactly the same form save for certain minor improvements which will avoid problems experienced on the original construction and the reconstruction of the scheme will utilise and incorporate the existing sub structure which will therefore comprise the support to the reconstructed scheme and the retained facade to St. Helen's Place (together referred to as the Retained Elements which are more particularly described in the appendix hereto. Our structural engineers Waterman Partnership Limited have devised a regime for inspecting and testing the Retained Elements in

order to be assured of their adequacy. The results may result in some repair work and further testing. In order to ensure that the new building is fully marketable it is imperative that we can demonstrate to potential purchasers, tenants and their financiers that the Retained Elements provide proper and adequate support for the new building not withstanding the bomb explosion mentioned above.

The damage caused by the explosion was covered by a policy of material damage insurance and a claim has been made under the insurance policy The insurers Norwich Union are represented by the loss adjusters, Messrs Davies & Co of Creechurch House Creechurch Lane London EC3A 5DJ.

Accordingly we and the insurers (acting by Davies & Co) hereby jointly engage you as an independent consulting engineer to provide professional services as hereinafter described on the following basis:

1. The provisions of the standard conditions of engagement of consulting engineers for report and advisory work (ACE Agreement 1) shall apply to this appointment.

2. You will report to Davies & Co and our project managers, Buro Four Project Services who will liaise with all other interested parties on all aspects although you will liaise directly with Waterman Partnership Limited. However, you will also provide copies of all reports to Messrs Davies & Co the duly authorised agent of your co-employer.

3. The scope of your appointment is as follows:

   3.1 Whilst Waterman Partnership Limited will be responsible for proposing appropriate tests, inspections and remedial works and preparing all necessary reports you are required to confirm that sufficient evidence by way of tests remedial works and reports etc is obtained to demonstrate to a prospective purchaser or tenant that the Retained Elements are unimpaired by the explosion for the purpose of completing the construction of the new building of which they will form part so that they:-

   3.1.1 will provide proper and adequate support for the new building

   3.1.2 will perform the other functions for which they are to be incorporated in the new building and

3.1.3 (in the case of the retained facade) that the facade is sound and is properly restrained

3.2 Particular regard should be had to the following:-

3.2.1 Unnecessary or inappropriate testing procedures should be avoided particularly those which are unlikely to produce tangible results. However, in the light of our requirements as set out above, we will look to you to recommend such additional or alternative tests and remedial works as you consider necessary to ensure our ability to satisfy the reasonably anticipated requirements of third parties as set out above and in particular in paragraph 3.1 hereof.

3.2.2 Confirmation that the interpretation of test results prepared by Waterman Partnership Limited is correct.

3.2.3 Confirmation that any additional testing and repair works proposed by Waterman Partnership Limited is appropriate and provides an efficient solution to the relevant problem.

3.2.4 To check that records of all proceedings including test results supplied to Waterman Partnership Limited are properly kept by them in a clear and accurate manner, in order that they can be clearly demonstrated to a prospective purchaser or tenant and their advisors and to advise us forthwith of any defect or deficiency in the compilation and/or maintenance of such records.

4. For the avoidance of doubt your appointment will not affect the existing responsibilities of Waterman Partnership Limited in any way.

5. The detailed services which you are to provide to achieve our general requirements set out in paragraph 3 above are as follows:

5.1 You will review Waterman Partnership Limited's proposals for the Retained Elements including the principles of their justification analysis and calculations. You will continue to carry out simple checks as you have already done for establishing ground pressures and overall horizontal forces on the building.

5.2 You will review and agree the method statements for the demolition work as it relates to the Retained Elements.

5.3 You will discuss the appropriate tests that are proposed to be carried out recommend such additional or alternative tests as you consider necessary having regard to the scope of your appointment and review the results and conclusions of the agreed testing program.

5.4 You will advise on the preparation of documentation aimed at demonstrating the sequence by which proposals and decisions have been made and as part of this process you will co-ordinate and document fortnightly liaison meetings with Waterman Partnership Limited.

5.5 You will monitor by spot check inspection on site implementation of proposed tests in relation to demolition works (eg. removal of base column elements and ground floor beams framing into the perimeter retaining walls) and review associated documents.

5.6 You will discuss all remedial and repair works proposed to be carried out and suggest any additional or alternative works and monitor by spot check inspection on site that such works have been properly carried out to achieve the purpose stated in the scope of your appointment. You will advise us forthwith upon becoming aware of any failure to carry out such works. You will provide us with a written report of the extent and manner of execution of such works.

5.7 On completion of the investigation and testing of the Retained Elements and the carrying out of any additional repairs arising out of such investigation and testing you will report in writing to us and Messrs Davies & Co your considered professional opinion to the effect that having properly monitored the investigation and testing and properly considered the results thereof the performance of Retained Elements has not been impaired by the effects of the explosion so that they will provide proper and adequate support for the new building and will perform in all respects the functions for which they were incorporated in the new building as if the explosion had not occurred.

APPENDIX 2

"Retained Elements" shall include:-

1. The facade to 9 St. Helen's Place together with the internal supporting structure, structural connections and foundations after the removal of the internal finishes, windows, roof structure and roof finishes.

2. The reinforced concrete waterproof sub structure founded on bored pile foundations, including plunged stanchions and all associate supporting structure, staircases and walls comprising:

   (a) part reinforced concrete suspended ground floor slab @ level 14.714 directly above the electrical switch room

   (b) reinforced concrete suspended lower ground floor slab @ level 11.185

   (c) reinforced concrete basement slabs @ levels 6.510 and 8.410

   (d) composite reinforced concrete basement wall comprising contiguous piled external wall and internal retaining wall, and any associated underpinning

3. A waterproof membrane with associated protection to provide a water retaining structure.