CI/SfB (2.3) (R8)

1987

The structural adequacy and durability of large panel system dwellings

Part 1

Investigations of construction

R J Currie, B R Reeves and J F A Moore

bre press

BUILDING
RESEARCH
ESTABLISHMENT

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

The report
This report comprises three documents: Part 1 and Part 2, which are not available separately, and a summary in the form of a Building Research Establishment Information Paper, which is available separately.

Their full titles are:

The structural adequacy and durability of large panel system dwellings: Part 1. Investigations of construction by **R J Currie, B R Reeves and J F A Moore**

The structural adequacy and durability of large panel system dwellings: Part 2. Guidance on appraisal by **R J Currie, G S T Armer and J F A Moore**

The structural adequacy and durability of large panel system dwellings: summary of the report

Enquiries
In the first instance, general enquiries concerning this report and its findings should be referred to the Building Research Advisory Service at BRE Garston (Tel: 0923 676612).

Specific technical questions relating to the contents of the report may be referred to the following contacts at BRE Garston (Tel: 0923 674040):

Contact	*Area of work*
Dr J F A Moore (project leader)	Overall co-ordination of the BRE programme and its findings and implications for the management of LPS dwellings
Mr R J Currie	Part 1 — BRE investigations into the condition of LPS dwellings
Mr B R Reeves	Part 1 — BRE site inspections
Mr G S T Armer	Part 2 — Assessment of the structural implications of the BRE investigations and structural appraisal of LPS dwellings
Mr R J Currie	Part 2 — Assessment of the risk of corrosion in LPS dwellings
Dr R C de Vekey	Part 2 — Radar inspection techniques
Mr G S T Armer	Part 2 — Non-destructive testing techniques other than radar

In addition, specialist advice on the performance of materials may be appropriate. The following contacts at BRE Garston are available:

Mr K W J Treadaway	Corrosion of steel in concrete: mechanisms, diagnosis and repair
Mr G W Rothwell	Coatings for the protection of reinforced concrete
Mr R N Cox	Performance of metallic fixings and their protection

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Building Research Establishment Report

The structural adequacy and durability of large panel system dwellings

Part 1

Investigations of construction

R J Currie, BSc(Eng), CEng, MICE, MIStructE
B R Reeves, BSc
J F A Moore, MA, BSc(Eng), ARSM, DIC, PhD, CEng, MIStructE

Building Research Station

Department of the Environment
Building Research Establishment
Building Research Station
Garston
Watford
WD2 7JR

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Price lists for all available
BRE publications can be
obtained from:
Publications Sales
Building Research Establishment
Garston, Watford, WD2 7JR
Tel: (Garston) (0923) 674040

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

This publication is one of a series being prepared as part of the Building Research Establishment's programme of investigation to assist local authorities and their consultants in appraisal, maintenance and repair of large panel system dwellings.

Other BRE publications on large panel system dwellings are:

Building Research Establishment. *The structure of Ronan Point and other Taylor Woodrow-Anglian buildings.* BRE Report. Garston, BRE, 1985.

Edwards M J. Weatherproof joints in large panel systems: 1 Identification and typical defects. *BRE Information Paper* IP8/86. Garston, BRE, 1986.

Edwards M J. Weatherproof joints in large panel systems: 2 Remedial measures. *BRE Information Paper* IP9/86. Garston, BRE, 1986.

Edwards M J. Weatherproof joints in large panel systems: 3 Investigation and diagnosis of failures. *BRE Information Paper* IP10/86. Garston, BRE, 1986.

Edwards M J. Weatherproof joints in large panel systems: 4 Flat roofs, balconies and deck accessways. *BRE Information Paper* IP15/86. Garston, BRE, 1986.

Harrison H W, Hunt J H and Thomson J. *Overcladding external walls of large panel system dwellings.* BRE Report. Garston, BRE, 1986.

Morris W A and Read R E H. Appraisal of passive fire precautions in large panel system blocks of flats and maisonettes. *BRE Information Paper* IP18/86. Garston, BRE, 1986.

Reeves B R. *Large panel system dwellings: preliminary information on ownership and condition.* BRE Report. Garston, BRE, 1986.

ISBN for complete set of 2 parts plus Information Paper 0 85125 250 8
ISBN 0 85125 251 6

©Crown copyright 1987
First published 1987
Second impression 1987

Applications to reproduce extracts
from the text of this publication
should be made to the Publications
Officer at the Building Research Establishment

11

Contents

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Preface

In October 1984 the Minister for Housing and Construction announced a programme of investigations by the Building Research Establishment (BRE) of dwellings constructed from large panel systems. This report arises from the programme and is in two parts.

Part 1, the present part, describes the investigations of structural adequacy and durability of large panel system (LPS) dwellings, and Part 2 gives general guidance on the appraisal of such dwellings. Research related to these investigations is continuing, particularly in relation to accidental loads such as those which may arise from explosions or fire. Further guidance, therefore, may be developed for assessing the sensitivity of LPS dwellings to accidental loads.

There are other aspects of the BRE programme of investigation of LPS dwellings which may impinge on the main theme of this report. Lack of weathertightness of joints between components or in flat roofs, for example, may in some circumstances promote the corrosion of reinforcement, quite apart from causing environmental problems of rain penetration. Recent guidance on inspection, diagnosis and remedy of such problems is available[1,2,3,4].

The possibility of spread of fire and smoke through gaps or voids may require consideration[5] and in general there will be needs for periodic appraisal of the passive fire precautions in buildings[6]. It may be appropriate to integrate inspections or any subsequent remedial measures in relation to weathertightness or passive fire precautions with the other issues addressed in this report.

The remaining major issue of LPS dwellings which is still under investigation in the BRE programme is that of the environment within the flat or house. Ventilation rates, insulation standards and heating systems are being examined in order to identify ways in which an appropriate balance between them may be achieved to improve comfort and to limit condensation and mould growth at a reasonable cost.

The BRE programme also aims to ensure that any remedial measures will not cause side-effects, such as interstitial condensation or cold bridging, which may have adverse effects on the durability of the structure. Equally, any remedial measures to the structure or the weather envelope, or passive fire precautions, should not have undesirable side-effects on each other or on the internal environment.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

1 Introduction

1.1 This first part of the report describes the investigations of the construction of large panel system (LPS) dwellings carried out by the Building Research Establishment (BRE) between April 1985 and August 1986. It provides the basis for the guidance on appraisal of structural adequacy and durability of LPS dwellings given in Part 2 of this report.

1.2 Sections 2 and 3 of this part describe, respectively, the scope of the investigations and the findings in relation to large panel systems as a whole. The findings and conclusions have been based on detailed information contained in Appendix A, which describes the field investigations carried out by BRE, and on more general information, not verified independently by BRE, given in Appendix B, which comprises a review by BRE of reports of investigations of LPS dwellings carried out by owners and their consultants. The broad implications of these findings are considered in Section 4, and conclusions are drawn in Section 5.

2 Scope of investigations

Objectives

2.1 The BRE investigations aimed to:

1 Assess overall the 'as built' form of construction

2 Assess the quality of workmanship and materials used in large panel structures to provide information on the nature and extent of variability of construction

3 Review the data obtained from inspections of large panel structures in order to provide an overview of the present and long-term structural soundness of these dwellings. This would give a basis (a) for suggesting procedures for assessing the ability of individual buildings to carry normal and accidental loads, and (b) for designing any remedial measures

4 Review the data obtained from inspections of large panel structures in order to provide an overview of the likely long-term durability of these dwellings in relation to corrosion of reinforcement. This would give a basis for suggesting test regimes to enable the long-term performance of individual buildings to be assessed by their owners, with suitable reliability and cost-effectiveness

2.2 These tasks compare broadly to the main steps which may be necessary for a full appraisal of a structure and its durability.

Systems inspected

2.3 Records of construction indicate that about 160 000 dwellings have been constructed in the United Kingdom using large panel systems. Recently published information[7] relates only to about 70% of this total. The number of flats in blocks over 4 storeys high in England is given in the form of a histogram in Figure 1. It shows the variety of systems and the preponderance of some of them.

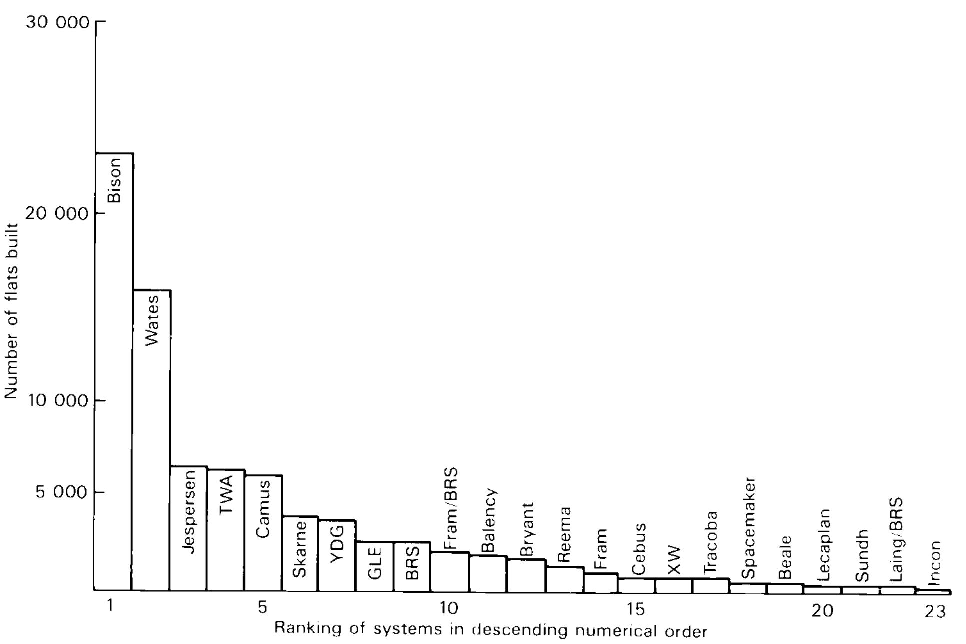


Figure 1 Numbers of flats in buildings over 4 storeys high constructed from different large panel systems, in England

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Table 1 Systems examined by BRE and by consultants

System	Number of blocks examined: By BRE	Number of blocks examined: By consultants	Approximate percentage of total LPS housing stock in the UK++
Balency	2	34	2.5
Bison	2	198**	23.3
Bryant	2	Not examined	8.3
Camus	2	11*	4.6
HSSB	3	—≠	0.7
Jespersen	3+	—≠	6.2
Reema	3	6**	5.9
Selleck Nicholls Williams	5	Not examined	2.9
Shepherd Spacemaker	+	Not examined	1.8
Skarne	4	4	5.3
TWA⊕	1	1	5.8
Wates	3	2**	14.2
Cebus	Not examined	6	0.5
PAC	Not examined	—≠	0.2
Tracoba	Not examined	14	0.5
YDG	Not examined	33**	2.7°
			85.4%

++ Based on DOE figures for dwellings, 1984
** Numerous other blocks examined — no figures available
* 98 dwellings examined at one site — no figures on number of blocks available
≠ No figures given in consultants' reports
\+ Visual inspection of complete estate at one site
° A high proportion of these blocks have now been demolished
⊕ Previously reported BRE investigation[5]

2.4 The condition of dwellings of the Taylor Woodrow-Anglian (TWA) system, which account for 5.8% of the total population of LPS dwellings, has been reported previously by BRE[5]. The present investigation aimed to carry out inspections to form an overview of the conditions obtaining in the remaining LPS system, and examples of buildings in 11 LPS systems were examined. These 11 systems account for approximately 80% of the remaining LPS dwellings. Table 1 gives the numbers of blocks and systems inspected by BRE, and also the coverage provided by the consultants' reports, and compares them with the corresponding total stock (UK figures).

2.5 Despite the ready co-operation of building owners in making buildings available for inspection, the sample examined was limited necessarily by the availability of individual dwellings. As a result the sample was not random but nevertheless contained dwellings which had been vacated primarily for non-structural reasons. The observations cannot be regarded therefore as forming a statistically valid sample but should be regarded as a factual account of a number of case histories.

2.6 In the large panel systems investigated, the forms of panels and methods of connecting them were essentially the same. The only more obvious variations were surface finish, panel arrangement (which may have structural implications) or layout on site or estate. Some 29 systems, accounting for approximately 18% of the stock, were not specifically investigated by BRE. (They are: Anglia, Basingstoke Development Group, Beale, Belfry, BRS, Carlton, Cebus, Dudley BC, Fram, Fram/BRS, Gerrard, GLE, Gregory, Housing Development Consortium, Laing/BRS, Lecaplan, Metracon, MFC, Modus, NCB, PAC, Ridgeway, SB2, Southend 3M, Stubbings, Sundh, Tracoba, Trentrox, and YDG.) Nevertheless it is considered that the findings reported here and the conclusions derived from them are likely to apply in principle to most large panel systems.

Method of working

2.7 The method of working adopted by BRE comprised four activities:

1 Historical reviews of performance with the building owners

2 Visual inspection of the structures and opening up joints physically (some 70, of various types) by removal of concrete to inspect and examine reinforcement details and quality of concrete in the connections between precast panels. This was followed by comparing these observations as far as possible with the specification and drawings for the structure, with the general details of construction given in the original National Building Agency certificates, or with information gained from similar buildings of a similar age

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

3 Testing concrete in the panels and joints for depth of carbonation and chloride content*. Some 400 samples were taken, 30% being from the outer envelope of which a third were from external surfaces

4 Review of relevant consultants' reports

2.8 These activities were undertaken with the co-operation of the building owners and in many cases in conjunction with their engineers or consultants. In the latter case the availability of structural drawings and the greater number of locations examined provided a greater insight into the condition of the structures and made possible a more efficient survey.

• • • • • • •

3 Main findings of BRE investigations

Introduction

3.1 The results of inspections carried out by BRE are reported in Appendix A. Appendix B provides summaries prepared by BRE of reports of investigations made by building owners and their consultants. The two appendices together give a consistent view of the range and variety of conditions which may be encountered in large panel construction.

3.2 The standard of workmanship and compliance with the design were found to differ considerably between buildings of the same system and between buildings on the same site. However, the standard of workmanship and construction practice was found to be reasonably consistent throughout individual buildings.

3.3 It is possible to draw only generalised observations and conclusions which apply to the population of LPS buildings as a whole because of the differences found between buildings. The findings and observations do not apply equally to all LPS buildings; some buildings were found to be virtually as designed and to have suffered only minimal deterioration.

3.4 The findings are considered below under the four headings of reinforcement in joints, reinforcement in panels, precast concrete, and in-situ concrete, followed by some points specific to parapets and balconies.

Reinforcement in joints†

3.5 This reinforcement includes steel positioned on site, steel cast projecting from precast panels to form part of the connection, steel used as a levelling system during erection, connections to non-loadbearing panels, and steel added subsequently as part of strengthening measures.

3.6 In a substantial number of buildings the arrangement of reinforcement in the joints between the precast components was found to be different from that specified in the original design. In some cases these variations consisted of detailed changes such as smaller diameter bars or changes to the type of end treatment given to the reinforcement. These minor variations were probably carried out to facilitate construction of the in-situ joints on site.

3.7 In many instances other changes appear to have been introduced in successive buildings as construction proceeded. Those commonly found were the omission of site-installed dowel bars between intersecting loop bars projecting from the precast components, or the misplacement of loop bars so that no interconnection was possible.

3.8 A few examples were found of reinforcement being cut off or bent back where it projected from the precast components. In some cases this resulted in joints without shear keys and in a lack of physical connection between the precast components other than the bond between the precast concrete and the in-situ concrete. Most cases identified were in vertical joints between panels and, in particular, at corner locations.

3.9 Where reinforcement was exposed it was generally found to be in good condition (condition 0 or 1, illustrated in Plate 32 in Appendix A). In a few cases in the outer envelope where joints had been poorly constructed the reinforcement condition corresponded to condition 2 (Plate 32). No cases were found where a substantial loss of cross-section had occurred.

3.10 Buildings with tying deficiencies were found in all ages of construction inspected, although buildings constructed about 1969 to 1972, immediately after the partial collapse of Ronan Point, tended to have fewer deviations from the design intentions and, as a result of redesign, had more substantial connection details specified. There is some evidence which suggests that increased vigilance in supervision of construction waned in later years.

3.11 Where strengthening to wall/floor joints had been specified following the partial collapse of Ronan

*Throughout this report chloride contents are referred to as a percentage, eg 1.0%. These figures are the percentage of total chloride ion by weight of cement. Three categories of chloride content are used, ie low, medium and high, which correspond to less than 0.4%, 0.4 to 1.0%, and over 1.0% respectively.

† In this report the term 'joints' is used to describe zones in which precast components come together, and the term 'connections' is reserved for the physical devices or mechanisms within the joints.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Point, the strengthening measures proposed had usually been implemented on site. There were a few cases, however, where the proposed strengthening schemes had not been implemented, had only been partially implemented or had been poorly installed.

3.12 Levelling bolts were occasionally found displaced from the vertical, and in a few panels there was minor cracking around bolt locations. It is not possible to say whether the deformation of the bolts or the presence of cracks were the result of damage, either during manufacture of the panels or during the original construction period, or of load transfer.

3.13 In many cases storey-height non-loadbearing panels and spandrel panels were supported by the main structural walls using metal brackets or angle connections. Little corrosion was found in this form of connection, the main faults identified being the occasional omission of bolts (as shown in Plate 18 in Appendix A) and the failure to tighten some of the bolts provided.

3.14 Connections of non-loadbearing panels were loose in some places and outwards movement was indicated by cracking visible at internal vertical joints. This cracking was observed only in some low-rise buildings and in the upper storeys of a few high-rise buildings.

3.15 The connection of non-loadbearing spandrel panels to the structural cross walls was the only substantial provision found for ensuring the longitudinal stability in some low-rise terraced dwellings.

Reinforcement in panels

3.16 The precast panels themselves had generally been manufactured as specified, but in some cases the position of the reinforcement and occasionally the thickness of the skins of sandwich panels were found to be incorrect. The consistency and accuracy of spacing of the reinforcement in the panels was often poor. In particular, low concrete cover to the reinforcement at edges of components and around window openings was found which had given rise to local cracking and spalling due to the corrosion of the reinforcement as a result of carbonation of the concrete.

3.17 In a few sandwich panels, lateral displacement of the insulating layer during panel manufacture had produced uneven thicknesses of concrete 'skins' which affected adversely both the concrete cover to the panel reinforcement and the length of embedment of the ties between the skins.

3.18 The most widely reported defect in the construction of sandwich panels concerned the ties between the two skins of sandwich panels[8]. Both the number of ties per panel and the material of manufacture were found to be at variance with the original specifications and on occasions differed from one building to another on the same site.

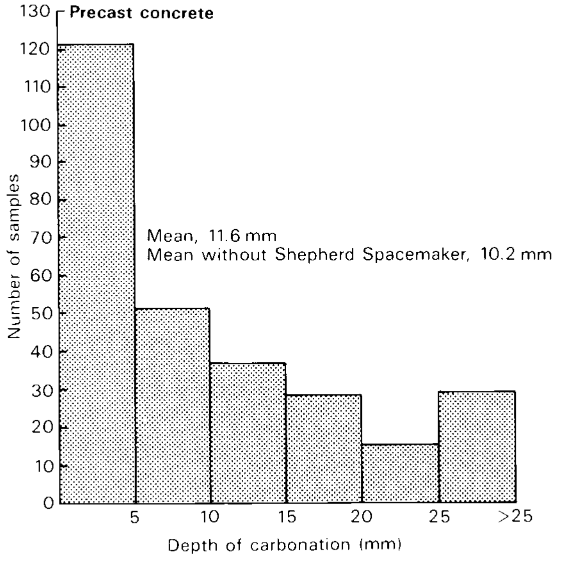
Precast concrete

3.19 The precast wall panels were generally found to be well made apart from the lack of care taken in the positioning of reinforcement (see above). The strength of the precast concrete proved to be adequate.

3.20 Recorded carbonation depths in panels are shown in Figure 2. The results show that the mean carbonation depth in the panels tested was 11 mm with some panels carbonated to a depth of 25 mm or more.

3.21 The measurements of chloride contents obtained by BRE for all precast panels are given in Figure 3. This shows that chloride was definitely added to 5.2% of samples and was probably added to a further 12.3%. The BRE results indicate that calcium chloride had been added during manufacture to some components in the Skarne, Bison and HSSB systems and that this use of calcium chloride was intermittent. One of the other systems inspected by BRE had chloride contents in the range 0.4 to 1.0% which is insufficient to conclude positively that calcium chloride had been added but indicates a strong likelihood that it was used, although possibly not to the maximum doses allowed at the time.

3.22 The most common use of calcium chloride was found in minor repairs to panels carried out at the factory or after delivery on site. The corners and edges of panels were the parts which had been repaired most commonly using concrete containing



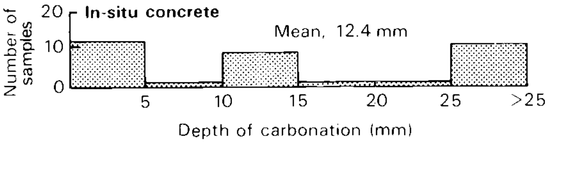


Figure 2 Depths of carbonation in precast and in-situ components measured by BRE

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

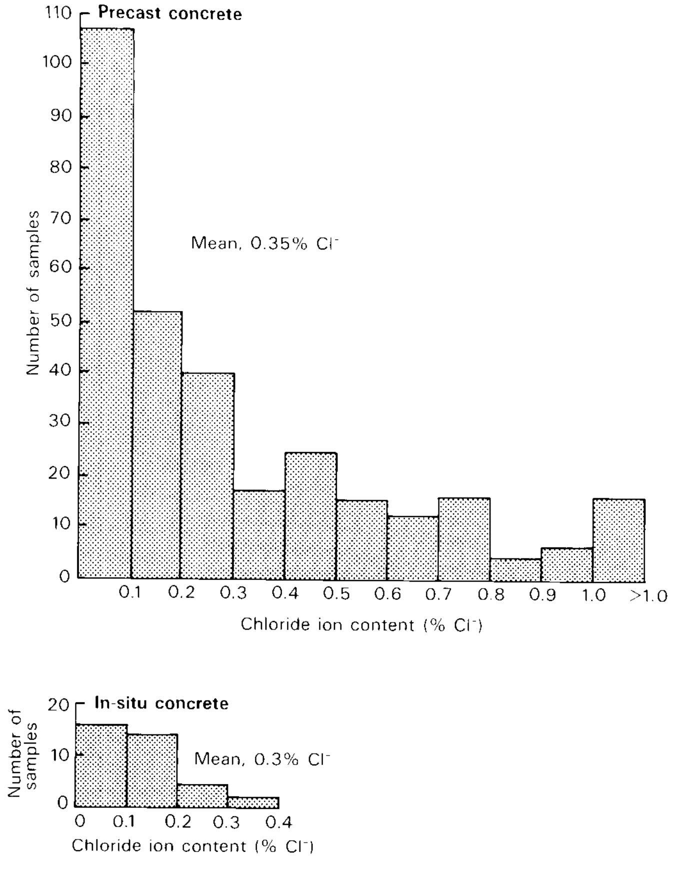


Figure 3 Chloride contents of precast and in-situ components measured by BRE

high doses of calcium chloride. Many of these repairs are now failing due to corrosion of embedded reinforcement.

3.23 A few wall panels had minor cracking beneath the bearing of floor-panel support nibs.

3.24 The quality of the precast panels was in line with the observations of other precast work[9]. In general, serious deterioration has not arisen so far. However, there were signs in some buildings of local cracking and spalling, for example at the edges and corners of panels and around openings. It was usually associated with low concrete cover to the reinforcement or with high chloride contents.

In-situ concrete

3.25 The term 'in-situ concrete' is used here to include the 'dry-pack' sand-cement mortar used for final bedding of loadbearing wall panels, as well as the concrete used to make horizontal and vertical joints between precast components.

3.26 Poor compaction was most commonly found where access had been difficult during construction or where reinforcement prevented the free flow of concrete into the joint. Such details were found in some vertical joints, where external panels and internal walls met, and in some horizontal joints, where floors and walls met.

3.27 The curing of in-situ concrete appeared to have been generally adequate because of the confined nature of the in-situ concrete in the joints. The concrete was of good quality where adequate compaction had been achieved. It is mainly where compaction has been poor that the concrete may not provide long-term chemical and physical protection to embedded reinforcement in the future.

3.28 As a result of the above differences in compaction, the quality of the concrete found in the in-situ joints between panels was found to be highly variable. In many cases carbonation had proceeded no further in the in-situ concrete than in the precast panels (Figure 2), although in some severely voided material the depth of carbonation was in excess of 60 mm.

3.29 Added chlorides had in general not been introduced to the in-situ concrete (Figure 3).

3.30 Placing and compaction of dry-pack material in the horizontal joints during construction was found to be the most poorly executed feature of these buildings. In some cases the material had been omitted almost completely and in others it was found to be friable, poorly compacted and severely voided. However in some structures the dry pack was found to be consistently well compacted.

3.31 Where dry pack is voided or missing, the vertical load present at the base of the panels is being transferred through local hard spots provided by levelling nuts and bolts or packing pieces[5], supplemented sporadically by support from the dry-pack mortar. However, no signs of associated distress were found in the structures inspected by BRE.

3.32 A high proportion of the dry-pack joints were found to be carbonated to a substantial depth.

3.33 The site investigations showed that, for each type of joint, some were made correctly and some were made incorrectly. No type of large panel system can be singled out as having a greater prevalence of poorly made joints; all systems examined had examples of poorly made joints on some sites.

3.34 In some cases the cladding panels were connected to the main structure using in-situ reinforced concrete stitches in the same manner as the connections between loadbearing panels were made. Where this was the case the comments above (paragraphs 3.26 to 3.30) apply equally to these joints.

Parapets

3.35 A few cases of significant deterioration to parapets and their copings were found. The deterioration was caused by corrosion of fixings or of reinforcement. Movement of other components had pushed parapets off their bearings and had sometimes debonded the parapets from their fixings, rendering

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

them unstable. In addition, it was reported by consultants that some parapets had less than the specified number of fixings.

Balconies

3.36 Four general problems were identified:

1 Significant deflection of balcony slabs primarily due to heavy balustrades which were not envisaged in the original design

2 Low concrete cover to the edges of balcony slabs giving rise to corrosion of the reinforcement and spalling of the cover

3 Screeds laid to incorrect falls allowing ponding of water and water penetration of the joint connecting the balcony slabs to the main structure

4 Corrosion of reinforcement and/or metal railings causing spalling of concrete balustrades

4 Discussion

Reinforcement in joints

4.1 Recorded information on the design of a large panel system building is not always an accurate reflection of the structure 'as built'. A range of departures from the original design and specification was observed. The variations in reinforcement (paragraphs 3.6 to 3.8) have different implications:

1 Nominal deviations from the design, introduced during construction, are commonplace although in the majority of cases the changes have not led to conditions which are significantly less satisfactory than those that would have been achieved if the original specifications had been followed

2 More substantial changes of arrangements of interconnecting reinforcement or its position have resulted in some cases in structures which do not conform to the original design intention, but which may nevertheless be acceptable

3 The absence of proper connections at some locations may have implications for structural adequacy in some buildings

4.2 The structural performance of these buildings under normal loads does not depend to a great extent on reinforcement in joints. It is not surprising therefore that alterations or omissions in joints, even when highly loaded as in the lower storeys of high-rise blocks, have had no significant effect. The evidence from the performance in service of LPS buildings confirms that they are insensitive to the small movements which occur as a result of normal loading, owing to their favourable structural form.

4.3 No discernible pattern to the occurrence of variations has been identified other than that the practice adopted in individual buildings, whether good or bad, has been consistent throughout the structure.

4.4 The only practical way of determining the structural connection system in an existing LPS building with a sufficient degree of assurance is to investigate joints in detail by opening up at a number of locations in the structure, using structural detail drawings as a guide. Such action may be necessary where available information on the connections is inadequate and the condition of joints is critical to the performance of the structure.

4.5 The significance of these variations for behaviour of a structure damaged as a result of accidental load will depend on the mechanisms which may be available to limit the spread of damage. These mechanisms may be explored objectively as suggested in Part 2 of this report.

4.6 In some low-rise LPS dwellings, provision for longitudinal stability depends on the ability of joints to transfer moments between roof and walls, floors and walls, and non-loadbearing cladding panels and walls. Movement between panels in these buildings indicates the need for investigation of the cause, especially where floor panels have limited bearings.

4.7 No buildings were found which showed signs of distress giving concern for the safety of people, and none were identified where the construction had failed to sustain the loads experienced in service, including fire loading. Any displacement of bolts or cracking of surrounding concrete is not conclusive evidence that excessive loads are being carried. Similarly, tightness of levelling nuts and washers may result from compression of joints onto previously loosened nuts. In either case the associated small movements are indicative of a local redistribution of loading to achieve a stable condition.

4.8 The small outwards displacement of cladding panels near the top of some tall buildings (see paragraph 3.14) probably results from the cumulative cyclic effects of wind loading and temperature changes on connections which permit limited progressive movement. The movement appears to have no effect on the integrity of the panel or the structure but may lead to lack of weathertightness.

Reinforcement in panels

4.9 Defective tying between the leaves of sandwich panels may give rise to a risk of detachment.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Precast concrete

4.10 The ages of the buildings inspected by BRE ranged from about 16 to 24 years, with 20 years being a representative age for the population of measured carbonation depths given in Figure 2. The variation in the mean depth of carbonation for individual systems is consistent with the variability of precast concrete in general. Within this variability, however, the concrete samples taken from some systems had carbonated to a consistently greater mean depth than the average for all systems.

4.11 If the permeability of the concrete of large panel systems components corresponds to that of other precast work[9], it would be expected that in the first 20 years average carbonation depths would be in the range 4 to 13 mm with a typical mean depth of 9 mm.

4.12 The carbonation depths measured in LPS structures (Figure 2 and paragraph 3.20) indicate that broadly this is the case. There seems to be no evidence to support the notion that the quality of concrete produced in the precast panels was significantly better or worse than that used in other forms of precast concrete building components. The few particularly high average carbonation depths were associated with an unusual concrete containing lightweight aggregate of small size.

4.13 Most reinforcement in precast components in the majority of LPS buildings is likely therefore to remain unaffected by corrosion for a long time. Major structural disruption because of reinforcement corrosion is unlikely to be a cause for concern in most buildings for many years. However it is expected that there will be an increasing incidence of local spalling of external concrete due to corrosion of reinforcement in most buildings, and some buildings may eventually require extensive repairs to the concrete panels.

4.14 Failures of repairs made to concrete panels during manufacture or construction (paragraph 3.22) are giving rise to hazards from falling concrete to users of both high-rise and low-rise dwellings. There is a growing need to remove such hazards and reinstate repairs.

4.15 Added chloride was identified in three of the systems examined by BRE and its sporadic use is strongly suspected in one other. Since corrosion of the reinforcement is more likely with increasing chloride contents, the amount of chloride present can be used as a means of determining priorities for building inspections, in the absence of overriding structural criteria. A method of interpretation of chloride contents and depths of carbonation in terms of risk of corrosion of reinforcement is given in Part 2.

In-situ concrete

4.16 In the long term, reinforcement forming the connections between panels may be susceptible to corrosion. Exclusion of free water from joints should minimise the likelihood of corrosion in those cases where the in-situ concrete has carbonated. The most severe corrosion is likely to occur in voided concrete, but such concrete is best able to accommodate the corrosion products without disruption of the joints. Substantial loss of cross-section would need to occur for response to accidental loads to be impaired, and then only if integrity of the joint were critical to the robustness of the structure (see Part 2).

4.17 Well compacted dry pack (paragraph 3.30) appeared to be of adequate quality, although no strength tests were made. It should be noted that original specification by cube strength is not directly relevant to performance in a thin layer confined in the horizontal joint between wall panels. Even a weakly cemented material will exhibit substantial strength under such triaxial restraint.

4.18 As the dry pack does not generally contain reinforcement (apart from levelling bolts passing through it), corrosion as a result of carbonation is not an issue.

Parapets and balconies

4.19 The condition of parapets should be assessed as part of any inspection of the outer envelope to avoid hazards from falling debris.

4.20 Balconies are incorporated in many LPS buildings but do not necessarily conform to a standard design for any one system. Any shortcomings are likely to be peculiar to the individual building or site.

5 Conclusions

5.1 Following the collapse of a part of Ronan Point in 1968, a programme of appraisal and strengthening of LPS buildings was undertaken. Since then no major structural failure of an LPS building in the UK has been reported, although there is evidence of local damage to parts of the outer envelope which is likely to increase in the future.

5.2 The Building Research Establishment has found no LPS building showing signs of structural distress sufficient to give concern for the safety of people; nor has it received any reports of an LPS building failing to sustain the loads experienced in service, including fire loading.

5.3 The quality of the reinforced precast concrete components in LPS buildings examined by BRE has been found not to be significantly better or worse

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

than that of precast components in other forms of construction of the period.

5.4 A number of variations from original designs and specifications have been found. Their occurrence and extent does not conform to any identifiable pattern, nor are they confined to particular types of LPS building or periods of construction. It is therefore suggested that assessment of the implications of any such variations can only be made satisfactorily on the basis of a structural appraisal of each individual LPS building. However, the information in this report on specific types of LPS building may be a useful guide to identifying variations which may be present in particular buildings.

5.5 Limited departures from the original design and specification in building construction are normally accommodated by the margins of safety provided by the standards and codes which applied at the time of construction. However, some variations found in these investigations may have implications for the structural adequacy of particular LPS buildings in respect of their performance under normal or accidental loads, and for their durability.

5.6 Cracking and spalling of concrete arising from corrosion of reinforcement in the external envelope, eg cladding panels, have been found in a substantial number of LPS buildings. There is likely to be an increasing incidence of these phenomena, especially where components:

(a) are exposed to wet conditions,

(b) are of poor quality,

(c) have inadequate depth of cover to the reinforcement, or

(d) contain high levels of chlorides.

There will be an increasing likelihood of hazards arising from falling debris around some buildings unless they are inspected and maintained to prevent such incidents.

5.7 Corrosion of reinforcement in wall or floor panels or in the connections between them is unlikely to present a risk to the stability of LPS buildings unless it becomes substantial and widespread. Corrosion of reinforcement in connections between walls and floor panels or between walls and cladding panels will be minimised by maintaining them in a dry condition.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Acknowledgements

This report was prepared as part of the Building Research Establishment's research programme on large panel prefabricated flats and houses which began in October 1984 under the general direction of Dr J B Menzies. Thanks are due to other colleagues who contributed to it, particularly Mr G R Martin and Mr R M Moss.

Grateful thanks are extended to all those local authorities who made buildings available for investigation, took part in detailed discussions and made available copies of reports prepared by their consultants.

• • • • • • •

References

1 **Edwards M J.** Weatherproof joints in large panel systems: 1 Identification and typical defects. *BRE Information Paper* IP8/86. Garston, BRE, 1986.

2 **Edwards M J.** Weatherproof joints in large panel systems: 2 Remedial measures. *BRE Information Paper* IP9/86. Garston, BRE, 1986.

3 **Edwards M J.** Weatherproof joints in large panel systems: 3 Investigation and diagnosis of failures. *BRE Information Paper* IP10/86. Garston, BRE, 1986.

4 **Edwards M J.** Weatherproof joints in large panel systems: 4 Flat roofs, balconies and deck access-ways. *BRE Information Paper* IP15/86. Garston, BRE, 1986.

5 **Building Research Establishment.** *The structure of Ronan Point and other Taylor Woodrow-Anglian buildings.* BRE Report. Garston, BRE, 1985.

6 **Morris W A and Read R E H.** Appraisal of passive fire precautions in large panel system blocks of flats and maisonettes. *BRE Information Paper* IP18/86. Garston, BRE, 1986.

7 **Reeves B R.** *Large panel system dwellings: preliminary information on ownership and condition.* BRE Report. Garston, BRE, 1986.

8 **The Institution of Structural Engineers, Scottish Branch.** *Guidance note on the security of cladding on large panel concrete construction.* September 1984.

9 **Currie R J.** *Carbonation depths in structural-quality concrete: an assessment of evidence from investigations of structures and from other sources.* BRE Report. Garston, BRE, 1986.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Page blank in original

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Appendix A Summary of investigations of LPS dwellings by BRE

A1 Introduction

A1.1 This Appendix describes the information obtained from BRE investigations into large panel system dwellings. The systems reported on include the most widely used types (see Table 1 in the main text). The opportunity was also taken to examine some examples of the less widely used systems. No further investigation of Taylor Woodrow-Anglian buildings was carried out following that made in 1984-85[1].

A1.2 The data from analysis of materials for all the sites examined by BRE are given in Tables A1 to A11. The low, medium and high categories of chloride content referred to in the accompanying text, correspond to chloride ion contents of less than 0.4%, 0.4 to 1.0%, and over 1.0% by weight of cement, respectively. Where chloride contents are in the low category it may be assumed that chlorides had not been added to the concrete during manufacture and will not generally lead to deterioration in uncarbonated concrete. Where a substantial number of measurements of chloride content is in the high category, ie in cases where the average chloride content is above or about 1.0%, it may be assumed that chlorides had been added deliberately to the concrete during manufacture, unless the concrete was exposed to external sources, eg deicing salts. Where the chloride content falls in the medium category, contamination with chlorides may have occurred from the use of poorly washed sea-dredged aggregates, accidental mis-dosing, or deliberate dosing with calcium chloride at levels lower than the maximum permitted at the time of manufacture.

A1.3 Information on the quality of structural concrete generally in relation to resistance to carbonation has been reported previously by BRE[2]. The quality of the precast concrete components examined in the present investigation has been related to this wider experience. In the context of large panel components, the description of average quality is the quality which is considered to obtain widely in other precast concrete of the same period.

A1.4 An essential part of BRE's investigation of LPS dwellings has been the 'opening up' of concrete joints between precast components. 'Opening up' has involved breaking concrete out of joints to expose the interconnecting reinforcement using rotorhammer drills and chisels. This work generates considerable noise, dust and vibration. In order to limit the nuisance experienced by occupants it has been necessary to restrict the number of locations examined in this way. As a result, it has not been possible to establish all the connection details at some sites.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A2 The Balency system

A2.1 The investigations into the Balency system consisted of inspections of two properties at one site in the South-East of England.

Site 14 (South-East)

A2.2 Three-storey deck access blocks and several 13-storey tower blocks, providing approximately 4000 dwellings, were built on this large estate (Plate 1). The buildings were approximately 17 years old, and the external condition at the site was good, although there are some problems with the waterproofing and drainage details of the dwellings.

A2.3 Piped gas was reported to be supplied to the dwellings. No information on the structural standard or connection details of the high-rise blocks was available at the time of inspection.

Extent of work

A2.4 One 3-storey town house and one flat in a 13-storey block were inspected.

A2.5 A very limited examination of the joints between components was carried out, since adjacent properties were occupied. Furthermore, in the absence of any detailed reinforcement drawings, the locations examined could not be chosen to yield the optimum information and therefore the information on the structural connections is very limited.

A2.6 An examination of six slab/wall joints was undertaken in the two dwellings and 36 concrete samples were taken for analysis from loadbearing wall panels, cladding panels (non-loadbearing and loadbearing inner leaves), floor slabs, in-situ joints and balcony parapets.

Discussion of physical conditions observed

A2.7 At the locations examined, hoop and bar reinforcement connections were exposed and, on the basis of information available from another Balency development, the reinforcement details appeared to comply with the design intentions.

A2.8 The reinforcement was in good condition although in some cases it appeared to be displaced. The dry pack examined was in position and well compacted and no cracking was observed. There were a few isolated areas of honeycombing in the otherwise well compacted in-situ concrete.

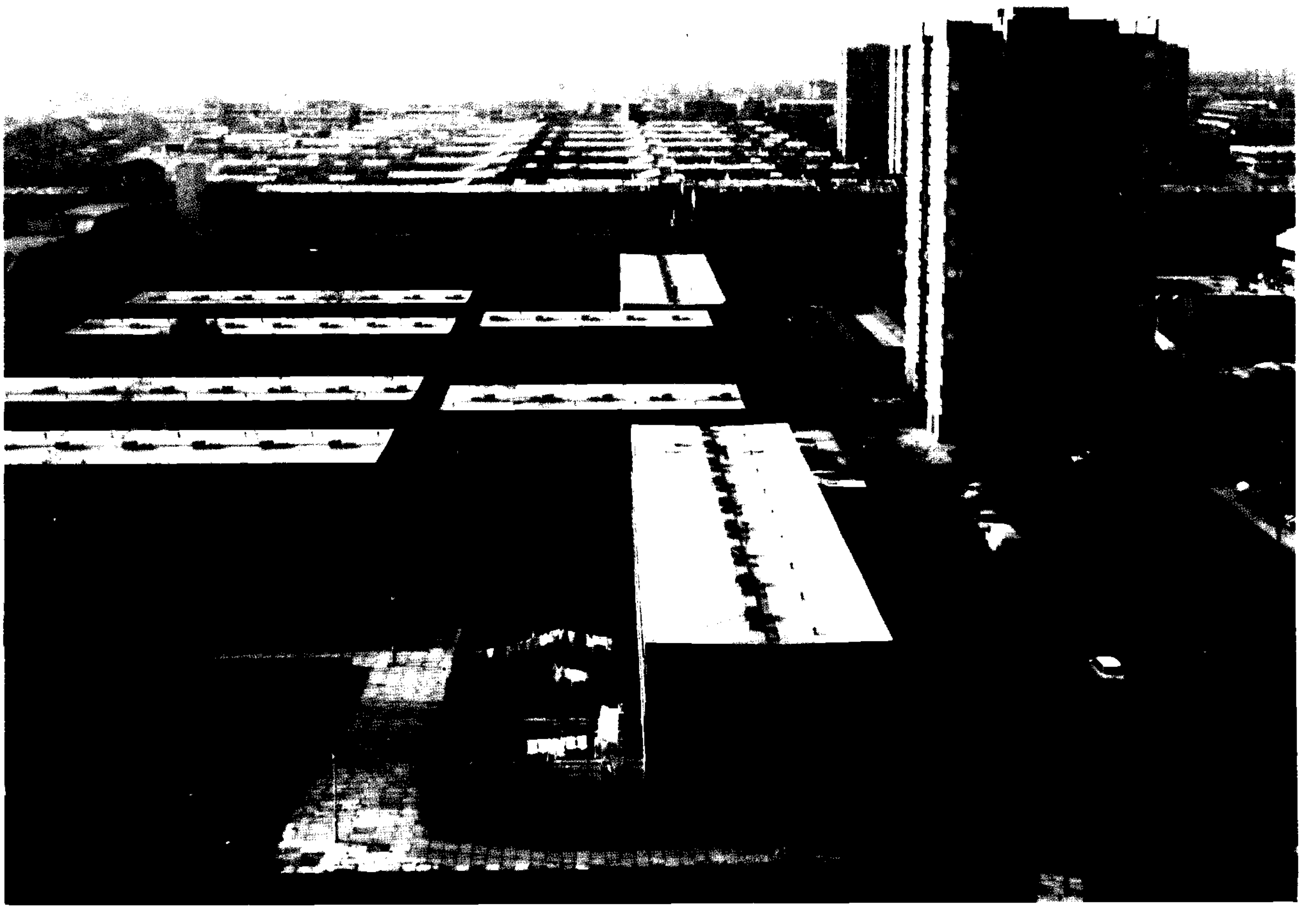


Plate 1 Balency: general view of estate

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Table A1 Materials data measured by BRE for each site inspected

Balency

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 14							
Cladding panel, loadbearing inner leaf	14/1/1/1	No det	—	10	0.16	—	—
Cladding panel, non-loadbearing inner leaf	14/1/2/1	No det	40	20**	0.26	15.1	1
Joint	14/1/3/1	Honeycombed	60	0	0.10	—	1
Balcony parapet panel	14/1/4/1	No det	—	0	0.2	—	—
Loadbearing wall panel	14/1/5/1	No det	—	0	0.08	—	—
Loadbearing wall panel	14/1/5/2	No det	—	10*	0.27	—	—
Floor slab	14/1/6/1	No det	—	0	0.28	17.8	—
Loadbearing wall panel	14/1/7/1	No det	—	10*	0.23	—	—
Cladding panel, non-loadbearing inner leaf	14/1/8/1	No det	—	10	0.12	—	—
Cladding panel, loadbearing inner leaf	14/1/9/1	No det	—	18	0.12	—	—
Joint	14/1/10/1	No det	—	12	0.19	17.6	—
Loadbearing wall panel	14/1/11/1	Well compacted	70	0	0.10	—	1
Loadbearing wall panel	14/1/12/1	No det	—	10	0.16	—	—
Loadbearing wall panel	14/1/12/1	No det	—	5*	0.19	—	—
Loadbearing wall panel	14/1/13/1	No det	—	11	0.15	—	—
Loadbearing wall panel	14/1/14/1	No det	—	10	0.19	—	—
Floor slab	14/1/15/1	No det	—	2	0.22	18.1	—
Cladding panel, loadbearing inner leaf	14/2/1/1	No det	15	0	0.21	—	1
Joint	14/2/2/1	Honeycombed	—	§	0.13	—	—
Cladding panel, non-loadbearing inner leaf	14/2/3/1	No det	40	0	0.26	15.1	1
Cladding panel, loadbearing inner leaf	14/2/4/1	No det	—	10	0.17	—	—
Loadbearing wall panel	14/2/5/1	No det	—	10	0.20	—	—
Loadbearing wall panel	14/2/6/1	No det	—	10	0.20	—	—
Cladding panel, non-loadbearing inner leaf	14/2/7/1	No det	70	2	0.33	17.2	1
Cladding panel, loadbearing inner leaf	14/2/8/1	No det	70	2	0.20	—	1
Loadbearing wall panel	14/2/9/1	No det	—	12	0.19	18.2	—
Loadbearing wall panel	14/2/9/2	No det	—	10	0.17	—	—
Loadbearing wall panel	14/2/10/1	No det	—	15	0.21	—	—
Joint	14/2/11/1	Honeycombed	—	—	0.15	—	—
Cladding panel, loadbearing inner leaf	14/2/12/1	No det	—	10	0.20	—	—
Cladding panel, loadbearing inner leaf	14/2/13/1	No det	—	6	0.26	—	—
Cladding panel, loadbearing inner leaf	14/2/14/1	No det	—	15	0.21	—	—
Floor slab	14/2/15/1	No det	—	0	0.36	17.2	—
Cladding panel, loadbearing inner leaf	14/2/16/1	No det	—	3	0.14	—	—
Floor slab	14/2/17/1	No det	—	5	0.15	—	—
Floor slab	14/2/18/1	No det	—	7	0.19	13.9	—

* No det, no deterioration
** Illustrated in Plate 32
* Variable
** Variable 0 – 20 mm
§ Localised areas of uncarbonated concrete

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A2.9 Spalling associated with reinforcement corrosion was present in the exposed edge of a floor slab abutting the balcony of the flat.

Summary of analysis of materials

i Floor slabs
A2.10 Chloride contents in the floor slabs examined were between 0.15 and 0.28%, with a mean of 0.22%, indicating that chlorides had not been added to the concrete during manufacture of the floor units in the dwellings examined.

A2.11 Carbonation depths varied from 0 to 7 mm, with a mean of 2.8 mm, which indicates a better than average precast concrete quality. Cement contents ranged from 13.9 to 18.1% with a mean of 16.8%.

A2.12 No depths of concrete cover to the reinforcement were recorded since the disturbance due to breaking out of the floor units was required to be kept to a minimum.

ii Precast wall/balcony parapet panels
A2.13 Chloride contents varied from 0.08 to 0.33%. The mean chloride content was 0.19%, showing that chlorides had not been added to the wall panels examined.

A2.14 Carbonation depths varied from 0 to 20 mm, with a mean of 8.1 mm, which suggests an average concrete quality. Concrete cover to the reinforcement ranged from 15 to 70 mm, with a mean of 50.8 mm, which was consistent with the design intentions. The mean cement content was 16.4%.

iii In-situ joints
A2.15 Chloride contents ranged from 0.1 to 0.15%, with a mean of 0.11%, again indicating that chloride had not been added to the concrete.

A2.16 Carbonation depths ranged from zero to almost fully carbonated with only localised areas of uncarbonated concrete.

A2.17 Reinforcing steel was exposed in two joints and was found to have 60 and 70 mm of cover respectively, which appears to be consistent with the design intentions.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A3 The Bison system

A3.1 The investigations into the Bison system consisted of inspections of two blocks at two sites, one in the West Midlands and the other in the North-East of England.

Site 9 (West Midlands)

A3.2 This urban estate situated on a level site consisted of forty-two 3-storey blocks built in the 1960s.

A3.3 Seventeen other blocks were present on or near the site, some of which were built to the Bison high-rise system.

A3.4 The 3-storey block inspected was being demolished as part of a replanning programme aimed at stemming vandalism and improving access on the estate. The blocks were generally in poor condition.

Extent of work

A3.5 The roof of the block had been removed, exposing the top edges of the third-floor wall panels. The investigation was limited to a visual inspection and sampling of readily accessible concrete components and joints, since suitable powered cutting tools were not available at the time of inspection. No reinforcement was exposed during concrete sampling.

A3.6 In total 17 concrete samples were taken for analysis, including samples from precast ring beams, cladding panels (loadbearing inner leaves), roof and floor beams, in-situ joints and loadbearing wall panels.

Discussion of physical conditions observed

A3.7 At the locations examined, the tying steel was in place and in good condition, and the in-situ concrete was in place and well compacted. Large areas of dry pack were missing from beneath internal wall panels which were largely supported by the levelling bolts (Plate 2). There was no indication of overstressing of the levelling bolts or the surrounding concrete.

A3.8 There were numerous instances of low bearing areas to the roof beams, although there was no evidence of distress in the units. Hardboard packing had been used to level the roof beams (Plate 3).

Summary of analysis of materials

i In-situ concrete

A3.9 The single sample taken from the in-situ concrete had a chloride content of 0.08%, and a depth of carbonation of 40 mm.

ii Roof beams

A3.10 Chloride contents ranged from 0.09 to 1.08%, giving a mean of 0.45%, and indicate that chlorides had been added to the concrete during manufacture of some of the components.

A3.11 The carbonation depth for two of the samples exceeded the depth of sampling and the end of a beam showed in excess of 25 mm (Plate 3).

iii Precast wall/cladding panels

A3.12 Chloride contents ranged from trace values to a maximum of 0.77%, with a mean of 0.29%. The results lie in the low and medium categories, which suggests that chlorides may have been added to some of the wall and cladding panels at this site.

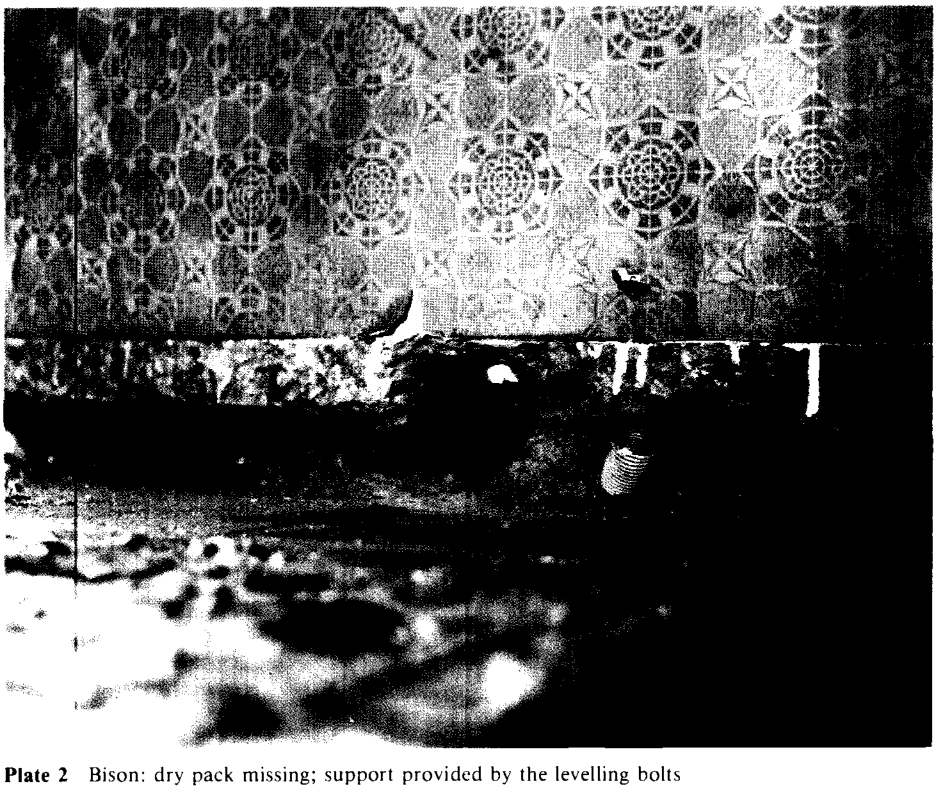


Plate 2 Bison: dry pack missing; support provided by the levelling bolts

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Table A2 Materials data measured by BRE for each site inspected

Bison

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 9							
Cladding panel, non-loadbearing inner leaf	9/1/1/1	No det	No reinforcement exposed	0	<0.07	—	No reinforcement exposed
Roof beam	9/1/2/1	No det		>12	0.09	—	
Precast ring beam	9/1/3/1	No det		0	Not analysed	—	
Cladding panel, non-loadbearing outer leaf	9/1/4/1	No det		0	0.23	—	
Loadbearing wall panel	9/1/5/1	No det		<5	0.17	—	
Loadbearing wall panel	9/1/6/1	No det		2	0.71	17.0	
Joint	9/1/7/1	No det		40	0.08	—	
Loadbearing wall panel	9/1/8/1	No det		>20	<0.07	—	
Loadbearing wall panel	9/1/9/1	No det		—	0.10	—	
Precast ring beam	9/1/10/1	No det		—	0.71	17.4	
Loadbearing wall panel	9/1/11/1	No det		>7	0.57	19.3	
Loadbearing wall panel	9/1/12/1	No det		>10	0.77	16.4	
Roof beam	9/1/13/1	No det		>10	1.08	12.0	
Cladding panel, non-loadbearing inner leaf	9/1/14/1	No det		>5	<0.07	—	
Loadbearing wall panel	9/1/15/1	No det		—	0.35	23.0	
Cladding panel, non-loadbearing outer leaf	9/1/16/1	No det		>10	<0.07	—	
Beam	9/1/17/1	No det		—	0.14	—	
Site number 10							
Floor plank	10/1/1/1	No det	5	0	0.68	19.0	1
Loadbearing wall panel	10/1/2/1	No det	—	10	0.09	—	—
Floor slab	10/1/3/1	No det	—	2	0.21	—	—
Joint	10/1/4/1	No det	—	0	<0.07	—	—
Floor plank	10/1/5/1	No det	10	0	0.58	18.6	1
Loadbearing wall panel	10/1/6/1	No det	—	3	0.39	22.2	—
Joint	10/1/7/1	No det	—	15	<0.07	—	—
Floor plank	10/1/8/1	No det	5	5	0.48	19.9	1
Loadbearing wall panel	10/1/9/1	No det	—	12	0.28	—	—
Cladding panel, non-loadbearing outer leaf	10/1/10/1	No det	—	0	0.22	—	—
Floor plank	10/1/11/1	No det	20	0	0.43	19.0	1
Loadbearing wall panel	10/1/12/1	No det	—	2	0.75	22.9	—
Loadbearing wall panel	10/1/13/1	No det	—	0	0.76	21.1	—
Cladding panel, non-loadbearing inner leaf	10/1/14/1	No det	—	0	0.09	—	—
Staircase	10/1/15/1	No det	—	0	0.49	17.0	—
Loadbearing wall panel	10/1/16/1	No det	—	6	0.42	17.1	—
Cladding panel, non-loadbearing outer leaf	10/1/17/1	No det	33	2	0.45	21.7	1
Cladding panel, non-loadbearing outer leaf	10/1/18/1	No det	—	2	0.18	—	—
Cladding panel, non-loadbearing outer leaf	10/1/19/1	(c)	5	5	3.11	29.1	3
Cladding panel, non-loadbearing outer leaf	10/1/20/1	(c)	—	13	0.55	15.5	—
Cladding panel, non-loadbearing outer leaf	10/1/21/1	(c)	—	13	0.63	16.1	—
Cladding panel, non-loadbearing outer leaf	10/1/21/2	(c)	—	10	0.72	13.6	—

(continued)

* No det, no deterioration; (c), deterioration as illustrated in Plate 33
** Illustrated in Plate 32

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 10 (continued)							
Cladding panel, non-loadbearing outer leaf	10/1/22/1	No det	—	10	0.47	12.9	—
Cladding panel, non-loadbearing outer leaf	10/1/23/1	No det	2	20	0.65	13.7	1
Loadbearing wall panel	10/1/24/1	No det	—	10	0.85	13.0	—
Loadbearing wall panel	10/1/25/1	No det	—	7	0.81	16.2	—
Cladding panel, non-loadbearing outer leaf	10/1/26/1	(b)	—	3	0.62	15.8	—
Loadbearing wall panel	10/1/27/1	No det	—	0	0.49	16.2	—
Loadbearing wall panel	10/1/28/1	No det	—	11	0.78	15.2	—

* No det, no deterioration; (b), deterioration as illustrated in Plate 33
** Illustrated in Plate 32

Plate 3 Bison: carbonated roof beams supported on hardboard packing

A3.13 Carbonation depths varied from 0 mm to more than 20 mm. The high values are conservative since in many cases the carbonation depth exceeded the depth of sampling. The mean cement content was 18.9%.

iv Other components
A3.14 One sample was taken from a precast ring beam and was found to have a chloride content of 0.71%, indicating that chlorides may have been added to this component. The sample had a cement content of 17.4%.

Site 10 (North-East)
A3.15 This sheltered site was situated near the outskirts of a large town and contained three flat-roofed 6-storey blocks, built in 1967.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A3.16 One block which was due for demolition as part of a proposed redevelopment scheme was inspected. There were no tenants in the block, which had been subject to repeated vandalism and consequently was in a poor condition. A second block was later examined during demolition.

A3.17 No details of the construction of the blocks were available at the time of inspection.

Extent of work

A3.18 Although construction drawings were not available, a portfolio of typical Bison joint details was assembled from leaflets produced at Bison and from known details from other Bison sites of similar construction, to determine if any serious deviations from normal construction practices existed in the blocks.

A3.19 Areas of a floor slab and panel levelling bolt pocket were 'opened up', the reinforcement and panel levelling mechanism exposed and the construction details noted. No other joints were opened up during this examination, since all the major connections were to be exposed during demolition.

A3.20 Twenty-nine concrete samples were taken from components comprising floor slabs, loadbearing wall panels, cladding panels (non-loadbearing inner and outer leaves), in-situ joints and a staircase.

A3.21 During the demolition of the second block, details of joint geometry and the condition and location of reinforcement, tying steel, flank-wall panel ties and in-situ concrete were recorded.

Discussion of physical conditions observed

A3.22 The details appeared to comply with the portfolio of typical Bison joint details.

A3.23 At the locations examined, floor-panel reinforcement and continuity steel were found to be in good condition, and the in-situ concrete was found to be in place and well compacted.

A3.24 Numerous flank-wall panel ties were found to be displaced within the sandwich construction, resulting in a reduced embedment length. At a number of locations this displacement was such that the skins of the two panels were not tied together.

A3.25 Fine diagonal cracking was found in a number of cladding panels. The cracks originated from the lower corner of window openings (Plate 4).

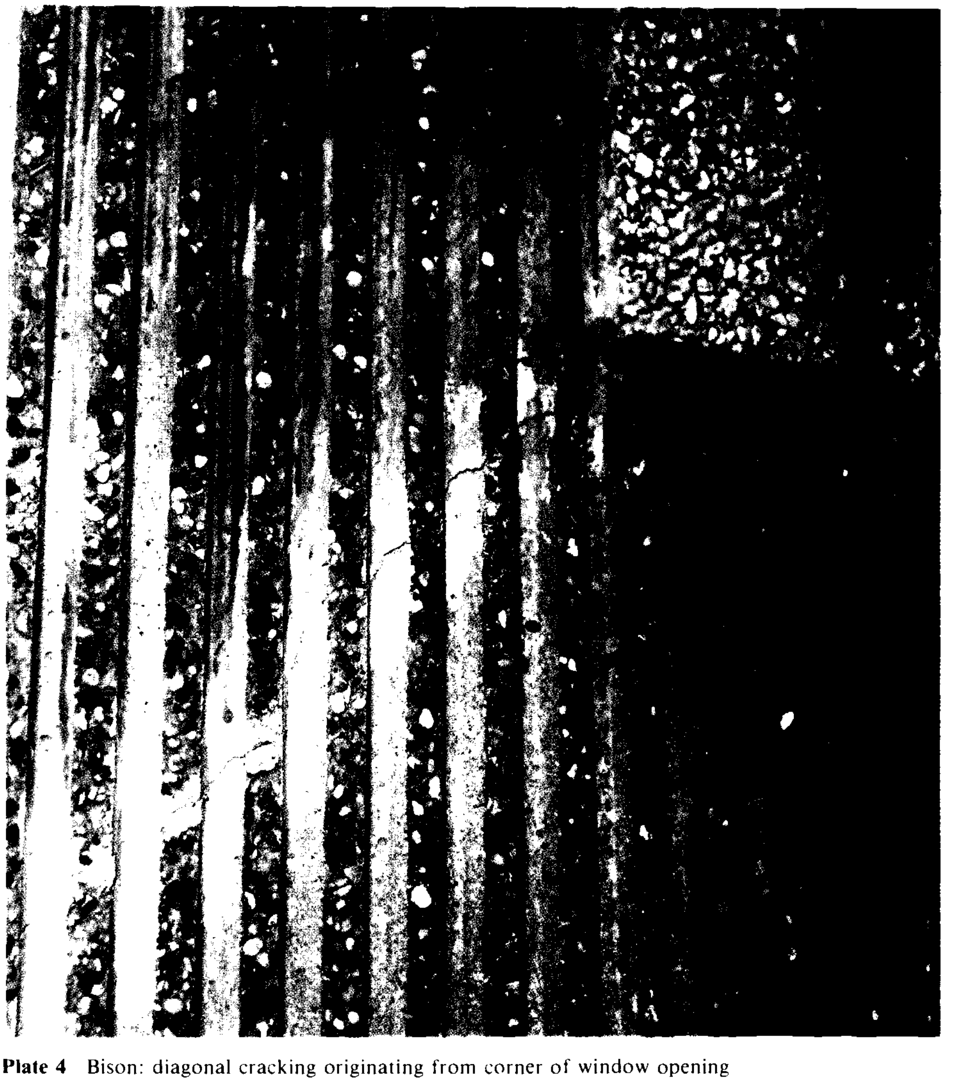


Plate 4 Bison: diagonal cracking originating from corner of window opening

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A3.26 One example of the failure of a previously repaired panel corner was found. Corrosion of underlying reinforcement had caused a crack to form along the interface between the parent panel and the repair (Plate 5).

Summary of analysis of materials

i In-situ concrete
A3.27 Only trace amounts of chlorides were present in the two samples taken, which indicates that no chlorides had been added to the in-situ concrete. The two carbonation depths measured were 0 and 15 mm.

ii Floor slabs
A3.28 Chloride contents in the concrete components examined were between 0.21 and 0.68%, giving a mean of 0.43%. The results lie in the low and medium categories and suggest that chlorides may have been added to the concrete during manufacture of some of the floor components.

A3.29 Carbonation depths ranged from 0 to 5 mm, with a mean of 1.4 mm, which implies a good-quality concrete.

A3.30 Concrete cover to the reinforcement ranged from 5 to 20 mm, with a mean of 10 mm, which is less than the 20 mm intended in the design. The mean cement content was 19.1%.

iii Precast wall/cladding panels
A3.31 Chloride contents ranged from 0.09% to a maximum of 0.85%, giving a mean of 0.49%, which suggests that chlorides may have been added to the concrete during manufacture of some of the components.

A3.32 Carbonation depths varied from 0 to 20 mm, with a mean of 6.6 mm, which implies a slightly better than average concrete quality.

A3.33 Concrete cover to the reinforcement measured in three samples was 2, 5 and 33 mm, and the mean cement content was 17.6%.

iv Other components
A3.34 The one sample taken from a staircase unit had a chloride content of 0.49% and a cement content of 17.1%. No carbonation of the concrete had occurred.

Plate 5 Bison: failure of factory repair to panel

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A4 The Bryant low rise system

A4.1 The investigations into the Bryant low rise system consisted of inspections of two properties in two estates a few miles apart in the North-West of England.

Site 21 (North-West)

A4.2 The two estates were well maintained and situated on level sites. They provided a mixture of dwelling types in 1-, 2- and 3-storey terraced form (Plate 6). Construction of the dwellings was completed in the late 1960s.

A4.3 The dwellings on one of the estates differed from the 'standard' Bryant construction in that the front and rear elevation spandrel panels had been replaced by traditional brick and block cavity construction (Plate 7), although the concrete party, spine and inner flank wall panels had been retained. These properties will be referred to as the 'modified' type.

Extent of work

A4.4 One 2-storey house and one flat in a 2-storey block were inspected. Only a limited examination of the joints between components was carried out, since adjacent properties were occupied. Furthermore, in the absence of detailed joint drawings, the locations examined could not be chosen to achieve optimum information.

A4.5 Two wall/wall joints and one wall/floor joint were examined in the two dwellings.

A4.6 In total 14 samples were taken for analysis, including samples from loadbearing wall panels, floor slabs and non-loadbearing spandrel panels.

Discussion of physical conditions observed

A4.7 At the locations examined, the party wall/spine wall joints in the modified house contained hoop and bar reinforcement, free from corrosion.

A4.8 Diagonal cracking of the brickwork was observed on a number of the modified end-terraced properties, and some of the mono-pitch-roofed bungalows had tiles missing, damaged or displaced.

A4.9 There was no diagonal lateral bracing to the timber roof trusses in the properties examined.

A4.10 A corner pocket in a first-floor slab was opened up to expose the loop reinforcement shown on construction drawings. It was not clear from the drawings if the loops were provided for lifting purposes or whether, when combined with other reinforcement, they provided tying between the wall and floor panels. However, no loop bars were found.

A4.11 The dry pack in the flank and party wall/floor joints was friable and voided. Shrinkage of the dry pack in each of these joints had caused a crack to form along the interface between the panels and the dry pack.

Summary of analysis of materials

(A) Modified Bryant

i Precast wall panels

A4.12 Chloride contents for the wall panels examined were less than 0.19%, with a mean of 0.13%. Carbonation depths were all less than 3 mm, with a mean of 1.2 mm, indicating a high-quality concrete. The two recorded measurements of concrete cover to the reinforcement were 5 and 25 mm, and the mean cement content of the panels was 16.1%.

(B) Bryant

i Floor slabs

A4.13 Chloride contents for the two samples taken from floor slabs were 0.36 and 0.47%. Reinforcement was exposed in one location which had 10 mm of concrete cover. The carbonation depths for the two

Plate 6 Bryant low rise: 2-storey terraced construction

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Table A3 Materials data measured by BRE for each site inspected

Bryant low rise

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 21							
Joint	21/1/1/1	No det	5*	2	0.1	14.7	1
Joint	21/1/1/2	No det	25§	1	<0.07	—	1
Loadbearing wall panel	21/1/2/1	No det	—	1	0.19	18.0	—
Joint	21/1/3/1	No det	—	1	0.19	—	—
Non-loadbearing wall panel	21/1/4/1	No det	—	1	0.15	15.7	—
Non-loadbearing wall panel	21/1/5/1	No det	—	—	0.1	—	—
Loadbearing wall panel	21/2/1/1	No det	—	5	0.49	13.7	—
Dry pack	21/2/2/1	Cracked, friable and voided	—	—	<0.07	—	—
Floor slab	21/2/3/1	No det	—	5	0.47	14.7	—
Spandrel panel, non-loadbearing	21/2/4/1	No det	—	0	0.48	16.7	—
Floor slab	21/2/5/1	No det	10	1	0.36	19.6	1
Loadbearing wall panel	21/2/6/1	No det	—	1	0.32	—	—
Spandrel panel, non-loadbearing	21/2/7/1	No det	—	0	0.44	27.1	—
Spandrel panel, non-loadbearing	21/2/8/1	No det	—	2	0.51	16.4	—

* No det, no deterioration
** Illustrated in Plate 32
* To loop reinforcement
§ To site bar

Plate 7 Bryant low rise: 'modified' version

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

samples were 5 and 1 mm, which indicate a good concrete quality.

A4.14 The mean cement content for the slabs was 17.2%.

ii Precast wall/cladding panels
A4.15 Chloride contents ranged from 0.32 to 0.51%, with a mean of 0.49%. Carbonation varied from zero to 5 mm, with a mean of 1.6 mm, which indicates a good concrete quality.

A4.16 Concrete cover to the reinforcement was not measured since the disturbance due to breaking out of the wall units was required to be kept to a minimum.

A4.17 The mean cement content was 18.5%.

iii Dry pack
A4.18 A sample of dry pack removed for analysis contained only traces of chloride.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A5 The Camus system

A5.1 The investigation into the Camus system consisted of inspections of two properties at one site in the South-East of England (Plate 8).

Site 19 (South-East)

A5.2 This urban site built on level ground consisted of four 20-storey tower blocks. The blocks were completed in 1970 and later strengthened to resist an equivalent static pressure of 2.5 psi. Steel angle cleats had been bolted to the wall/ceiling joints in rooms adjacent to flank walls. The dwellings were heated by a radiator system fed by a communal external gas-fired boiler.

A5.3 The internal and external decoration of these blocks was in good order.

Extent of work

A5.4 BRE inspected two flats, each one in a different block. An examination of six wall/wall and two wall/floor joints was undertaken, and the reinforcement and construction details determined.

A5.5 Twenty-seven concrete samples were taken for analysis from loadbearing wall panels, cladding panels (loadbearing and non-loadbearing leaves), floor and balcony slabs, and in-situ joints.

Discussion of physical conditions observed

A5.6 At the locations examined, hoop and bar reinforcement connections were exposed and were found to be in good condition. The construction details agreed with those found during local authority

Plate 8 Camus: 20-storey construction

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Table A4 Materials data measured by BRE for each site inspected

Camus

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 19							
Joint	19/1/1/1	Well compacted	80	0	0.07	12.3	1
Floor slab	19/1/2/1	No det	16	1	<0.07	—	1
Loadbearing cladding panel	19/1/3/1	No det	30	7	<0.07	—	1
Joint	19/1/4/1	Well compacted	—	6	<0.07	—	1
Cladding panel, non-loadbearing inner leaf	19/1/5/1	No det	—	15	<0.07	15.0	—
Loadbearing wall panel	19/1/6/1	No det	—	8	<0.07	—	—
Loadbearing wall panel	19/1/7/1	No det	40	4	<0.07	—	1
Loadbearing wall panel	19/1/8/1	No det	—	1	<0.07	—	—
Loadbearing wall panel	19/1/9/1	No det	—	2	<0.07	13.5	—
Loadbearing wall panel	19/1/10/1	No det	—	5	<0.07	—	—
Loadbearing wall panel	19/1/11/1	No det	—	5	<0.07	—	—
Balcony slab	19/1/12/1	No det	—	1	0.17	24.8	—
Loadbearing wall panel	19/1/13/1	No det	—	4	0.19	18.4	—
Floor slab	19/1/14/1	No det	—	5	<0.07	—	—
Balcony slab	19/2/1/1	No det	—	3	0.08	17.1	—
Loadbearing wall panel	19/2/2/1	No det	—	8	<0.07	—	—
Loadbearing wall panel	19/2/3/1	No det	—	5	0.38	14.5	—
Loadbearing wall panel	19/2/4/1	No det	—	5	<0.07	—	—
Loadbearing wall panel	19/2/4/2	No det	25	3	<0.07	—	1
Cladding panel, non-loadbearing inner leaf	9/2/5/1	No det	30	8	<0.07	16.2	1
Joint	19/2/6/1	Well compacted	50	0	<0.07	—	1
Joint	19/2/7/1	Well compacted	—	1	<0.07	—	—
Floor slab	19/2/8/1	No det	—	2	<0.07	15.7	—
Loadbearing wall panel	19/2/9/1	No det	—	6	<0.07	—	—
Loadbearing wall panel	19/2/9/2	No det	—	4	<0.07	—	—
Joint	19/2/10/1	Well compacted	80	—	<0.07	10.9	1
Loadbearing wall panel	19/2/11/1	No det	—	4	<0.07	—	—

* No det, no deterioration
** Illustrated in Plate 32

investigations of Camus dwellings elsewhere. The details were largely as indicated on drawings obtained from other sites.

A5.7 The in-situ concrete examined in these two dwellings was found to be in position, well compacted and free from cracking.

A5.8 Cracking of the joints between panels was observed in the corridors. This cracking was associated with shrinkage of the in-situ concrete in the joint and thermal movement of the structure.

Summary of analysis of materials

i Floor/balcony slabs
A5.9 Chloride contents ranged from trace values to 0.17%, with a mean of 0.09%, which is in the low category. These results indicate that chlorides had not been added during manufacture of the floor/balcony slabs in the dwellings examined.

A5.10 Carbonation depths varied from 1 to 5 mm, with a mean of 2.4 mm, which indicates a high quality precast concrete. The mean cement content was 19.2% which is also above average.

A5.11 Concrete cover to the reinforcement in one location was 16 mm.

ii Precast cladding/wall panels
A5.12 Chloride contents varied from trace values to 0.38%, with a mean of 0.09%. This is in the low category and suggests that chlorides had not been added during manufacture of these components in the dwellings examined.

A5.13 Carbonation depths varied from 1 to 15 mm, with a mean of 5.5 mm, which suggests a good concrete quality.

A5.14 Concrete cover to the reinforcement ranged from 25 to 40 mm, with a mean of 31.3 mm, and the

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

mean cement content was 15.5%.

iii In-situ joints

A5.15 Chloride contents for the in-situ concrete were all less than 0.08%, which is in the low category. The results indicate that chlorides had not been added to the joints inspected.

A5.16 Carbonation depths ranged from zero to 6 mm, with a mean of 1.8 mm, which implies a good-quality concrete despite the low cement contents, which were found to be 12.3 and 10.9% in the two samples tested.

A5.17 Concrete cover to the reinforcement ranged from 50 to 80 mm.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A6 The HSSB system

A6.1 The investigations into the HSSB (High Speed System Build) system consisted of inspections of four properties at two sites in the South-East of England.

Site 11 (South-East)

A6.2 This large estate of ninety-eight 1-, 2-, 3- and 4-storey blocks (Plate 9) was situated on a gently undulating south-east-facing site. The flat-roofed blocks were built between 1964 and 1967. The external walls were cavity construction with an external leaf of brickwork and an inner leaf of lightweight concrete, cast in half-storey-height panels. The internal loadbearing walls were storey-height concrete panels.

A6.3 The external decoration of the dwellings was generally in good order. A few of the buildings were affected by differential movement.

Extent of work

A6.4 Two 2-storey terraced houses and one flat in a 3-storey block were inspected.

A6.5 There were no restrictions on 'opening up' of joints or components in the two houses as they were vacant. Only a limited examination of the flat was carried out, since the work is disruptive and adjacent flats were occupied.

A6.6 An examination of one floor slab/precast ring beam joint, two floor/floor joints and eight wall/wall joints was undertaken.

A6.7 Twenty-eight concrete samples were taken for analysis from loadbearing wall panels, cladding panels (non-loadbearing inner leaves) and floor and roof slabs.

Discussion of physical conditions observed

A6.8 Differential movement reported to be due to clay heave had caused extensive cracking between the precast concrete units of some terraced dwellings. The coarse cracking resulting from foundation movement was compounded by the lack of tying between the precast units. These dwellings were to be refurbished and strengthened.

A6.9 The joints examined in the two houses were poorly constructed and the 'as built' details often differed from the construction drawings. Vertical lacing reinforcement was omitted from five out of the eight wall/wall joints inspected. In addition, the loop reinforcement placed in the bed joints between panels was sometimes bent down flush with the panel (Plate 10), or one or more of the loops were omitted.

A6.10 An area of floor screed adjacent to the window in the flat was removed, and no evidence was found of any mechanical ties between the floor slab and ring beam. The floor slab/ring beam ties exposed in the houses were not installed 'as designed' nor in the specified numbers. The end of the tie bars should have located in a continuous rebate in the floor slab, but were actually located in a hole punched through the top flange of the hollow slab.

Plate 9 HSSB: 3-storey construction

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Table A5 Materials data measured by BRE for each site inspected

HSSB

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 11							
Loadbearing wall panel	11/1/1/1	(c)	50	FC*	0.08	—	3
Loadbearing wall panel	11/1/1/2	No det	50	FC	0.1	—	3
Loadbearing wall panel	11/1/1/3	No det	80	FC	<0.07	—	3
Floor slab	11/1/2/1	No det	—	30	0.75	10.6	—
Floor slab	11/1/2/2	No det	30	40	0.94	10.1	1
Floor slab	11/1/3/1	No det	30	FC	0.91	12.4	1
Floor slab	11/1/4/1	No det	35	FC	1.9	12.5	1
Loadbearing wall panel	11/1/5/1	No det	100	20	0.21	—	1
Loadbearing wall panel	11/1/6/1	No det	80	3	0.18	14.8	2
Cladding panel, non-loadbearing inner leaf	11/1/7/1	No det	—	3	0.21	—	1
Floor slab	11/1/8/1	No det	—	3	0.74	19.7	1
Loadbearing wall panel	11/2/1/1	No det	—	40	<0.07	—	—
Floor slab	11/2/2/1	No det	—	40	0.97	9.5	—
Loadbearing wall panel	11/2/3/1	No det	—	0	<0.07	—	—
Loadbearing wall panel	11/2/4/1	No det	10	5	<0.07	—	1
Loadbearing wall panel	11/2/5/1	No det	35	5	<0.07	—	1
Loadbearing wall panel	11/2/5/2	No det	0	—	1.12	10.0	2
Floor slab	11/2/6/1	No det	—	0	1.63	12.6	—
Floor slab	11/2/7/1	No det	—	3	1.25	11.2	—
Cladding panel, non-loadbearing inner leaf	11/3/1/1	No det	35	FC	<0.07	—	2
Cladding panel, non-loadbearing inner leaf	11/3/1/2	No det	—	FC	0.08	—	—
Roof slab	11/3/2/1	No det	25	15	<0.07	—	1
Loadbearing wall panel	11/3/3/1	No det	70	—	<0.07	—	2
Roof slab	11/3/4/1	No det	20	15	0.5	8.6	1
Loadbearing wall panel	11/3/5/1	No det	—	FC	<0.07	—	—
Roof slab	11/3/6/1	No det	20	40	1.01	10.9	1
Roof slab	11/3/6/2	No det	20	40	0.96	14.1	1
Roof slab	11/3/7/1	No det	25	10	0.22	—	1
Site number 23							
Cladding panel, non-loadbearing inner leaf§	23/1/1/1	No det	40	—	1.14	—	1
Non-loadbearing wall panel§	23/1/2/1	No det	—	—	0.86	—	—
Lintel (ring beam)	23/1/3/1	No det	—	13	0.18	—	—
Floor slab	23/1/4/1	No det	7	2	0.49	13.8	1
Floor slab	23/1/5/1	No det	2	7	0.58	14.7	1
Loadbearing wall panel§	23/1/6/1	No det	—	—	0.82	—	—
Joint	23/1/7/1	Poorly compacted and honeycombed	60	—	0.08	—	2
Loadbearing wall panel	23/1/8/1	No det	—	1	<0.07	—	—
Loadbearing wall panel	23/1/9/1	No det	—	15	0.65	14.2	—
Cladding panel, loadbearing inner leaf§	23/1/10/1	No det	80	—	0.61	—	1
Non-loadbearing wall panel	23/1/11/1	No det	—	‖	<0.07	—	—
Non-loadbearing wall panel	23/1/12/1	(b)	30	17	0.58	18.3	2
Floor slab	23/1/13/1	No det	25	5	0.58	15.4	1
Floor slab	23/1/14/1	No det	10	0	0.70	17.7	1
Floor slab	23/1/15/1	No det	15	0	0.48	16.2	1
Staircase	23/1/16/1	No det	—	‖	0.88	10.9	—

* No det, no deterioration; (b) and (c), deterioration as illustrated in Plate 33
** Illustrated in Plate 32
* FC, fully carbonated
§ Blastfurnace concrete
‖ Patchy, no defined carbonation front

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Plate 10 HSSB: loop bar bent down flush with panel

A6.11 The level of compaction of the in-situ and precast concrete was variable and reinforcement corrosion ranged from condition 1 to condition 3 (see Plate 32).

A6.12 There were numerous instances of spalling associated with reinforcement corrosion in the precast ring beams, corner panels (Plate 11) and external stair areas.

A6.13 Movement of the parapet was also evident on a number of the 3-storey blocks (Plate 12).

Summary of analysis of materials

i Floor/roof slabs

A6.14 Chloride contents in the concrete components examined were up to 1.9%, with a mean of 0.91%, and indicate that chlorides had been added to the floor and roof units during manufacture.

A6.15 The depth of carbonation varied from 3 mm to over 40 mm, with a mean of 21.3 mm, which suggests that the concrete quality in these units was rather poor. The cement content varied ranging from 8.6 to 19.7% with a mean of 12.0%. The high carbonation depths were probably due in part to the low mean cement content of 12.0%.

A6.16 Concrete cover to the reinforcement ranged from 20 to 30 mm, which is consistent with the design intentions.

ii Precast wall/cladding panels

A6.17 Chloride contents were generally between 0.07 and 0.21%, with just one sample at 1.12%. The mean chloride content was 0.17%.

A6.18 Carbonation depths ranged from 0 to 75 mm (fully carbonated). The highest carbonation depths may be attributed to the very porous nature of the

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

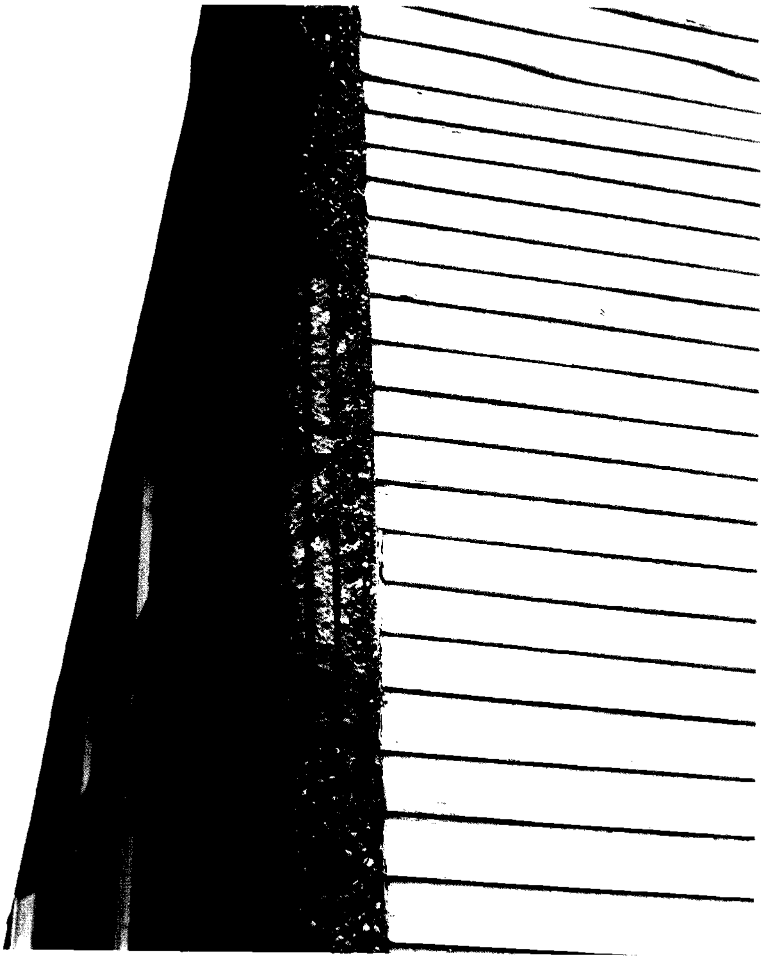


Plate 11 HSSB: spalling associated with reinforcement corrosion

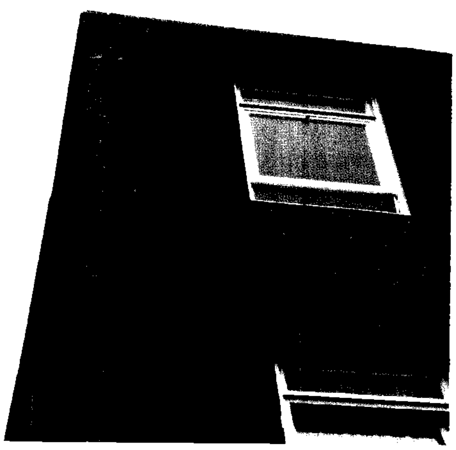


Plate 12 HSSB: movement of parapet components

foamed slag aggregate used in some of the panels. However, some of the gravel-aggregate concrete panels were also found to be fully carbonated.

A6.19 Concrete cover to the reinforcement ranged from zero, in one case, to 100 mm. The mean depth of cover was 51.0 mm which is consistent with the nominal design intentions.

A6.20 The mean cement content was 12.4% which is a little low.

Site 23 (South-East)
A6.21 This small estate of six 4-storey blocks is situated on a sheltered level site — the blocks are flat-roofed and were built in 1967. The blocks were of standard HSSB construction with internal staircases.

A6.22 The external decoration of the buildings was in good order. A number of the external walls were saturated below the cistern overflow pipes.

Extent of work
A6.23 One vacant first-floor flat was inspected, but only a limited examination was carried out since the work is disruptive and adjacent flats were occupied. Three wall/wall joints were examined.

A6.24 In total 16 concrete samples were taken for analysis, including samples from loadbearing and non-loadbearing wall panels, cladding panels (loadbearing and non-loadbearing inner leaves), floor slabs and staircases.

Discussion of physical conditions observed
A6.25 Of the three joints examined only the cross wall/cladding panel joint contained tying reinforcement. The loop reinforcement from the cross-wall panel and the cladding panel bed joints had been badly positioned in a number of instances. In addition one of the lacing bars had been either displaced vertically downwards in the joint or cut too short. The top portion of the second lacing bar was not exposed. The combination of these two defects prevented the lacing bars from mating correctly with five out of the seven loops exposed.

A6.26 Cracking between the components framing the balcony was observed. Poor tying between these components may have allowed movement which led to this cracking. This pattern of cracking was evident on balconies elsewhere on the estate.

A6.27 Drawings from another HSSB structure showed the party wall/cladding panel joint to contain a single vertical lacing bar; however a partial examination of this joint in a kitchen area produced no evidence of vertical reinforcement.

A6.28 The in-situ concrete in the joint was poorly compacted and voided and the panel and tying reinforcement exhibited surface corrosion.

Summary of analysis of materials

i Floor slabs
A6.29 Chloride contents in the floor units were all in the medium category and varied from 0.48 to 0.88%, with a mean of 0.57%. The results suggest that chlorides are likely to have been added to the concrete during manufacture of the units examined.

A6.30 Carbonation depths for the five samples varied from zero to 7 mm giving a mean of 2.8 mm, which implies a better than average concrete quality. The mean cement content was 15.6%.

A6.31 Concrete cover to the mesh reinforcement varied from 2 to 25 mm, with a mean of 12 mm which is lower than that found on other structures.

ii Precast wall/cladding panels
A6.32 Chloride contents varied from trace values to a maximum of 1.14%, which indicates that chlorides had been added to the concrete during manufacture of some of the units examined. The mean cement and chloride contents were 16.3 and 0.6%, respectively.

A6.33 The depths of carbonation measured on three normal-weight concrete samples was 1, 15 and 17 mm, which implies a better than average concrete quality for the first sample, and a lower than average quality for the other two samples.

iii Other components
A6.34 Single samples were taken from a lintel, an in-situ joint and a staircase.

A6.35 The lintel was carbonated to a depth of 13 mm and had a chloride content of 0.18%, which indicates that no chlorides had been added to this component. There were only trace levels of chlorides in the in-situ concrete, and there was 60 mm of concrete cover to the tying steel. The staircase had a chloride content of 0.88%, which strongly suggests that chlorides had been added to the concrete during manufacture of this component. The sample had a low cement content of 10.9%.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A7 The Jespersen system

A7.1 The investigation into the Jespersen system consisted of inspections of eight properties at three sites, one site in the South-East and two in the North-West of England.

Site 16 (North-West)
A7.2 The site was situated on a north-east-facing slope in an urban area. The eight flat-roofed blocks of 3 to 6 storeys were 18 years old (Plate 13).

A7.3 The 6-storey block examined was being demolished as a result of redevelopment. A general visual inspection was made of the remaining blocks.

A7.4 The estate was largely vacated by the tenants and vandalism was evident throughout.

A7.5 Piped gas was not supplied to the dwellings and no information on the structural standard of the blocks was available.

Extent of work
A7.6 BRE examined two flats in a 6-storey block in detail. There were no restrictions on the amount or extent of 'opening up' of joints or components, since the block was to be demolished. Two wall/wall, four floor/floor and three wall/floor joints were cut away, the reinforcement exposed and the construction details recorded. In total 34 concrete samples were taken for analysis, including samples from wall panels, cladding panels (loadbearing), non-loadbearing spandrel panels, floor slabs, in-situ joints, walkway parapet panels and columns.

Discussion of physical conditions observed
A7.7 At the joint positions examined, hoop and bar reinforcement connections were located. The reinforcement details appeared to comply with the design intentions as indicated by the few details available from a Jespersen design guide. The joint reinforcement was in good condition except where, in the presence of carbonated concrete, water had caused corrosion following penetration through the joints of flank-wall cladding panels. Corrosion had also occurred in floor-slab joints adjacent and perpendicular to flank walls.

A7.8 The dry pack examined was in position and well compacted and no cracking was observed. Four of the in-situ concrete joints between floor slabs were examined and were found to be poorly compacted, containing numerous voids. Elsewhere, the in-situ concrete was in place and well compacted.

A7.9 In some columns there was spalling associated with reinforcement corrosion due to carbonation and low concrete cover to the reinforcement (Plate 14).

A7.10 A number of cracked panels were found during an external examination of blocks on the estate, and

Plate 13 Jespersen: 18-year-old flats

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Table A6 Materials data measured by BRE for each site inspected

Jespersen

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 16							
Walkway support columns	16/1/1/1	No det	25	4	0.21	—	—
Walkway support columns	16/1/1/2	No det	10	8	0.12	—	2
Walkway parapet panel	16/1/2/1	No det	14	0	0.39	13.5	1
Cladding panel, loadbearing inner leaf	16/1/3/1	No det	25	10	<0.07	—	1
Cladding panel, loadbearing inner leaf	16/1/3/2	No det	1	1	0.46	10.5	1
Spandrel panel, non-loadbearing	16/1/4/1	No det	20	10	<0.07	—	1
Spandrel panel, non-loadbearing	16/1/5/1	No det	—	1	0.59	12.5	—
Loadbearing wall panel	16/1/6/1	No det	—	5	<0.07	—	—
Floor slab	16/1/7/1	No det	0	5	<0.07	—	2
Loadbearing wall panel	16/1/8/1	No det	40	5	0.12	—	1
Loadbearing wall panel	16/1/9/1	No det	40	7	<0.07	—	1
Floor slab	16/1/10/1	No det	20	20	0.08	8.9	1
Floor slab	16/1/11/1	No det	20	17	<0.07	—	1
Floor slab	16/1/12/1	No det	20	25	<0.07	—	1
Floor slab	16/1/13/1	No det	20	20	<0.07	—	1
Loadbearing wall panel	16/1/14/1	No det	—	5	<0.07	14.0	—
Floor slab	16/1/15/1	No det	15	20	<0.07	—	1
Floor slab	16/1/16/1	No det	10	20	<0.07	—	1
Joint	16/2/1/1	Well compacted	80	2	0.21	11.1	1
Joint	16/2/2/1	Well compacted	—	—	0.38	—	—
Floor slab	16/2/3/1	No det	25	20	0.14	—	1
Spandrel panel, non-loadbearing	16/2/4/1	No det	—	12	0.07	—	—
Cladding panel, loadbearing inner leaf	16/2/5/1	No det	12	15	0.11	10.3	1
Cladding panel, loadbearing inner leaf	16/2/5/2	No det	—	5	0.07	—	1
Spandrel panel, non-loadbearing	16/2/6/1	No det	—	16	0.2	—	—
Joint	16/2/7/1	Well compacted	70	—	0.14	—	1
Loadbearing wall panel	16/2/8/1	No det	—	10	0.24	8.9	—
Floor slab	16/2/9/1	No det	15	10	0.14	—	1
Floor slab	16/2/10/1	No det	30	—	0.11	—	1
Floor slab	16/2/11/1	No det	—	8	0.07	—	—
Loadbearing wall panel	16/2/12/1	No det	65	15	0.14	—	1
Non-loadbearing wall panel	16/2/13/1	No det	45	10	0.07	—	1
Loadbearing wall panel	16/2/14/1	No det	—	10	<0.07	10.7	—
Loadbearing wall panel	16/2/15/1	No det	1	15	—	—	1
Site number 20							
Spandrel panel, non-loadbearing	20/1/1/1	Fine cracking	—	5	0.08	24.9	—
Spandrel panel, non-loadbearing	20/1/1/2	Fine cracking	—	5	0.14	—	—
Spandrel panel, non-loadbearing	20/1/2/1	Fine cracking	—	15	0.09	—	—
Spandrel panel, non-loadbearing	20/1/2/2	Fine cracking	50	10	<0.07	25.5	1
Floor slab	20/1/3/1	No det	—	2	<0.07	—	—
Floor slab	20/1/4/1	No det	—	2	<0.07	—	—
Spandrel panel, non-loadbearing	20/1/5/1	Fine cracking	—	—	0.11	—	—
Cladding panel, loadbearing inner leaf	20/1/6/1	No det	—	2	0.14	—	—
Floor slab	20/1/7/1	No det	—	—	0.21	—	—
Dry pack	20/1/8/1	Very soft	—	—	<0.07	—	—

(continued)

* No det, no deterioration
** Illustrated in Plate 32

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 20 (continued)							
Floor slab	20/1/9/1	No det	10*	—	<0.07	—	1
Loadbearing wall panel	20/1/10/1	No det	—	5	<0.07	13.3	—
Joint	20/1/11/1	Well compacted	—	—	0.14	—	—
Non-loadbearing wall panel	20/1/12/1	No det	—	3	0.07	12.6	—
Spandrel panel, non-loadbearing	20/2/1/1	Fine cracking	—	—	0.09	—	—
Non-loadbearing wall panel	20/2/2/1	No det	—	2	0.09	—	—
Non-loadbearing wall panel	20/2/3/1	No det	—	2	<0.07	14.3	—
Non-loadbearing wall panel	20/2/4/1	No det	—	2	0.07	—	—
Spandrel panel, non-loadbearing	20/2/5/1	Fine cracking	—	—	0.09	—	—
Spandrel panel, non-loadbearing	20/2/6/1	Fine cracking	—	0	<0.07	27.3	—
Loadbearing wall panel	20/2/7/1	No det	—	0	0.14	—	—
Floor slab	20/2/8/1	No det	—	—	0.11	—	—
Loadbearing wall panel	20/2/9/1	No det	—	3	0.12	—	—
Loadbearing wall panel	20/2/10/1	No det	—	0	0.09	12.4	—
Joint	20/2/11/1	Well compacted	40	0	0.09	—	1
Non-loadbearing wall panel	20/2/12/1	No det	30	1	0.12	—	1
Loadbearing wall panel	20/2/13/1	No det	—	0	<0.07	—	—
Floor slab	20/2/14/1	No det	—	—	0.09	13.0	—
Floor slab	20/2/15/1	No det	—	—	0.11	—	—
Floor slab	20/2/16/1	No det	—	—	0.09	—	—
Loadbearing wall panel	20/2/17/1	No det	—	0	0.09	11.8	—
Site number 22							
Spandrel panel, non-loadbearing	22/1/1/1	No det	—	21	0.26	—	—
Spandrel panel, non-loadbearing	22/1/1/2	No det	—	20	0.17	—	—
Cladding panel, loadbearing inner leaf	22/1/2/1	No det	20	10	0.61	12.2	1
Loadbearing wall panel	22/1/3/1	No det	—	15	0.11	—	—
Floor slab	22/1/4/1	No det	—	§	0.15	—	—
Floor slab	22/1/5/1	No det	—	12	0.45	8.7	—
Spandrel panel, non-loadbearing	22/1/6/1	No det	—	15	0.23	—	—
Cladding panel, loadbearing inner leaf	22/1/7/1	No det	25	15	0.28	—	1
Floor slab	22/1/8/1	No det	—	§	0.30	14.7	—
Cladding panel, loadbearing inner leaf	22/1/9/1	No det	—	20	0.93	12.6	—
Cladding panel, loadbearing inner leaf	22/1/10/1	No det	—	13	0.20	—	—
Cladding panel, loadbearing inner leaf	22/1/11/1	No det	—	13	0.38	13.9	—
Floor slab	22/1/12/1	No det	—	20	<0.07	—	—
Floor slab	22/1/13/1	No det	—	20	<0.07	—	—
Loadbearing wall panel	22/1/14/1	No det	—	10	<0.07	—	—
Loadbearing wall panel	22/1/15/1	No det	—	10	<0.07	—	—
Loadbearing wall panel	22/1/16/1	No det	—	10	<0.07	—	—
Loadbearing wall panel	22/1/17/1	No det	—	11	0.09	11.7	—
Non-loadbearing wall panel	22/2/1/1	No det	No reinforcement exposed	13‖	<0.07	—	No reinforcement exposed
Spandrel panel, non-loadbearing	22/2/2/1	No det	No reinforcement exposed	23‖	0.59	12.5	No reinforcement exposed
Spandrel panel, non-loadbearing	22/2/2/2	No det	No reinforcement exposed	6	0.24	—	No reinforcement exposed
Cladding panel, loadbearing inner leaf	22/2/3/1	No det	No reinforcement exposed	7	0.17	14.8	No reinforcement exposed

(continued)

* No det, no deterioration
** Illustrated in Plate 32
* To loop in floor slab
§ Dust contamination
‖ Patchy carbonation

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 22 (continued)							
Cladding panel, loadbearing inner leaf	22/2/4/1	No det	No reinforcement exposed	7	0.11	—	No reinforcement exposed
Loadbearing wall panel	22/2/5/1	No det	No reinforcement exposed	17	<0.07	—	No reinforcement exposed
Cladding panel, loadbearing inner leaf	22/2/6/1	No det	No reinforcement exposed	10	<0.07	12.6	No reinforcement exposed
Loadbearing wall panel	22/3/1/1	No det	No reinforcement exposed	17	<0.07	—	No reinforcement exposed
Loadbearing wall panel	22/3/2/1	No det	No reinforcement exposed	17	<0.07	—	No reinforcement exposed
Spandrel panel, non-loadbearing	22/3/3/1	(b)	No reinforcement exposed	13	0.33	13.1	No reinforcement exposed
Floor slab	22/3/4/1	No det	No reinforcement exposed	§	0.48	16.2	No reinforcement exposed
Loadbearing wall panel	22/3/5/1	No det	No reinforcement exposed	15	<0.07	—	No reinforcement exposed
Floor slab	22/3/6/1	No det	No reinforcement exposed	§	<0.07	—	No reinforcement exposed
Floor slab	22/3/7/1	No det	No reinforcement exposed	§	0.25	15.7	No reinforcement exposed
Loadbearing wall panel	22/3/8/1	No det	No reinforcement exposed	18	0.17	—	No reinforcement exposed
Loadbearing wall panel	22/3/9/1	No det	No reinforcement exposed	10	<0.07	—	No reinforcement exposed
Loadbearing wall panel	22/3/10/1	No det	No reinforcement exposed	13	<0.07	—	No reinforcement exposed
Floor slab	22/3/11/1	No det	No reinforcement exposed	15	0.09	—	No reinforcement exposed
Floor slab	22/3/12/1	No det	No reinforcement exposed	18	0.17	14.3	No reinforcement exposed
Spandrel panel, non-loadbearing	22/4/1/1	No det	—	10	0.19	—	—
Spandrel panel, non-loadbearing	22/4/1/2	No det	—	10	0.26	14.0	—
Loadbearing wall panel	22/4/2/1	No det	—	15	0.10	—	—
Loadbearing wall panel	22/4/3/1	No det	—	17	0.09	8.2	—
Loadbearing wall panel	22/4/3/2	No det	—	22	0.14	8.6	—
Loadbearing wall panel	22/4/4/1	No det	—	11	<0.07	—	—
Floor slab	22/4/5/1	No det	—	25	0.10	—	—
Floor slab	22/4/6/1	No det	—	15	<0.07	9.0	—
Loadbearing wall panel	22/4/7/1	No det	—	14	<0.07	—	—
Loadbearing wall panel	22/4/8/1	No det	—	17	0.13	8.3	—
Non-loadbearing wall panel	22/4/9/1	No det	27	20	0.19	9.7	1
Floor slab	22/4/10/1	No det	—	28	0.12	—	—
Spandrel panel, non-loadbearing	22/4/11/1	No det	—	11	0.07	—	—
Floor slab	22/4/12/1	No det	—	9	0.07	—	—
Loadbearing wall panel	22/4/13/1	No det	—	21	<0.07	8.2	—
Loadbearing wall panel	22/4/14/1	No det	—	9	<0.07	—	—
Loadbearing wall panel	22/4/15/1	No det	—	16	0.08	9.1	—

* No det, no deterioration; (b), deterioration as illustrated in Plate 33
** Illustrated in Plate 32
§ Dust contamination

extensive mould growth (Plate 15) was found on walls in some of the dwellings.

Summary of analysis of materials

i Floor slabs
A7.11 Chloride contents ranged from trace values to 0.14%, with a mean of 0.08%, which is in the low category, indicating that chlorides had not been added during manufacture of the floor units in the dwellings examined.

A7.12 Carbonation depths varied from 5 to 20 mm, with a mean of 16.1 mm, which indicates a lower than average precast concrete quality.

A7.13 Concrete cover to the reinforcement varied between 0 and 30 mm, with a mean of 16.25 mm, which is consistent with the design intentions.

ii Precast cladding/wall/walkway panels
A7.14 Chloride contents varied from trace values to 0.59%, with a mean of 0.14%. The chloride contents were generally low, which suggests that chlorides had not been added during manufacture of the wall panels in the dwellings examined. However, two results were in the medium category which indicates that isolated chloride contamination had occurred.

A7.15 Carbonation depths were in the range of 0 to 15 mm, with a mean of 8.1 mm, which is low considering the mean cement content of only 11.5% for these components.

A7.16 Although the measured concrete cover to the reinforcement varied from 1 to 65 mm, a mean of

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

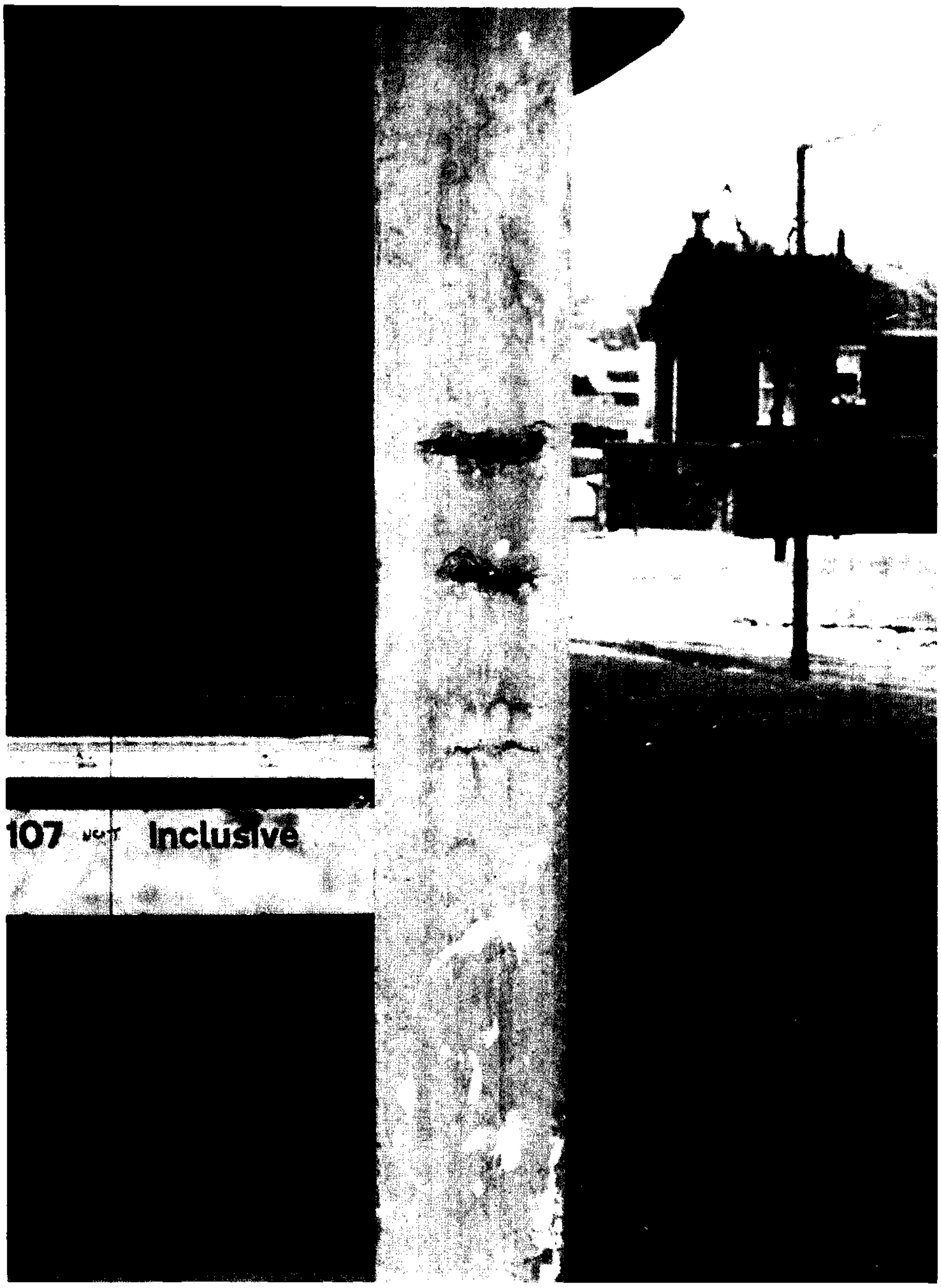


Plate 14 Jespersen: corrosion due to carbonation and low concrete cover to the reinforcement in columns

26.3 mm was generally attained which is consistent with the nominal intentions of the design.

iii In-situ joints
A7.17 Chloride contents ranged from 0.14 to 0.38%, with a mean of 0.24%, which is low, indicating that chlorides had not been added to the concrete used to make the joints inspected.

A7.18 Carbonation depth was measured in only one location and was found to be 2 mm, which is low considering the cement content of 11.1%.

A7.19 Reinforcement exposed in two locations had 70 and 80 mm of concrete cover, which was consistent with the design intentions.

iv Columns
A7.20 Chloride contents for the two samples were 0.12 and 0.21%, which are both low and indicate that chlorides had not been added to these components during manufacture.

A7.21 Carbonation depths were 4 and 8 mm, which suggests a better than average concrete quality.

A7.22 Concrete cover to the reinforcement for the two samples was 10 and 25 mm. No information was available on the design requirements for concrete cover for these components.

Site 20 (South-East)
A7.23 This site was situated in an urban area and consisted of 15 blocks ranging in height from 4 to 14 storeys. Construction of the blocks was completed in 1971.

A7.24 External decoration of the buildings at this site was generally in good condition, although there were localised examples of vandalism.

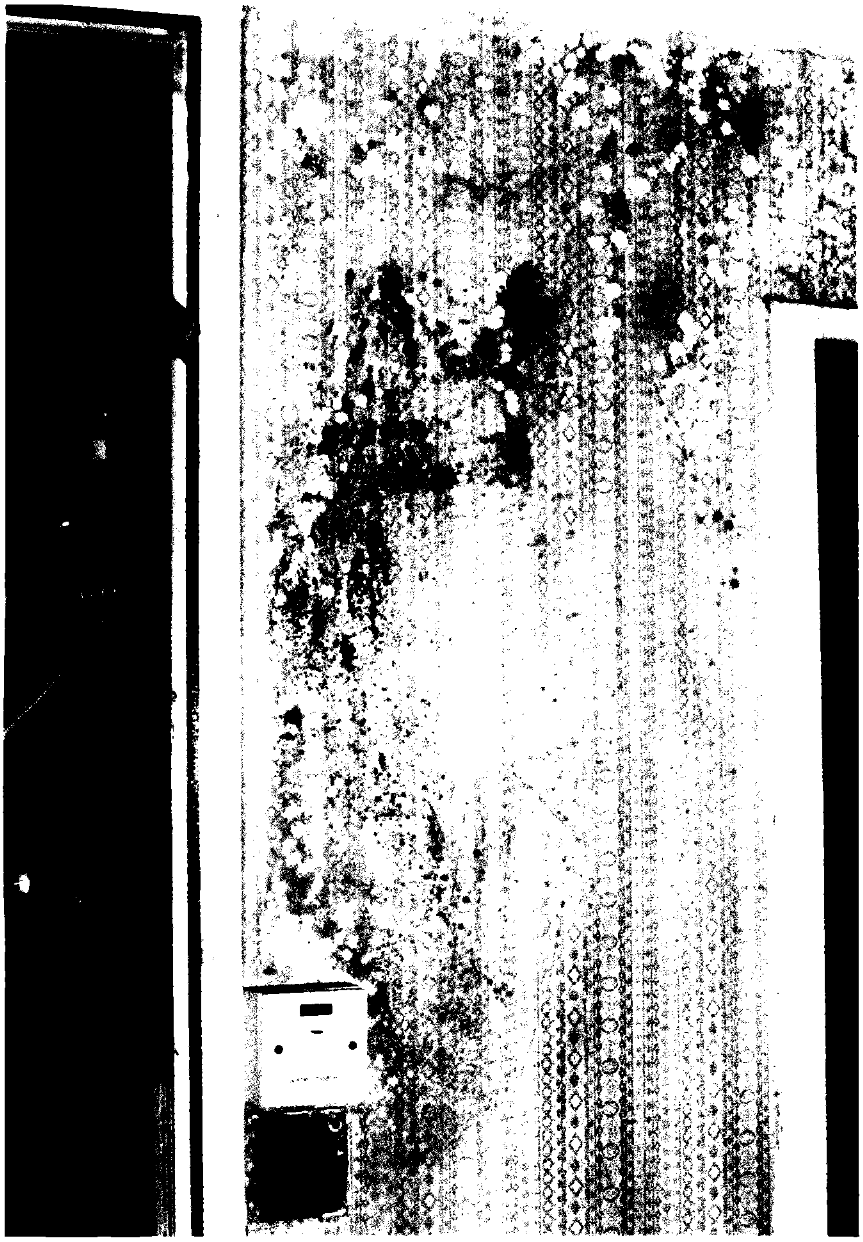


Plate 15 Jespersen: extensive mould growth on wall

A7.25 No piped gas was supplied to the blocks. No information on the structural standard of the blocks was available at the time of inspection.

Extent of work
A7.26 BRE inspected two adjacent vacated flats in a 12-storey block. An examination of five wall/floor and three wall/wall joints was undertaken. There were no restrictions on the amount of 'opening up' of joints since the majority of flats in the 11th and 12th storeys were vacant.

A7.27 In total 31 concrete samples were taken for analysis, including samples from cladding panels (loadbearing), non-loadbearing spandrel panels, loadbearing and non-loadbearing wall panels, floor slabs and in-situ joints.

Discussion of physical conditions observed
A7.28 Examination of the joints showed them to be generally well constructed and to contain tying reinforcement which was free from corrosion. In the absence of details showing the type of construction joints and their locations, it was not possible to confirm in all locations if all the tying and reinforcement details were 'as designed'. In locations for which details were available two discrepancies were found:

1 One drawing showed a gable wall tie plate linking a floor slab to a gable wall panel. Neither the plate, levelling bolt nor anchor bolt were found when their expected locations were examined.

2 The tying details of the spine wall/floor slab joint differed depending on whether there were one or two floor slabs adjacent to the joint. The latter geometry required the use of site reinforcement to tie the adjacent floor slabs together. At the location examined no reinforcement was found even though a two-floor-slab configuration was thought to be present.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A7.29 The quality of the dry pack was very variable ranging from well compacted and free from voids to friable with voids present.

A7.30 Hair-line cracking was observed in some of the non-loadbearing cladding panels (Plate 16).

A7.31 Diagonal cracking of the non-loadbearing cladding panels beneath window openings (Plate 17) had allowed rain to penetrate.

Summary of analysis of materials

i Floor slabs
A7.32 Chloride contents ranged from trace values to a maximum of 0.21%, giving a mean of 0.11%. This indicates that chlorides had not been added to the floor units during manufacture. Carbonation depth measured on two samples was 2 mm in both cases. Concrete cover to the reinforcement measured in one instance was 10 mm, and the cement content of one sample was 13%.

ii Precast wall/cladding panels
A7.33 Chloride contents of the components examined ranged from trace values to a maximum of 0.14%, with a mean of 0.09%. This shows that chlorides had not been added during manufacture of the panels sampled. Carbonation depths were generally low, ranging from zero to 15 mm, with a mean of 1.2 mm.

A7.34 Concrete cover to the reinforcement measured for two samples was found to be 30 and 50 mm respectively. The average cement content was 19.7%.

iii In-situ concrete/dry pack
A7.35 The chloride content of the three samples ranged from trace values to 0.14%, which is in the low category. The results indicate that chlorides had not been added to this concrete. The carbonation and concrete cover to the reinforcement measured for one of the in-situ concrete samples taken from a wall/wall joint were zero and 40 mm, respectively.

Site 22 (North-West)
A7.36 This semi-urban estate situated on a steep exposed hillside comprised nine flat-roofed blocks ranging from 5 to 8 storeys high. Construction of the blocks started in 1966.

A7.37 After construction the 7- and 8-storey blocks had been strengthened to resist an equivalent static pressure of 2.5 psi. Inclined stainless steel anchor rods were used resin-bonded into the floor/wall joints adjacent to flank walls and vertical expansion joints. There was no piped gas supplied to the dwellings.

A7.38 BRE inspected four flats in one of the 7-storey blocks. The dwellings were in a fair condition, although the link bridges and balustrades showed evidence of reinforcement corrosion and there was wet

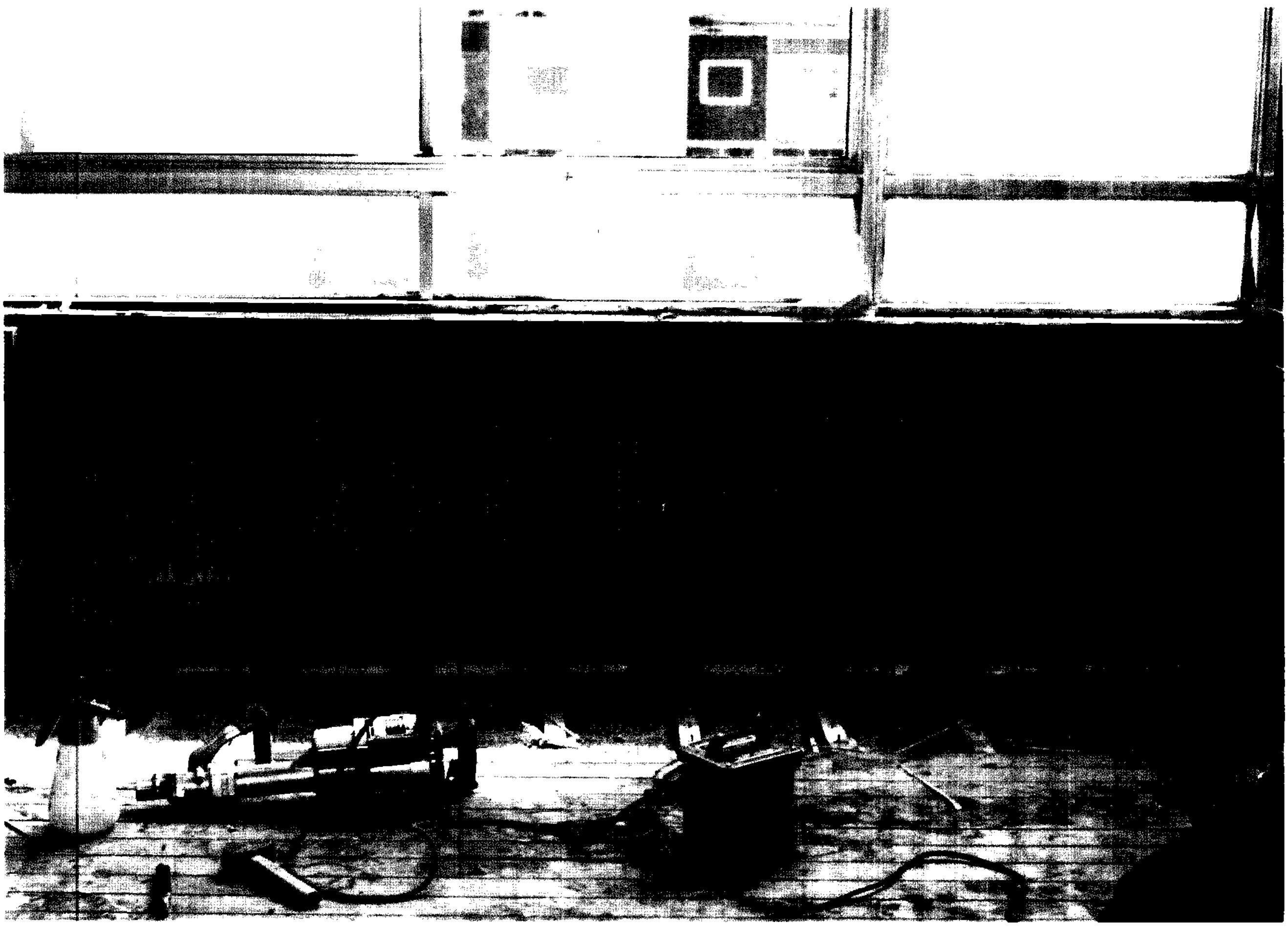


Plate 16 Jespersen: hair-line cracking in non-loadbearing cladding panels

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

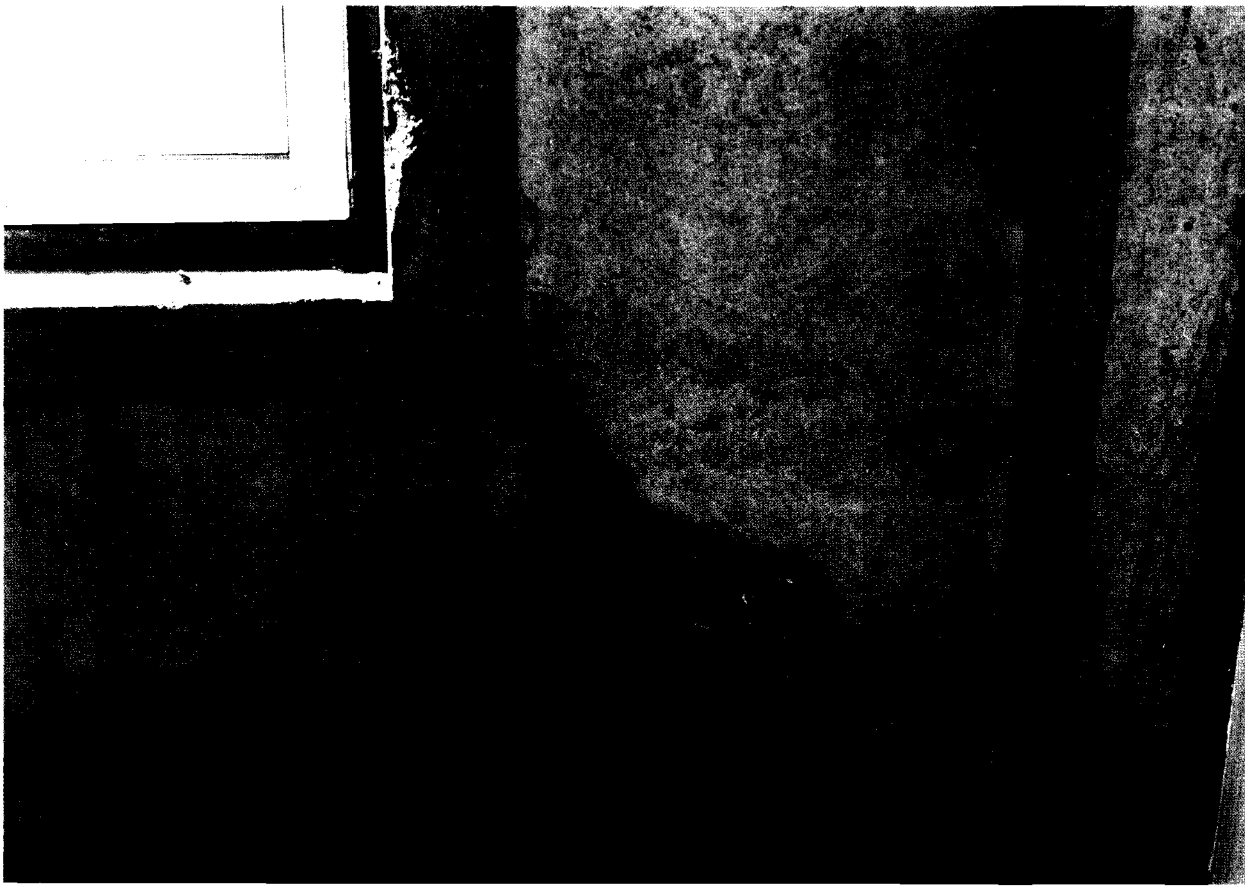


Plate 17 Jespersen: rain penetration through diagonal cracking at window openings

rot in a number of the window frames. There was evidence of vandalism on the estate.

Extent of work

A7.39 There were no restrictions on the amount or extent of 'opening up' of joints in two of the adjacent flats inspected. Five wall/floor joints were examined and the construction details noted. Also the condition of the spandrel panel/cross wall tie brackets was examined where the dry lining had been removed prior to concrete sampling.

A7.40 Only a limited examination of three wall/floor joints was undertaken in the other two dwellings since the adjoining properties were occupied.

A7.41 In total 54 concrete samples were taken for analysis, including samples from floor slabs, cladding panels (loadbearing inner leaves), non-loadbearing spandrel panels and wall panels.

Discussion of physical conditions observed

A7.42 Construction drawings were not available but the reinforcement and tying details appeared to comply with drawings from another Jespersen site.

A7.43 At the locations examined, panel and site reinforcement was found to be in good condition. Generally the in-situ concrete and dry pack was in place and well compacted. However a large void was found in the dry pack adjacent to a flank-wall-panel levelling bolt.

A7.44 Two flank-wall-panel fixing plates and associated bolts were examined and found to be loose following the removal of adjacent dry pack.

A7.45 A 'stayfix' stainless steel anchor bar was located and found to be in good condition and securely fixed into the surrounding concrete. A bolt was found to be missing from a spandrel panel/flank-wall panel fixing bracket (Plate 18), though no signs of distress or movement were observed.

A7.46 Spalling associated with reinforcement corrosion due to carbonation and low concrete cover to the reinforcement was present in some of the walkway columns.

Summary of analysis of materials

i Floor slabs

A7.47 Chloride contents in the floor slabs examined were mostly in the low category with just two results in the medium category at 0.45 and 0.48%. The mean chloride content was 0.12% indicating that chlorides had not been added to the slabs during manufacture. Carbonation depths ranged from 9 to 28 mm, with a mean of 18 mm, which suggests that the concrete quality was below average, a factor which may be attributable to the variability in the cement content which ranged from 8.7 to 16.2%.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

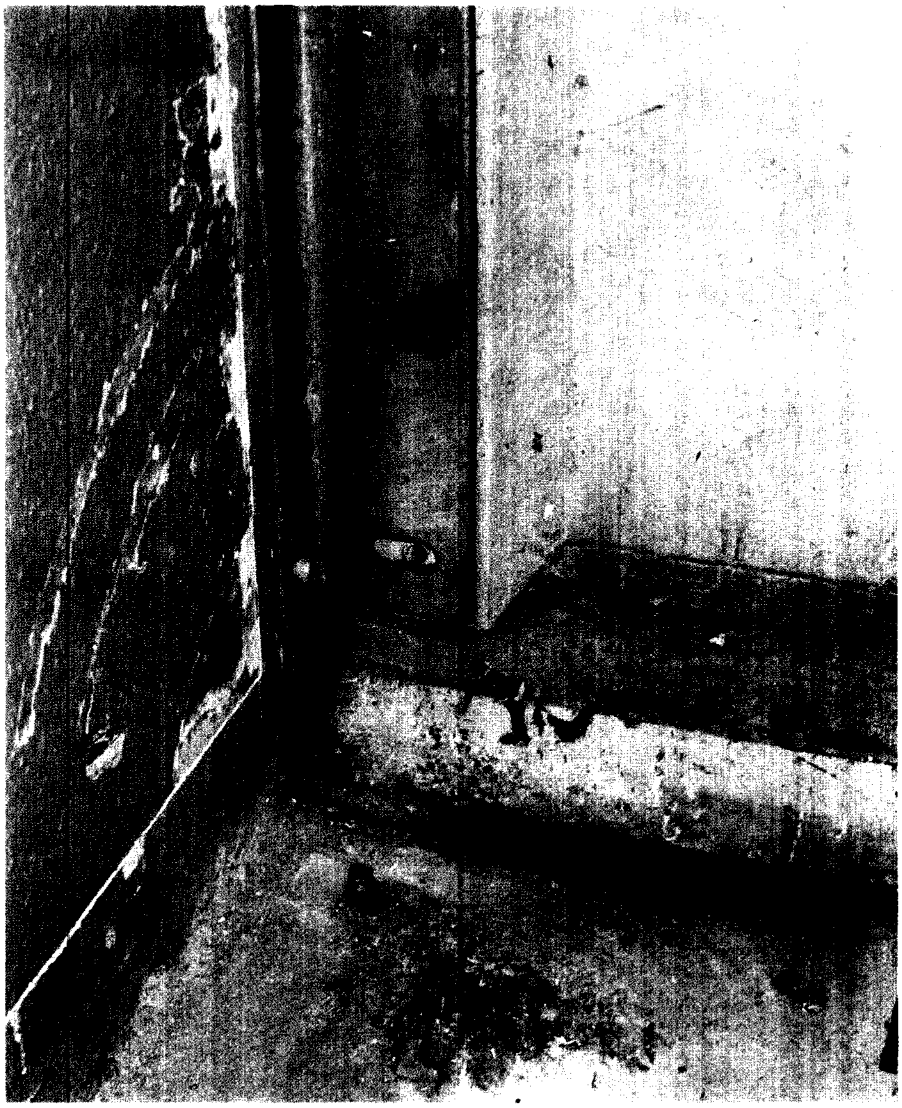


Plate 18 Jespersen: omission of bolts from connection plates

ii Precast cladding/wall panels
A7.48 Chloride contents ranged from trace values to a maximum of 0.93%, giving a mean of 0.18%, which indicates that the majority of the components sampled were free from added chlorides. However, three results were in the medium category which indicates that chloride may have been added to some components during manufacture. Carbonation depths were in the range 6 to 23 mm, giving a mean of 14.1 mm, which implies a slightly below average concrete quality for this type of concrete.

A7.49 Concrete cover to the reinforcement in three samples was 20, 25 and 27 mm, which is consistent with design intentions. The mean cement content was 11.3% which is low.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A8 The Reema system

A8.1 The investigations into the Reema system consisted of inspections of two properties at one site in the South-East of England. The system employs a range of building elements[3]. The use of Reema hollow panels for low-rise housing was investigated earlier[4].

Site 12 (South-East)

A8.2 This site was situated near the outskirts of a large coastal town and contained two 18-storey blocks, one 9-storey and one 11-storey block.

A8.3 The Reema 'Conclad' system of construction was used for the two 18-storey blocks, and Reema 'sandwich panel' systems were used in the 9- and 11-storey blocks[3].

A8.4 All the Reema blocks were built between 1964 and 1968 (Plate 19) and later strengthened to resist an equivalent static pressure of 2.5 psi, using steel angles bolted to the flank wall/ceiling joints and to a number of the wall/ceiling joints in corridors adjacent to the lift shaft. The piped gas supply had been disconnected.

A8.5 The site was tidy and the blocks of flats were well maintained.

Extent of work

A8.6 BRE inspected one vacant dwelling from each of the 18-storey Reema 'Conclad' blocks.

A8.7 Only a limited examination of two wall/floor and two wall/wall joints was possible in a single flat, since the work is very disruptive and adjacent flats were occupied. The danger of falling debris restricted the work which could be carried out on the external panels.

A8.8 No joints were broken out in the second dwelling for the above reasons. Thirty-one concrete samples were taken from components including floor and roof slabs, loadbearing wall panels, loadbearing

Plate 19 Reema Conclad construction

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Table A7 Materials data measured by BRE for each site inspected

Reema

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 12							
Floor slab	12/1/1/1	No det	15	30	<0.07	—	0
Floor slab	12/1/1/2	No det	15	35	0.41	—	1
Cladding panel, loadbearing (Conclad)	12/1/2/1	No det	—	22	<0.07	10.3	—
Joint	12/1/3/1	No det	—	—	<0.07	—	—
Cladding panel, non-loadbearing (Conclad)	12/1/4/1	No det	—	12	<0.07	—	—
Cladding panel, non-loadbearing (Conclad)	12/1/4/2	No det	—	13	<0.07	—	—
Floor slab	12/1/5/1	No det	—	25	0.36	11.5	—
Floor slab	12/1/5/2	No det	—	—	<0.07	—	—
Joint	12/1/6/1	No det	—	—	0.17	—	—
Cladding panel, loadbearing (Conclad)	12/1/7/1	No det	—	25	<0.07	—	—
Joint	12/1/8/1	No det	17	17	<0.07	—	0
Cladding panel, loadbearing (Conclad)	12/1/9/1	No det	—	20	0.43	10.6	—
Loadbearing wall panel	12/1/10/1	No det	30	25	0.07	—	—
Joint	12/1/11/1	No det	—	15	0.17	—	—
Cladding panel, non-loadbearing (Conclad)	12/1/12/1	No det	—	10	<0.07	—	—
Floor slab	12/1/13/1	No det	—	15	<0.07	—	—
Cladding panel, non-loadbearing (Conclad)	12/1/14/1	No det	—	15	0.2	—	—
Ground-floor facade ribs	12/1/15/1	(d)	30	2	0.67	16.5	3
Ground-floor facade ribs	12/1/16/1	(d)	—	4	0.57	14.0	3
Cladding panel, loadbearing (Conclad)	12/2/1/1	No det		10	0.35	15.1	
Cladding panel, loadbearing (Conclad)	12/2/1/2	No det		25	<0.07	—	
Roof slab	12/2/2/1	No det		2	0.44	12.9	
Cladding panel, non-loadbearing (Conclad)	12/2/3/1	No det		8	0.71	10.4	
Cladding panel, loadbearing (Conclad)	12/2/4/1	No det		1	0.65	15.3	
Floor slab	12/2/5/1	Coarse cracking*	No reinforcement exposed	20	0.11	—	No reinforcement exposed
Cladding panel, non-loadbearing (Conclad)	12/2/6/1	No det		2	0.58	12.8	
Cladding panel, non-loadbearing (Conclad)	12/2/7/1	No det		5	0.43	13.4	
Floor slab	12/2/8/1	No det		25	0.27	—	
Cladding panel, loadbearing (Conclad)	12/2/9/1	No det		20	0.62	11.4	
Loadbearing wall panel	12/2/10/1	No det		25	0.08	—	
Loadbearing wall panel	12/2/11/1	No det		10	0.19	—	

* No det, no deterioration; (d), deterioration as illustrated in Plate 33
** Illustrated in Plate 32
* Not caused by reinforcement corrosion

and non-loadbearing single-leaf cladding panels, in-situ joints and ground-floor facade ribs.

Discussion of physical conditions observed
A8.9 The joints examined were well constructed and in accordance with the drawings. The in-situ and precast concrete was well compacted and the joint reinforcement was correctly sized and positioned. Where exposed, the dry-pack mortar was also found to be in place and well compacted. However, optical probe examinations carried out by the local authority showed areas of dry pack to be missing in the gable-end wall/floor joints in one of the properties.

Plate 20 Reema Conclad: fine cracking in panel under bearing nib of floor, and reduced bearing area of floor nib

A8.10 There was only slight surface corrosion to the steel reinforcement in the joint, which was probably present prior to casting.

A8.11 Flank-wall panels were found to be cracked in areas directly beneath a number of the floor-slab nibs (Plate 20). The fine vertical cracks were not related to reinforcement corrosion and may have resulted from high localised stresses (Plate 20). Associated with this there was evidence of panel misalignment resulting in reduced bearing areas between the floor slabs and flank-wall panels also shown on Plate 20.

A8.12 Rust staining on the cladding panels found during an external visual inspection of both blocks had resulted from iron pyrites inclusions. A number of corners were missing from cladding panels at higher levels. Coarse cracking* was found in a number of the exposed ground-floor facade ribs. Thermal expansion of adjacent brick infill panels may have initiated hair-line cracking in the units, enabling corrosion to occur in the presence of moisture and medium levels of chloride and resulting in the development of the coarse cracking observed.

A8.13 The local authority have reported that some of the expanding anchors used to fix the strengthening angles to the concrete panels may have been incorrectly installed. The pilot holes were often drilled too close to the panel edge and an incorrect type of fixing bolt was used. As a result, cracking of some of the panels had occurred.

Summary of analysis of materials

i In-situ concrete

A8.14 Chloride contents ranged from trace values to 0.17%, with a mean of 0.12%, which is in the low category. On the basis of these results it can be assumed that no chlorides had been added to the in-situ concrete. Carbonation depths were measured on two samples and were found to be 15 and 17 mm.

A8.15 Concrete cover to the reinforcement measured at one location was 17 mm.

ii Floor/roof slabs

A8.16 Chloride contents in the concrete components examined varied from trace values to 0.44%, with a mean of 0.22%, which is in the low category and indicates that chlorides had not been added to the floor units in the dwellings examined.

A8.17 Carbonation depths varied from 2 to 35 mm with a mean of 21.7 mm. The high carbonation depths may have been due in part to the low mean cement content of 12.2%.

*Types of cracking and spalling are illustrated in Plate 33.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A8.18 Concrete cover to the reinforcement measured at two locations was 15 mm in both cases.

iii Precast cladding/wall panels

A8.19 Chloride contents varied from trace values to a maximum of 0.71%, giving a mean of 0.33%. These chloride contents are in the low and medium categories which suggests that there was probably some form of chloride contamination.

A8.20 Carbonation depths varied from 1 to 25 mm, giving a mean of 13.4 mm, which implies a lower than average concrete quality for precast concrete wall panels based on earlier findings[2]. Concrete cover to the reinforcement ranged from 15 to 30 mm with a mean of 21.4 mm, which is consistent with the design intentions.

A8.21 The mean cement content was 13%, which is a little low.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A9 The Selleck Nicholls Williams system

A9.1 The investigations into the cross-wall system consisted of inspections of five properties at one site in the North-West (Plate 21) and one in the South-East (Plate 22) of England.

Site 15 (North-West)

A9.2 This sloping north- and east-facing estate consisted of 2-, 3-, 4-, 5- and 6-storey blocks in both linear and deck-access forms (Plate 21).

A9.3 External decoration was good, although there were defects in the waterproofing membrane of the communal walkway.

A9.4 Strengthening modifications had been made during construction in the light of the partial collapse at Ronan Point. Piped gas was supplied to all dwellings.

Extent of work

A9.5 A 2-storey house and two flats, one in a 4-storey block and one in a 5-storey block, were inspected.

A9.6 It was only possible to carry out a very limited inspection of the joints between components, since adjacent properties were occupied.

A9.7 An examination of five wall/wall and two wall/floor joints was undertaken in the three dwellings and 34 concrete samples were taken for analysis from components comprising non-loadbearing single-leaf cladding panels, loadbearing and non-loadbearing wall panels, floor slabs, in-situ joints and walkway support columns.

Discussion of physical conditions observed

A9.8 Drawings for the 4- and 5-storey buildings were examined and it was possible to confirm that in general the original design intentions had been adhered to except that one wall/floor joint examined adjacent to a party wall did not contain a half-inch diameter transverse bar specified.

A9.9 The dry pack and in-situ concrete examined in these two dwellings was found to be in position, well compacted and free from cracking.

A9.10 Corrosion of tying steel in a drying-room wall/floor joint was found in association with failure of an asphalt waterproofing membrane on the walkway, but generally the panel and tying reinforcement exhibited only very slight surface corrosion.

A9.11 Drawings were not available for the house to enable comparison to be made with the design. It was only possible to determine the quality of workmanship and the condition of the components.

Plate 21 Selleck Nicholls Williams: 3-storey construction

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Table A8 Materials data measured by BRE for each site inspected

Selleck Nicholls Williams

Component/ joint	Sample reference number	Component/ joint condition'	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel''
Site number 15							
Loadbearing wall panel	15/1/1/1	No det	20	6	<0.07	—	2
Cladding panel, non-loadbearing, single skin	15/1/2/1	No det	—	0	0.11	28.8	—
Cladding panel, non-loadbearing, single skin	15/1/3/1	No det	—	0	0.07	—	—
Cladding panel, non-loadbearing, single skin	15/1/4/1	No det	—	0	0.17	—	—
Cladding panel, non-loadbearing, single skin	15/1/5/1	No det	—	0	0.21	23.7	—
Walkway support column	15/1/6/1	No det	—	10	0.25	18.4	—
Loadbearing wall panel	15/1/7/1	No det	15	>30	<0.07	—	1
Floor plank	15/1/8/1	No det	15	3	0.1	—	1
Loadbearing wall panel	15/1/9/1	No det	—	>25	<0.07	—	—
Loadbearing wall panel	15/1/9/2	No det	—	7	<0.07	—	—
Loadbearing wall panel	15/1/10/1	No det	28	20	<0.07	—	1
Loadbearing wall panel	15/1/10/2	No det	—	15	<0.07	—	—
Non-loadbearing wall panel	15/1/11/1	No det	20	15	<0.07	—	1
Non-loadbearing wall panel	15/1/11/2	No det	10	20	0.09	10.0	1
Joint	15/1/12/1	No det	25	4.0	<0.07	—	1
Loadbearing wall panel	15/1/13/1	No det	—	2	0.07	—	—
Cladding panel, non-loadbearing, single skin	15/2/1/1	No det	—	1	0.09	—	—
Cladding panel, non-loadbearing, single skin	15/2/2/1	No det	—	1	0.18	—	—
Cladding panel, loadbearing, single skin	15/2/3/1	No det	—	1	0.32	15.7	—
Cladding panel, non-loadbearing, single skin	15/2/4/1	No det	—	0	0.22	19.3	—
Joint	15/2/5/1	No det	10	30	0.13	—	1
Joint	15/2/6/1	No det	10	30	<0.07	—	1
Joint	15/2/7/1	No det	10	25	0.13	—	1
Joint	15/2/7/2	No det	15	15	0.18	12.9	1
Cladding panel, non-loadbearing, single skin	15/2/8/1	No det	—	10	0.14	—	—
Cladding panel, non-loadbearing, single skin	15/3/1/1	No det	—	10	0.14	—	—
Loadbearing wall panel	15/3/2/1	No det	—	*	0.32	9.5	—
Joint	15/3/3/1	No det	35	0	0.11	—	1
Loadbearing wall panel	15/3/4/1	No det	—	*	0.13	—	—
Walkway support column	15/3/5/1	No det	—	10	0.27	18.3	—
Cladding panel, non-loadbearing, single skin	15/3/6/1	No det	—	1	0.17	28.8	—
Floor plank	15/3/7/1	No det	—	3	0.24	—	—
Loadbearing wall panel	15/3/8/1	No det	—	10	0.11	—	—
Cladding panel, non-loadbearing, single skin	15/3/9/1	No det	—	0	0.13	—	—

(continued)

' No det, no deterioration
'' Illustrated in Plate 32
* Patchy carbonation, no well defined carbonation front

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 24							
Joint	24/1/1/1	Well compacted	28	35	—	—	1
Loadbearing wall panel	24/1/2/1	No det	28	33	—	—	1
Loadbearing wall panel	24/1/3/1	Honeycombed	0	40	—	—	1–2
Joint	24/1/4/1	Well compacted	20§	30	—	—	1–2
Loadbearing wall panel	24/1/5/1	Honeycombed	5	38	—	—	2
Cladding panel, non-loadbearing, single skin	24/1/6/1	No det	—	2	—	—	—
Floor beam	24/1/7/1	No det	12	3	—	—	0–1
Floor beam	24/1/8/1	No det	15	2	—	—	0–1
Joint	24/1/9/1	Well compacted	34	42	—	—	0–1
Cladding panel, non-loadbearing, single skin	24/1/10/1	No det	—	8	—	—	—
Joint	24/1/11/1	Well compacted	35	35	—	—	0–1
Cladding panel, non-loadbearing, single skin	24/1/12/1	No det	10	3	—	—	0–1
Joint	24/1/13/1	Well compacted	30	50	—	—	0–1
Cladding panel, non-loadbearing, single skin	24/1/14/1	No det	—	3	—	—	—
Floor beam	24/1/15/1	No det	10	0	—	—	0–1
Joint	24/2/1/1	Honeycombed	25	35	—	—	0–1
Loadbearing wall panel	24/2/2/1	No det	15	>35	—	—	1
Loadbearing wall panel	24/2/3/1	No det	15	20‖	—	—	1
In-situ floor topping	25/2/4/1	No det	90	—#	—	—	1

* No det, no deterioration
** Illustrated in Plate 32
§ To loop bars
‖ Variable and patchy
\# Dust contamination

A9.12 The in-situ concrete examined in the house was well compacted and free from cracking. The tying steel, panel reinforcement and panel fixings exhibited only slight surface corrosion.

Summary of analysis of materials

i Floor slabs

A9.13 Chloride contents for the two samples taken from floor slabs were 0.1 and 0.24%, which indicates that no chlorides had been added to the concrete during the manufacture of the slabs.

A9.14 Carbonation depth for both samples was 3 mm, which indicates a better than average precast concrete quality.

A9.15 Reinforcement exposed in only one location had 15 mm of concrete cover, which is in accordance with the drawings.

ii Precast wall/cladding panels

A9.16 Maximum chloride content was 0.32%, with a mean of 0.13%, which indicates that chlorides had not been added during manufacture of the wall or cladding panels in the dwellings examined.

A9.17 Carbonation depths varied from zero to over 30 mm, although the mean carbonation depth of 8 mm suggests that the concrete was of average quality for this type of construction. The mean cement content was quite high at 19.4%.

A9.18 Concrete cover to the reinforcement ranged from 10 to 28 mm, with a mean of 18.6 mm, which was consistent with the nominal design intentions.

iii In-situ joints

A9.19 The maximum chloride content in the in-situ concrete joints was 0.18%, with a mean of 0.11%, which indicates that chlorides had not been added to the concrete in the in-situ joints examined.

A9.20 Concrete cover to the reinforcement varied from 10 to 35 mm, with a mean of 17.5 mm, which is consistent with the design intentions, and the single concrete sample tested for cement content was found to contain 12.9%.

iv Walkway support columns

A9.21 Chloride contents for the two samples were 0.25 and 0.27%, respectively, indicating that chlorides had not been added to the columns examined.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Plate 22 Selleck Nicholls Williams: 2-storey construction (variation reported by local authority)

A9.22 The carbonation depth for each sample was 10 mm, which indicates an average concrete quality in the precast concrete columns, and cement contents for the two samples were 18.3 and 18.4%, respectively.

Site 24 (South-East)
A9.23 This level sheltered estate consisted of 2- and 3-storey terraced blocks which were built between 1966 and 1968. The concrete cross walls of the 3-storey blocks were stabilised laterally by narrow storey-height concrete panels fixed to their vertical edges on the ground floor, with similar double-storey-height panels used on the upper storeys. The double-height panels were used also on the 2-storey blocks.

A9.24 The front and rear elevations were infilled with storey-height glazed timber panels. Brick or cut stonework cladding was applied to the gable ends.

A9.25 External decoration of the estate was in good order.

Extent of work
A9.26 BRE was invited to inspect two vacant flats in two adjacent 3-storey blocks. Only a limited examination was carried out since adjacent flats were occupied. An examination of six wall/wall joints and one wall/floor joint was undertaken.

A9.27 Nineteen concrete samples were taken for analysis from loadbearing wall panels, non-loadbearing cladding panels, floor beams, and in-situ floor and joint concrete.

Discussion of physical conditions observed
A9.28 Of the six wall/wall joints examined only one was found in which a lacing bar failed to mate correctly with a panel loop bar. The tying reinforcement exposed showed only slight surface corrosion, whereas reinforcement mesh in the loadbearing wall panels had corroded further in areas where there was low concrete cover.

A9.29 The concrete of the cladding panels and floor beams was good quality, whereas the concrete in the cross walls was often porous and honeycombed.

A9.30 A partial examination of a wall/floor joint produced no evidence of any tying between the components and since drawings were not available it was not possible to confirm if this was 'as designed'. Furthermore, no shear walls were provided in the construction of the 3-storey blocks.

Summary of analysis of materials
A9.31 All the chloride contents in the components examined were in the low category, which indicates that the components examined were free from added chlorides.

i Floor beams
A9.32 The depth of carbonation was measured for

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

the four floor beams and was found to be less than 4 mm in each case, indicating good-quality concrete. Concrete cover to the reinforcement at three locations examined was 10, 12 and 15 mm, and the cement content ranged from 10.7 to 12.9%.

ii Cladding panels
A9.33 The concrete quality in the units sampled was good, resulting in low depths of carbonation between 2 and 8 mm. The concrete cover to the reinforcement at one location was 10 mm, and the cement content at another was 12.1%.

iii Loadbearing wall panels
A9.34 Depth of carbonation was high in the components examined and varied from 20 to 40 mm, with a mean of 33.2 mm. Concrete cover to the reinforcement was variable ranging from zero to 40 mm, with a mean of 12.6 mm. Cement content measured for one sample was 8.7% which is very low.

iv In-situ concrete
A9.35 The depth of carbonation was high at all of the locations examined, ranging from 30 to 50 mm, with a mean of 37.8 mm. Concrete cover to the reinforcement ranged from 20 to 90 mm, and the cement content in two of the samples was 9.5 and 11.3%, which is again low.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A10 The Shepherd Spacemaker system

A10.1 The investigations into the Shepherd Spacemaker system consisted of an inspection of a property at one site in the North-West of England.

Site 17 (North-West)

A10.2 This semi-rural estate consisted of twenty 3-storey blocks (Plate 23) and thirty 2-storey terraced blocks (Plate 24). The former were flat-roofed and the latter had conventional pitched timber roofs. The blocks were built around 1966.

A10.3 External decoration of the estate was good.

Extent of work

A10.4 The visit was primarily to advise the local authority on the probable cause of some concrete deterioration that had already been identified. A general external inspection was made of a number of dwellings on the estate and five concrete samples from the solid loadbearing cross-wall panels were obtained for analysis.

Discussion of physical conditions observed

A10.5 Extensive cracking and spalling was found (Plate 25) due to reinforcement corrosion occurring in the exposed ends of cross walls, cladding panels and roof perimeter beams. The concrete contained foamed blastfurnace aggregates and was relatively porous.

A10.6 As a result of this high porosity carbonation had reached or passed the reinforcement in all the locations sampled. In some instances the decorative coating had inhibited carbonation from the outer face but carbonation had proceeded from the uncoated back face to the reinforcement.

Summary of analysis of materials

Loadbearing cross-wall panels

A10.7 Chloride contents in the concrete components examined ranged from 0.21 to 0.56%, with a mean of 0.36%. These results were mostly in the low to medium categories indicating that chlorides had not been deliberately added during the manufacture of the panels in the dwellings examined. However, contamination of the aggregates had probably occurred in some of the units resulting in medium levels of chloride being present.

A10.8 Carbonation depths varied from 10 to 60 mm, with a mean of 26.4 mm, which suggests that these units are relatively porous. The cement content ranged from 25.3 to 28.6% with a mean of 27.6%, and there was virtually no aggregate over 3 mm in size.

A10.9 Concrete cover to the reinforcement was mostly 10 mm with one value of 5 mm, which is less than the design requirements.

Plate 23 Shepherd Spacemaker: 3-storey construction

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Table A9 Materials data measured by BRE for each site inspected

Shepherd Spacemaker

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 17							
Loadbearing cross-wall panels	17/1/1/1	(d)	10	10	0.28	25.3	2
Loadbearing cross-wall panels	17/1/2/1	(d)	10	20	0.21	—	2
Loadbearing cross-wall panels	17/1/3/1	(d)	10	30	0.34	27.9	2
Loadbearing cross-wall panels	17/1/4/1	(d)	5	12	0.56	28.5	2
Loadbearing cross-wall panels	17/1/5/1	(d)	10	60	0.41	28.6	2

* (d), deterioration as illustrated in Plate 33

** Illustrated in Plate 32

Plate 24 Shepherd Spacemaker: 2-storey construction

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Plate 25 Shepherd Spacemaker: extensive cracking and spalling in exposed ends of cross walls

A11 The Skarne system

A11.1 The investigation into the Skarne system consisted of inspections of eight properties at two sites in the North-East of England.

Site 8 (North-East)

A11.2 This undulating urban site was situated on the outskirts of a large town and contained two 16- and two 17-storey blocks and a number of 4-storey terraced blocks.

A11.3 The high-rise Skarne blocks were built in 1967, and later strengthened to resist an equivalent static pressure of 2.5 psi. Steel angles had been bolted to the wall/ceiling joints and flat steel ties were provided at internal joints between floor slabs. The piped gas supply had been disconnected.

A11.4 The site was tidy and the blocks of flats were in a fair state of repair.

Extent of work

A11.5 BRE carried out a limited examination of four vacant flats in the 17-storey block and made a visual examination of two vacant dwellings in the low-rise blocks. A detailed investigation of the blocks, including concrete sampling, had been carried out by the local authority.

A11.6 No joints were opened up in the dwellings examined but 18 concrete samples were taken for analysis, including samples from floor slabs, walls, cladding panels (loadbearing inner leaves) and balcony components to augment the sampling of the local authority.

Discussion of physical conditions observed

A11.7 Coarse cracking, spalling and rust staining associated with reinforcement corrosion were observed in the exposed ends of cladding panels and on balcony soffits. Cracking of the joints between panels, associated with shrinkage of the in-situ concrete in the joints and thermal movement of the structure, was observed.

A11.8 Cracking of the precast panels beneath the corners of windows was found to be common. As a result rain penetration had occurred causing corrosion of the steel tying straps.

A11.9 A number of panels had suffered damage at edges and corners and this had been repaired. There were indications that some of the repairs were deteriorating.

A11.10 Leaks, as a result of defects in the asphalt roof membrane, were evident on the ceiling over the public hall on the top floor and on the walls to the stair-well.

A11.11 Most balconies situated at the corners of the block had deflected at their outer unsupported corner to the extent that remedial work was necessary. A pattern of fine linear cracks and map cracking was evident on a number of balcony soffits.

Summary of analysis of materials

i Floor slabs

A11.12 Chloride contents in the two concrete components sampled were 0.42 and 2.03%, respectively. The chloride contents lie in the medium and high categories and indicate that during manufacture chlorides had been added to some of the floor units in the dwellings examined.

A11.13 The single measurement of carbonation depth was 20 mm. This high carbonation depth is probably due in part to the cement content of 7.7%, which is well below that required for good structural concrete.

A11.14 Concrete cover to the reinforcement was measured in two components and was found to be 15 mm in both cases.

ii Precast cladding/wall panels

A11.15 Chloride contents varied from trace values to a maximum of 0.97%, giving a mean of 0.35%. These results lie in the low and medium categories and suggest that chlorides had been added during manufacture of the concrete in some of the wall panels.

A11.16 Carbonation depths ranged from 0 to 20 mm, with a mean of 9.1 mm, which implies an average concrete quality for the precast concrete wall panels. The mean cement content was 14.1%.

A11.17 Concrete cover to the reinforcement ranged from 10 to 70 mm, with a mean of 41 mm. It was not possible to confirm if the original specifications for cover had been complied with, since no drawings were available.

iii Balcony components

A11.18 Three concrete samples were taken from these components and there was no measurable carbonation in the two samples tested.

A11.19 Chloride contents ranged from 0.36 to 1.16%, with a mean of 0.7%, which indicates that chlorides had been added to some of the balcony components during manufacture. Reinforcement was exposed in only one component and was found to have 40 mm of concrete cover.

A11.20 The mean cement content of the balcony components was 9.9% which again is low.

Site 13 (North-East)

A11.21 This urban estate situated on an exposed, level site near the coast comprised one thousand and fifty-seven 2-storey terraced houses, built between 1965 and 1970.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Table A10 Materials data measured by BRE for each site inspected

Skarne

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 8							
Loadbearing wall panel	8/1/1/1	No det	10	10	0.36	—	0
Loadbearing wall panel	8/1/1/2	No det	—	20	<0.07	—	—
Loadbearing wall panel	8/1/2/1	No det	—	12	0.42	12.0	—
Loadbearing wall panel	8/1/3/1	No det	30	—	0.23	—	0
Cladding panel, loadbearing inner leaf	8/1/4/1	No det	70	0	<0.07	—	0
Cladding panel, loadbearing inner leaf	8/1/4/2	No det	70	3	<0.07	—	0
Floor slab	8/1/5/1	No det	—	20	0.42	—	—
Loadbearing wall panel	8/1/6/1	No det	—	—	0.21	—	—
Loadbearing wall panel	8/1/7/1	No det	—	14	0.43	13.8	—
Cladding panel, loadbearing inner leaf	8/1/8/1	No det	—	2	<0.07	—	—
Balcony slab	8/1/9/1	No det	—	0	1.16	9.5	—
Balcony parapet panel	8/1/10/1	No det	40	0	0.36	—	0
Floor slab	8/1/11/1	(d)	15	—	2.03	7.7	3
Balcony slab	8/1/12/1	No det	—	—	0.58	10.3	—
Loadbearing wall panel	8/1/13/1	No det	—	15	0.85	14.2	—
Loadbearing wall panel	8/1/14/1	No det	25	15	0.97	16.5	2
Loadbearing wall panel	8/1/15/1	No det	—	0	0.42	—	—
Floor slab	8/1/16/1	(c)	15	—	*	*	3
Site number 13							
Cladding panel, loadbearing inner leaf	13/1/1/1	No det	Not recorded	>30	0.24	—	—
Floor slab	13/1/2/1	No det	Not recorded	>30	0.84	8.5	—
Floor slab	13/1/3/1	No det	Not recorded	>15	0.79	10.4	—
Floor slab	13/1/4/1	No det	Not recorded	15	0.5	—	—
Cladding panel, loadbearing inner leaf	13/1/5/1	No det	Not recorded	—	0.56	11.4	—
Cladding panel, loadbearing inner leaf	13/1/6/1	No det	Not recorded	>20	0.22	—	—
Cladding panel, loadbearing inner leaf	13/1/7/1	No det	Not recorded	12	0.53	13.5	—
Joint	13/1/8/1	No det	Not recorded	§	0.1	—	3
Floor slab	13/1/9/1	No det	Not recorded	15	0.24	—	—
Cladding panel, loadbearing inner leaf	13/1/10/1	No det	Not recorded	20	0.64	13.8	—
Cladding panel, loadbearing inner leaf	13/1/11/1	No det	Not recorded	>20	0.46	—	—
Cladding panel, loadbearing inner leaf	13/2/1/1	No det	—	20	0.79	10.8	—
Cladding panel, loadbearing inner leaf	13/2/2/1	No det	—	15	0.6	12.9	—
Cladding panel, loadbearing inner leaf	13/2/2/2	No det	—	20	0.43	—	—
Cladding panel, loadbearing inner leaf	13/2/3/1	No det	—	20	0.73	9.2	—
Cladding panel, loadbearing inner leaf	13/2/4/1	No det	—	15	0.58	—	—
Floor slab	13/2/5/1	No det	—	10	0.46	—	—

(continued)

* No det, no deterioration; (c) and (d), deterioration as illustrated in Plate 33
** Illustrated in Plate 32
* Sample not analysed
§ Fully carbonated

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 13 (continued)							
Floor slab	13/2/5/2	No det	15	25	0.78	8.2	1
Floor slab	13/2/6/1	No det	—	25	0.65	—	—
Floor slab	13/2/7/1	No det	15	>25	0.78	8.2	2
Cladding panel, loadbearing inner leaf	13/2/8/1	No det	15	20	0.79	9.9	2
Floor slab	13/2/9/1	No det	—	25	0.65	—	—
Floor slab	13/2/10/1	No det	20	30	0.51	—	2
Cladding panel, loadbearing inner leaf	13/2/11/1	No det	—	25	1.0	8.5	—
Floor slab	13/2/12/1	No det	—	18	0.75	11.4	—

* No det, no deterioration
** Illustrated in Plate 32

A11.22 BRE inspected two houses which were in the process of renovation as part of a local authority scheme for the estate (Plate 26). The houses that had not been renovated were in a poor to fair condition externally.

Extent of work

A11.23 The rehabilitation work required the removal of front and rear timber infill panels, the brick cladding to the concrete flank walls (Plate 27) and some of the internal finishes. This exposed the structural joints and the tying reinforcement between the floor and flank wall (Plate 28). In addition, consulting engineers had previously carried out examinations of other Skarne dwellings on the estate and had noted shortcomings and defects in the construction. It was therefore unnecessary to 'open up' any further joints.

A11.24 Twenty-five concrete samples were taken for analysis from components including cladding panels (loadbearing inner leaves), floor slabs and one wall/floor joint.

Discussion of physical conditions observed

A11.25 The connections between wall and floor slabs differed from the details shown on the drawings. The fishplate connectors, which should have been bolted to studs welded to the panel reinforcement, had been replaced by 3 mm diameter steel wire wrapped around the projecting studs.

A11.26 Some of the tying steel was badly corroded (condition 3, see Plate 32) where the in-situ concrete had been incorrectly placed or omitted (Plate 29).

A11.27 The blocks had suffered from dampness and water penetration due to defective roof membranes and/or defective internal roof drainage pipes. There was also evidence of subsidence in some terraces.

Summary of analysis of materials

i In-situ concrete

A11.28 Chloride content of the single sample was 0.1%, which is in the low category. The concrete was found to be fully carbonated.

ii Floor slabs

A11.29 Chloride contents in the concrete components examined varied from 0.24 to 0.84%, giving a mean of 0.63%, which strongly suggests that chlorides had been added to some of the floor units in the dwellings examined.

A11.30 Carbonation depths ranged from 10 mm to over 30 mm, which suggests that the concrete is below average quality for this type of construction. The high carbonation depths are probably due in part to the low mean cement content of 9.3%.

A11.31 Concrete cover to the reinforcement measured for two samples was 15 mm in both cases. However it was not possible to confirm if the original specifications for cover had been compiled with since no drawings were available.

iii Precast cladding panels

A11.32 Chloride contents varied from 0.22% to a maximum of 1.0%, giving a mean of 0.58%, which suggests that chlorides had been added to the concrete during manufacture of some of the wall panels.

A11.33 Carbonation depths varied from 15 mm to over 30 mm, giving a mean of 18.5 mm, which implies a lower than average concrete quality for the precast concrete wall panels. This may be partly explained by the low mean cement content of 11.3%.

A11.34 It was not possible to confirm if the original specifications for cover had been complied with, since no drawings were available.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Plate 26 Skarne: renovation of low-rise dwellings (original and renovated types)

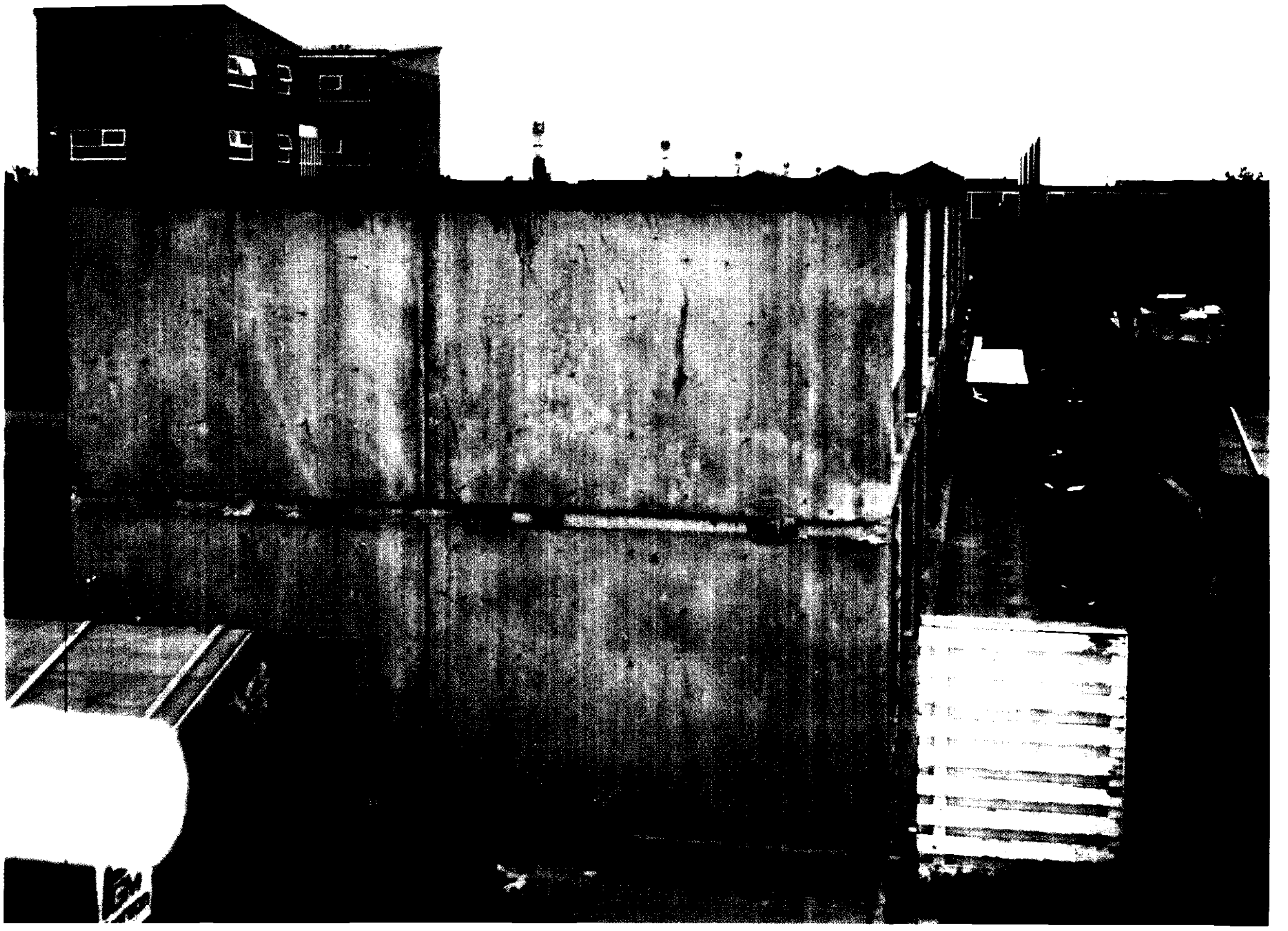


Plate 27 Skarne: removal of brick cladding from flank walls as part of renovation scheme

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Plate 28 Skarne: tying reinforcement between floor and flank wall

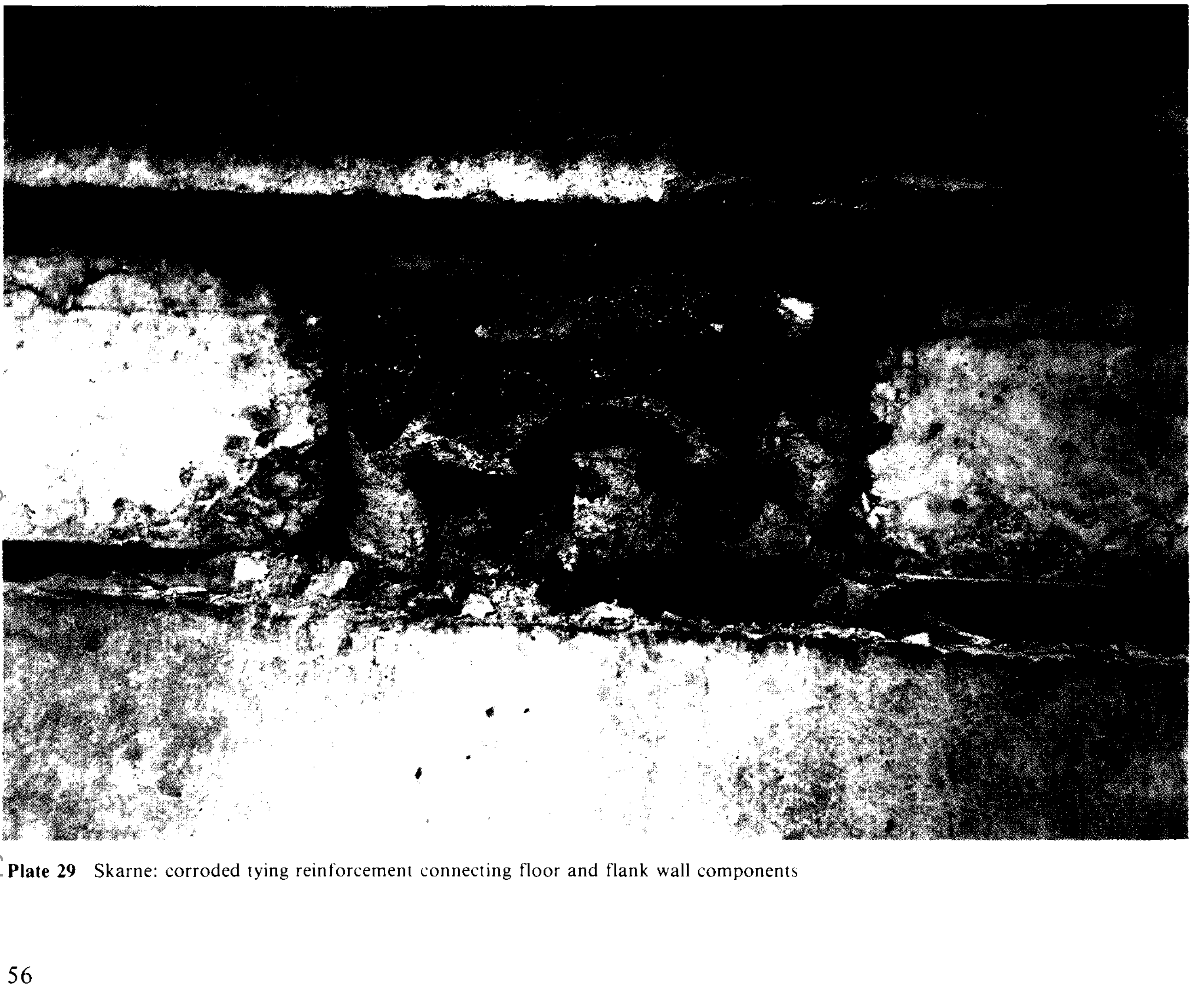


Plate 29 Skarne: corroded tying reinforcement connecting floor and flank wall components

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A12 The Wates system

A12.1 BRE was unable to carry out any surveys on Wates blocks during the period of the LPS investigation since no Wates dwellings were made available by building owners. However, following the completion of BRE's main investigation, the opportunity arose to conduct a visual examination of one 16-storey and one 10-storey block in the South of England in conjunction with a local authority and their consultants. A limited number of samples were also taken. This section briefly summarises defects found during the visual examinations and the materials data obtained.

Site 18 (South)

Discussion of physical conditions observed

A12.2 The lower section of the outer leaf of a number of first-floor flank-wall panels was removed to expose the in-situ joints, as part of the local authority's investigations. Areas of the mortar bed were found to be missing in some of these joints and shrinkage had occurred in some instances, which reduced the seating area of the panel above. Nuts on the levelling bolts were not loose (Plate 30) and the dry pack had been omitted from the majority of the bolt pockets. However, no signs of structural distress were observed in any of the joints examined.

A12.3 The two blocks examined had been strengthened following the advice in MHLG circulars 62/68 and 71/68[5]. Stainless steel dowel bars were resin-grouted into inclined holes drilled through into the inner leaf of the flank-wall panels, from the soffit of the adjacent floor slabs. The pilot holes had been drilled so that the upper ends of the bars coincided with the levelling bolt pockets (Plate 30). Since these pockets were ungrouted the strengthening was ineffective and a new set of strengthening measures are being considered.

A12.4 The cladding-panel tie bars were found to be misplaced within the thickness of the panel in a number of instances, thus reducing their embedment length. These bars consisted of pure copper with just trace levels of tin. Although softer than the tie material assumed in the design, in the absence of added chlorides this material can be assumed to be durable, although where high chlorides are present its performance cannot be guaranteed.

A12.5 Longitudinal cracking, spalling and rust staining resulting from reinforcement corrosion were observed in a number of the ground-floor precast cantilevers at one site (Plate 31).

Summary of analysis of materials

A12.6 Fourteen concrete samples were taken from cladding panels (inner and outer leaves) and floor slabs, and one sample was taken from a ground-floor cantilever. In general chloride levels were low. Four samples contained medium to high levels of chloride. The cantilever beams contained 2.42% chloride and samples from three cladding panels contained chloride levels of 0.46, 0.51 and 1.37%.

Plate 30 Wates: levelling bolt and strengthening bar

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Table A11 Materials data measured by BRE for each site inspected

Wates

Component/ joint	Sample reference number	Component/ joint condition*	Concrete cover (mm)	Depth of carbonation (mm)	% chloride ion by wt of cement	% cement	Condition of steel**
Site number 18							
Cladding panel, non-loadbearing outer leaf	18/1/1/1	No det	120	0	0.46	15.4	1
Joint	18/1/2/1	No det	10	—	0.3	—	—
Cladding panel, non-loadbearing outer leaf	18/2/1/1	No det	10	50	1.37	13.2	1
Joint	18/2/2/1	No det	10	—	0.21	—	—
Cladding panel, non-loadbearing outer leaf	18/2/3/1	No det	15	—	0.21	—	—
Joint	18/3/1/1	No det	0	—	0.24	—	—
Cladding panel, non-loadbearing outer leaf	18/3/2/1	No det	0	—	0.19	—	—
Cladding panel, non-loadbearing outer leaf	18/3/3/1	No det	10	—	0.4	13.3	—
Cladding panel, non-loadbearing outer leaf	18/4/1/1	No det	—	5	0.13	—	—
Cladding panel, loadbearing inner leaf	18/4/2/1	No det	—	13	0.07	—	—
Cladding panel, non-loadbearing outer leaf	18/4/3/1	No det	—	8	0.51	19.0	—
Cladding panel, non-loadbearing outer leaf	18/4/4/1	No det	—	13	0.18	—	—
Precast cantilever	18/4/5/1	(d), (f)	—	—	2.42	18.3	—
Floor slab	18/4/6/1	No det	—	2	0.24	20.7	—
Floor slab	18/4/7/1	No det	—	12	0.18	—	—

* No det, no deterioration; (d) and (f), deterioration as illustrated in Plate 33

** Illustrated in Plate 32

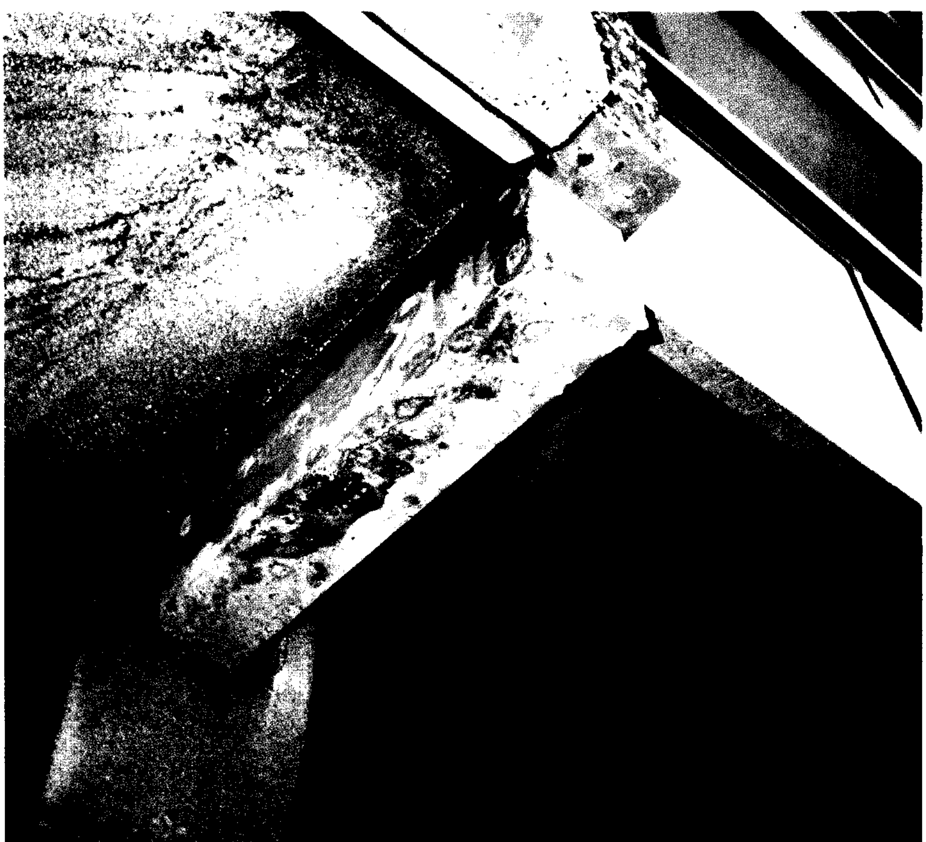


Plate 31 Wates: rusting and cracking in in-situ podium cantilever

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

A13 References

1 **Building Research Establishment.** *The structure of Ronan Point and other Taylor Woodrow-Anglian buildings.* BRE Report. Garston, BRE, 1985.

2 **Currie R J.** *Carbonation depths in structural-quality concrete: an assessment of evidence from investigations of structures and from other sources.* BRE Report. Garston, BRE, 1986.

3 **Hotchkiss A R and Edwards M J.** *Reema large panel system dwellings.* BRE Report. Garston, BRE, 1987. (In Press.)

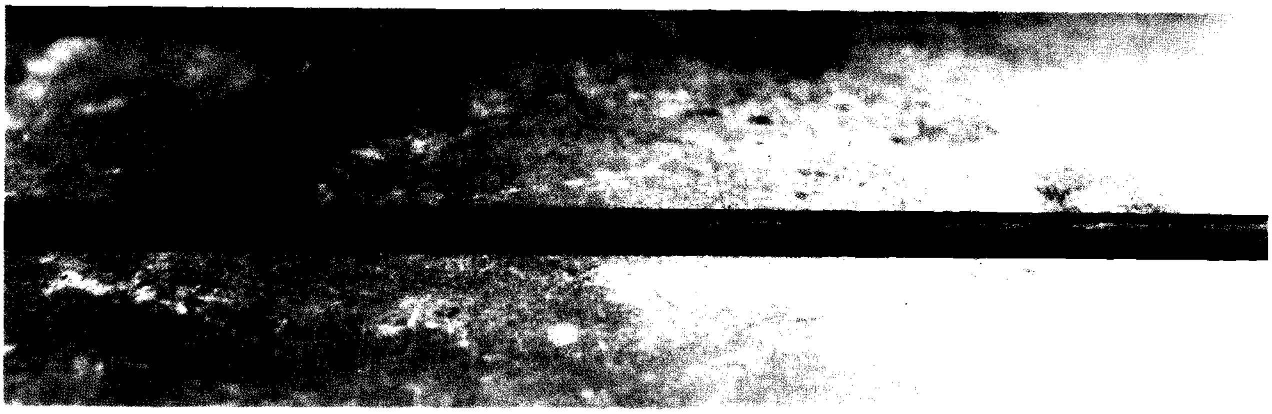
4 **Building Research Station.** *The structural condition of Reema hollow panel system houses.* BRE Report. Garston, BRE, 1984.

5 **Ministry of Housing and Local Government.** Flats constructed with precast concrete panels. Appraisal and strengthening of existing high blocks. Design of new blocks. Circulars 62/68 and 71/68.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Condition 0 Bright steel — no corrosion

Condition 1 Tendon with slight surface corrosion. No visible loss of area of sound metal at any one cross-section



Condition 2 Tendon with surface corrosion and pitting at the onset of visible loss of cross-sectional area of sound metal. Small reduction of tensile strength possible

Condition 3 Severely corroded tendon. Estimated 20% or more of area lost at any one cross-section and corresponding reduction of tensile strength

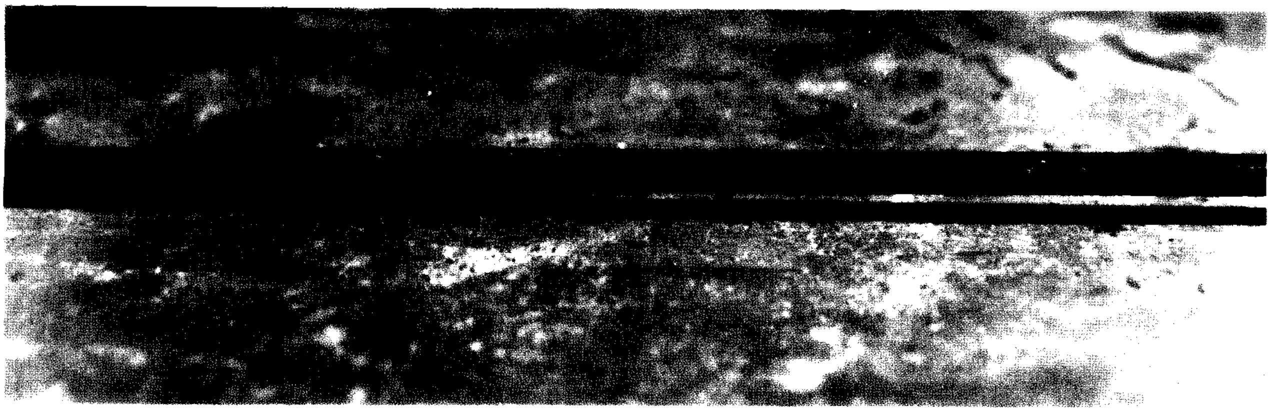
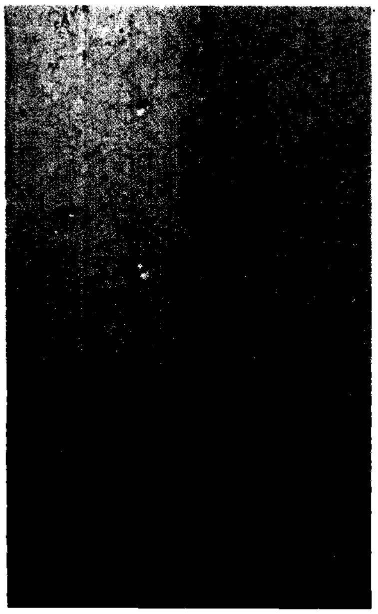
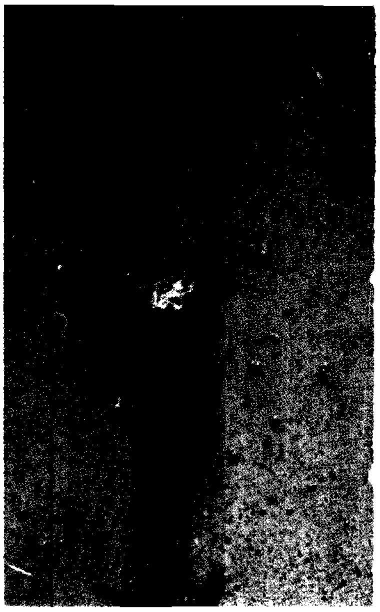


Plate 32 Classification of reinforcement corrosion

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press


(a) Fine cracking


(b) Coarse cracking


(c) Coarse cracking and local spalling


(d) General spalling


(e) Coarse cracking and rust staining

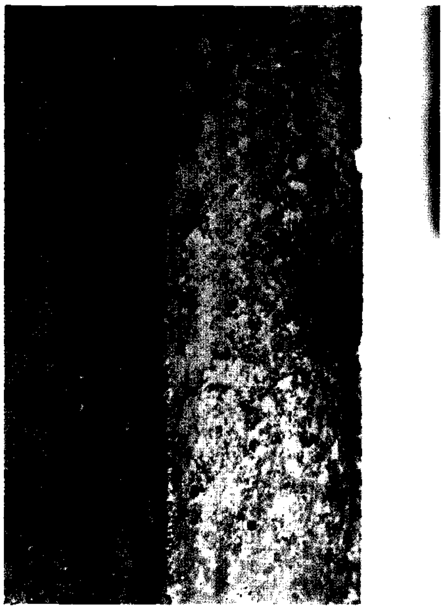

(f) Rust staining

Plate 33 Classification of signs of deterioration in concrete components

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Page blank in original

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Appendix B Review by BRE of reports of investigations of LPS dwellings by owners and their consultants

B1 Introduction

B1.1 When the investigation of LPS dwellings was announced, local authorities were invited to send to BRE, in confidence, relevant reports of investigations which they had carried out or had commissioned.

B1.2 One hundred and twenty-six reports were examined, excluding those on the Taylor Woodrow-Anglian system already considered[1,2]; 64 contained information relevant to this review. Many of the reports are those already referred to in the publication by Reeves[2] but, whereas that document contained in effect a catalogue of shortcomings which had been found, this Appendix extracts detailed information relevant to strength, stability, robustness and durability. Eleven were received too late for inclusion but they have been examined to check that the information they contain is consistent with the conclusions of this report.

B1.3 The terms low, medium and high categories of chloride used here are defined in paragraph A1.2 of Appendix A.

• • • • • • •

B2 The Balency system

Site CBA1

B2.1 The dwellings at this site were constructed in three phases between 1967 and 1976, and five types of dwelling were built. All dwellings contained piped gas.

B2.2 In total 34 buildings were inspected and 376 samples of concrete tested. The results of analysis showed:

(a) Generally carbonation depths were low, usually less than 10 mm with occasional depths of carbonation between 15 and 25 mm.

(b) The concrete cover to the reinforcement was usually found to be between 40 and 50 mm with only isolated instances of the cover being as low as 15 mm.

(c) The chloride contents were generally low with a few results in the medium category and just one isolated high level result recorded.

(d) The average cement content was 16.5%.

B2.3 The results are very similar to those found in a preliminary inspection by BRE (Appendix A) with the exception of the one high chloride content which was not present in the limited sampling undertaken by BRE.

B2.4 The report concludes that there is a very low risk of corrosion from reinforcement in the long term. This supports the BRE view that the long-term durability of the houses examined can be expected to be good. The report stated that only a limited investigation into the stability aspects of the five types of dwellings was possible. However a provisional statement on stability was provided for the dwelling types, as follows:

Type A Linear Housing Phase 1

B2.5 These dwellings were reported to consist of a reinforced cast-in-situ concrete frame infilled with Balency precast concrete panels. The initial view expressed was that the dwellings were not sensitive to progressive collapse and were probably satisfactory. This has to be checked when the relevant design information becomes available.

Type A Linear Housing Phase 2

B2.6 This type of housing has a cast-in-situ first storey with a Balency superstructure. Again it was thought that they were not sensitive to progressive collapse and calculations showed that they had been designed to reduce the possibility of progressive collapse. Further checks are still required.

Type C

B2.7 Insufficient information was available to form a view on this type of construction.

Type E

B2.8 These were 13-storey blocks which had been strengthened. Some differences were found between the detailing specified on the available drawings and that found through inspection on site. There was no evidence of any structural problems with the dwellings but further work is needed to verify the adequacy of the 'as built' construction.

Types F and G

B2.9 These were later designs and documented evidence showed that they had been designed to modern standards of stability and therefore no further work was recommended.

B2.10 The overall impressions gained from the investigations of this site to date were that the general quality of concrete was higher than average and the standard of the construction and workmanship employed had been good.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

B3 The Bison system

B3.1 BRE received many more reports from consultants on the Bison system of construction than on any other type. This is probably because Bison construction constitutes the largest single type amongst the large panel system building population (approximately 23%) and because Bison buildings were the subject of the DOE letter of 23 October 1983 advising local authorities to assess them.

B3.2 BRE received a total of 80 reports on the Bison system, of which 31 contained information relevant to this review. These reports described conditions at 22 sites and very brief summaries of the observations and findings of the relevant reports are given below.

B3.3 Many of the reports referred to the Bison 'Wallframe' system of construction and, although in many cases this description may be accurate, some reports would appear to have used the description 'Wallframe' as a general term to describe other variants of the Bison large panel range of construction.

Site CB1

B3.4 BRE received four reports of this site which covers four estates. Each report contained information on different aspects of the buildings on each estate.

Estate 1

B3.5 This comprised one high-rise block and some low-rise development. The main problem identified in the high-rise block was the condition of the cladding. Reinforcement corrosion was causing spalling in places and repairs to damaged panels undertaken at the factory incorporated calcium chloride which was now causing failure of the repaired areas due to corrosion of the reinforcement.

B3.6 No in-depth structural investigation of the high-rise block was reported but the observation was made that there were no obvious signs of structural distress.

B3.7 Limited investigation of the low-rise dwellings revealed that the floor/wall junctions were of an early type and provided no effective tie between these components. The in-situ concrete in the joints was found to be of poor quality and inadequately compacted.

B3.8 The original design incorporated internal buttress panels to provide lateral stability. These had not been constructed, the lateral stability being provided mainly by the fixings to the front and rear spandrel panels. There was evidence of movement between the floor and wall panels which had caused spalling of the floor-panel-bearing nibs. The report concluded that the poor level of tying and inadequate lateral stiffness was probably a contributory factor to this spalling.

B3.9 In view of advanced corrosion of the spandrel panels and their relatively light fixings, the report recommended strengthening in all the low-rise dwellings.

Estate 2

B3.10 This estate contained three high-rise blocks and one low-rise block. The structural condition of the high-rise blocks was not investigated, but again visual inspection revealed no obvious signs of structural distress. The cladding was reported to be in fairly good condition but chlorides were found to have been added to the factory repairs and this had resulted in failure of the repair due to corrosion of reinforcement.

B3.11 The low-rise dwellings were to the same design as those at Estate 1 and were essentially in a similar condition exhibiting similar shortcomings and defects.

Estate 3

B3.12 This estate was entirely of low-rise construction but was of a later design which, according to drawings, incorporated more positive tying between floors and walls.

B3.13 No structural investigation of the joints was carried out but it was reported that there was little sign of movement between components.

B3.14 Cracking and spalling of the concrete was occurring at the gable wall return and factory repairs were also failing. In general the deterioration was superficial in nature and did not give cause for concern.

Estate 4

B3.15 This estate was again low-rise of the later type (similar to Estate 3) and, although not investigated structurally, it was reported as showing no signs of structural distress. It was stated that the panels contained no chlorides but that the repaired areas of panels contained high levels of chloride.

B3.16 The numerical results for chloride contents of the concrete samples were not presented in a way which enabled interpretation with respect to sample locations, but a total of 37 samples were taken of which 62% were in the low category, 30% were in the medium category and 8% were in the high category. No measurements of carbonation depths were given.

Site CB2

B3.17 The report of this site contained information of a survey of the condition of the cladding of three 15-storey Bison Wallframe blocks. It did not contain any structural information.

B3.18 It was reported that shrinkage cracks were present at window openings in the long loadbearing gable wall panels, and spalling caused by corrosion of reinforcement was apparent on one elevation of one of the blocks.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

B3.19 The external walls were sampled for chloride content and half the results fell in the low category and half in the medium category. However it was noted that the reported cement contents were abnormally high, which may mean that the percentage chlorides quoted are an underestimate of the true values.

B3.20 One spandrel panel was described as having low concrete cover to the reinforcement and showing signs of significant deterioration but no chloride or carbonation figures were reported.

Site CB3

B3.21 There were four high-rise blocks on this site of which one was investigated. It was reported that a large number of cladding panels had been damaged prior to erection and that the repairs carried out were now failing.

B3.22 The general impression gained from the inspections of the blocks was that the site supervision had been poor during construction resulting in many instances of bad workmanship. Three concrete samples were taken for analysis which gave chloride values of 0.14, 3.98 and 0.46%, indicating that chloride had been added to the concrete during manufacture of some of the components.

B3.23 Inspection of the dry pack had revealed that it was generally of poor quality and that it was missing in some locations. The consultant's overall view was that the structure was in a safe condition under normal loading but that the bottom four storeys should have the dry pack reinstated.

B3.24 It was additionally reported that weathering details were not in accordance with the drawings and the structure was subject to severe condensation and to water penetration through the roof.

Site CB4

B3.25 This site contained two Bison Wallframe 11-storey blocks, one built in 1963 and the other built in 1967. Both were investigated and the results reported.

Block 1, constructed 1963

B3.26 Wall panels removed from this block showed that the ties between the inner and outer skins had negligible bond in the concrete and could be easily pulled out by hand. It is believed that the polystyrene filling to the panel was largely supporting the outer skins.

B3.27 The dry-pack material between the panels was friable and weak and was not supporting the panel in the manner intended, and cracks were present at levelling bolt locations.

B3.28 The in-situ make-up concrete in the wall was generally poor and there were many instances of corrosion of embedded bars; a tie bar had corroded through completely in one case.

B3.29 Seventeen samples were taken for analysis of chloride and the results showed that 63% of the samples were in the low category and 47% were in the medium category, with no high results reported.

B3.30 The decorative facing concrete to the panels was fully carbonated in all samples but in general the structural backing concrete was carbonated to a depth of less than 10 mm, although two results in excess of 30 mm were recorded.

B3.31 The conclusions for block 1 were:

(a) The attachment of the outer skin of the cladding panels was unsatisfactory.

(b) Reinforcement corrosion occurring in the horizontal joints would eventually lead to distress in the structure.

(c) Many corners of panels were loose or cracked and represented a safety hazard to the building users.

(d) Serious shortcomings existed in the in-situ joints and required remedial action.

B3.32 The structure's design had been assessed previously on the assumption that full frictional resistance occurred between components. As this was not the case, the view was taken that the structure needed reappraisal.

Block 2, constructed 1967

B3.33 Investigation of this building showed the ties in the wall panels to be better embedded and fixed at a greater number of locations than those in block 1. It was concluded that there was no problem in relation to the tying back of the outer skins of these panels. The panels themselves were less carbonated than those of block 1 with only 30% of the facing concrete fully carbonated and the rest carbonated to a depth of between 10 and 50 mm.

B3.34 Twenty-two concrete samples were analysed for chloride content. 64% were found to be in the low category, 32% in the medium category and 4% in the high category. Some corrosion of reinforcement was observed.

B3.35 Again, as in the previous block, the dry pack was generally of poor quality and often absent, leading to the view that some of the vertical load was being transferred through the levelling bolts.

B3.36 The overall impression gained was that block 2 was in a significantly better condition than block 1 but still contained shortcomings which needed reappraisal with a view to strengthening.

Site CB5

B3.37 Information from this site was gained during demolition of a 3-storey block of flats. Demolition of

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

these flats was reported to be difficult.

B3.38 The floor and roof were of timber construction. Many roof joists were found not to be fixed to the gable panels as specified. However the concrete beams at roof level were found to be adequately fixed to the walls and provided sufficient fixity at the top of the structure.

B3.39 None of the levelling bolts inspected in the second-floor gable wall had been provided with nuts, and packing had been used to level the panels. Other in-situ joints in the structure were found to be adequate and constructed with the correct interlocking reinforcement. No materials information was reported.

Site CB6

B3.40 The report of this site was only concerned with the condition of the cladding of one 11-storey Bison Wallframe block built in 1965. The structure had been appraised in 1969 when it was concluded that the structure was satisfactory. No piped gas was supplied to the building.

B3.41 In 1977 a substantial piece of concrete was reported to have fallen from the building and the external condition was reassessed. It was found that the parapets were badly cracked and spalled and repairs to the panels carried out at the factory at the time of construction were failing.

B3.42 There was also general crazing and rust staining on panels. As a result remedial work was carried out in 1978. The report contained no materials data nor investigations into the condition of the structure.

Site CB7

B3.43 The investigation at this site, which comprised six 7-storey blocks and one 15-storey block, was mainly concerned with the condition of the cladding. However one flat in one of the 7-storey blocks was examined in detail; the construction was found to be in accordance with the drawings and to be of a satisfactory standard.

B3.44 Galvanised wall ties had been used to connect the brick cladding to the concrete panels, and corrosion of these ties had started at the outer face.

B3.45 No materials data were included.

Site CB8

B3.46 The report of this site was a summary of an extensive visual inspection of cladding panels of 57 Bison cross-wall blocks of 2, 3 or 4 storeys in height. Some materials sampling had been carried out but the detail figures were not included.

B3.47 Approximately 3000 panels were inspected and the following observations made:

(a) 2% (60 panels approximately) were found to be cracked and half of these had cracks wider than hair-line cracks.

(b) 0.75% (22 panels approximately) had sections of loose concrete.

(c) 6% (180 panels approximately) had casting damage which had been repaired at the time of construction; these repairs were in general less than 150 × 150 mm.

(d) 0.9% of panels (approximately 27) showed reinforcement that was exposed or showed corrosion staining.

B3.48 The reported materials data showed that chloride had not been added to the panels during manufacture but had been added to the repairs, and that carbonation had penetrated to an average depth of 10 mm with a maximum of 20 mm.

Site CB9

B3.49 This site comprised four 19-storey blocks and four 4-storey maisonette blocks built between 1967 and 1971. One high-rise flat had been inspected in detail and the report was primarily an account of the strengthening history and future requirements.

B3.50 Following the Ronan Point Inquiry serious attempts were reported to have been made to devise strengthening measures to meet the design criteria for piped gas (5 psi). It was concluded that strengthening to the 5 psi standard was not possible because of the light reinforcement in the panels and the inadequate tying details. Gas was therefore removed from the high-rise blocks and they were strengthened to meet the lower requirement of 2.5 psi. This strengthening had been checked and the work inspected. The report concluded that the strengthening was satisfactory in all respects and no further action was required, provided gas continued to be excluded.

B3.51 The low-rise construction was designed after the Ronan Point Inquiry and as a result the tying of the panels and the panels themselves were more robust. The overall condition of the buildings was good and it was known that the construction had been closely supervised. It was therefore concluded that no further investigation of these dwellings was necessary. No materials data were included in the report.

Site CB10

B3.52 The report from this authority was a comprehensive structural review covering four locations each of which contained a number of estates. In total 77 structures were considered in the report. Only the more significant observations which may have a direct bearing on the structural condition of large panel structures generally are summarised here.

Location 1

B3.53 The structure examined at this location was an 11-storey Bison Wallframe block, built in 1964, which had subsequently been strengthened.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

B3.54 Two flats had been investigated in depth. The floor/wall joints were exposed and in the first flat the interconnecting loop and dowel bars were found to be in place but the corresponding reinforcement in the second flat was not present. In addition the floor/gable wall joints in the second flat contained reinforcement different from that shown on the drawings. In both flats the dry pack was found to be in good condition.

Location 2

B3.55 At this location there were 30 blocks with heights within the range 5 to 8 storeys. Twenty-six of the blocks were finished prior to the partial collapse of Ronan Point (referred to in the report as Type 1) and four of the blocks were built to amended designs after the partial collapse of Ronan Point (referred to in the report as Type 2).

B3.56 The details in the Type 1 blocks were found not always to correspond to the drawings, and distorted loops, inadequately bonded bars or bars missing resulted in no mechanical linkage between some components. These defects were considered to be due to poor workmanship and supervision during construction.

B3.57 Twenty-three of the 26 Type 1 blocks had been strengthened previously and the view expressed in the report was that the strength of these 23 blocks was adequate to resist their normal loadings taking into account the defects observed but that the blocks may not be sufficiently robust to resist accidental loads in a satisfactory manner.

B3.58 It was recommended that the three Type 1 blocks which had not previously been strengthened should now be strengthened.

B3.59 The investigation into the four Type 2 blocks showed that the interlocking loop and dowel connections were present although the dry pack quality was poor. Further investigation into the amended design of these blocks was in hand and no firm conclusions were made in the report.

B3.60 None of the structures inspected were showing obvious signs of structural distress.

Location 3

B3.61 The 27 structures at this location consisted of 21 medium-rise blocks and six high-rise blocks all of which had been designed after the Ronan Point Inquiry between 1968 and 1977.

B3.62 The inspection showed that the improved designs had been implemented and that the workmanship was generally good. It was concluded that the blocks were satisfactory in all respects.

Location 4

B3.63 The 22 blocks at this location were built between 1968 and 1975. Nine were Type 1 and 13 were Type 2. Eight of the nine Type 1 structures were low rise and one was high rise. Investigations showed that the loop bars in the floor/wall connections in the high-rise block were missing in many instances and the dry pack was of poor quality. The low-rise construction had additional reinforcement in the joints but the quality of the concrete was poor. However none of the Type 1 blocks were showing any signs of distress.

B3.64 Eight of the 13 Type 2 blocks were low rise and five were of high-rise construction. The inspections showed that the joints in both the low-rise and high-rise blocks were constructed as intended and that the quality of workmanship was adequate. No materials information was included in the report.

Site CB11

B3.65 This site contained five 17-storey blocks built in 1966. The cladding on the blocks was generally in good condition with some minor cracking around openings and with some evidence of factory repairs becoming loose.

B3.66 The connections between components were, in the main, constructed according to the drawings, although four out of 15 of the corner wall panel/wall panel joints were constructed incorrectly. Shortcomings such as loop bars bent up and not straightened to receive dowel bars, and missing dowel bars, occurred, resulting in cracking at some of the corner joint locations. Chloride determinations were reported for six concrete samples. Five of the results gave low chloride contents and one was in the high category. The locations from which the samples were taken were not stated. The only carbonation results obtained were taken from beneath an asphalt screed and were therefore not representative of the condition of the concrete.

B3.67 No signs of significant structural distress were reported.

Site CB12

B3.68 The report of this site covered 32 low-rise blocks built in the late 1960s. Excessive deterioration in the cladding panels was reported to have occurred due to corrosion of reinforcement which had caused cracking and spalling. The concrete cover to the reinforcement was found to be generally low, which, in combination with carbonation and medium levels of chloride, probably accounts for the excessive deterioration.

B3.69 Twenty-two concrete samples were analysed. Only two samples had chloride levels in the low category, 17 were in the medium category and three were in the high category. This indicated that chlorides had been added to the concrete during manufacture of the panels. Sixteen of the samples had carbonation depths less than 10 mm and six had carbonation depths of greater than 10 mm.

B3.70 Many of the joints exposed were found to be

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

different from those shown on the drawings. Often dowel bars had been left out and loop bars did not intersect. The overall view expressed was that some of the substitute details were satisfactory but that others were not providing adequate mechanical connection between panels. The conclusion reached was that the structures were satisfactory for their normal service loads but not for abnormal loading such as may arise from a gas explosion. Piped gas was still supplied to these dwellings.

Site CB13

B3.71 The report of this site was concerned mainly with the cladding performance but contained some observations of the joints examined. It was concluded that, in general, the joints were as specified with the exception of the vertical corner joints which contained many discrepancies probably due to the difficulty of constructing them. The dry pack was often poorly compacted and missing in some places.

Site CB14

B3.72 This site was reported to have an early type of Bison 2-storey dwelling since, although most of the joints were reinforced as shown on the drawings, many did not have the specified interconnecting reinforcement. Where reinforcement was provided in the gable/first floor connections, it was not embedded in the components but laid in the floor screed.

B3.73 The first floor was specified as 245 mm (10 inch) thick but it was found that it had been constructed using 50 mm thick prestressed planks with a 60 mm in-situ reinforced topping giving an overall thickness of 110 mm. Since all the floor/wall details assumed a floor thickness of 245 mm, the geometry of the connections was different from that assumed in the design.

B3.74 The panel concrete was found to have a low chloride content. The depth of carbonation of the panels was less than 10 mm. It was therefore concluded that deterioration of the panels due to reinforcement corrosion was unlikely.

B3.75 The report concluded that the dwellings were satisfactory under normal loading but recommended strengthening to the joints at the gable wall/first floor, first floor/front and rear panels, lower gable/upper gable panels and lower gable/floor panels.

Site CB15

B3.76 Three 9-storey blocks were investigated. The reports concluded that the connections between the loadbearing walls and floors were satisfactory and buttress walls provided adequate lateral stability. Five concrete samples were taken and these showed chloride levels to be low and the carbonation depths of the exposed aggregate finish to be between 5 and 40 mm. Carbonation had not penetrated the dense backing concrete of the panels.

B3.77 There were cases of the exposed aggregate finish becoming debonded from the surface, although the frequency of debonding was described as occasional or very occasional.

B3.78 The ties in the sandwich panels were made of stainless steel and were in good condition. However the design of the ties was considered to be poor and this, combined with low embedment as a result of misplacement, led to a recommendation that the outer skins of all sandwich panels should be tied back as a remedial measure.

Site CB16

B3.79 The report of this site was mainly concerned with the long-term durability of an 8-storey block constructed in 1965 which had been strengthened subsequent to the partial collapse of Ronan Point. The dry pack was found to be of good quality, the strengthening had been carried out satisfactorily and the floor/wall connections examined were correctly made according to the drawings.

B3.80 One hundred and two concrete samples were taken from panels and were analysed for chloride content. The average of the results was in the low category with some results in the medium category and just one in the high category. Ninety-nine measurements of carbonation depth were also made in two types of panel. The average depth of carbonation in the white panels was 3 mm and in the black panels was 20 mm.

B3.81 It was estimated from these data that it would be approximately 17 years before 10% of the panels lost their protection to the reinforcement. Isolated rust staining was present in approximately 12% of the panels.

B3.82 All balcony slabs were inspected and 16% were found to be cracked. Concrete cover to the transverse reinforcement was 11 to 16 mm and the depth of carbonation averaged 5 mm with a maximum of 12 mm. The average chloride content in the slabs was 0.39% with a maximum value of 1.5% recorded. It was therefore concluded that chlorides had been added to the concrete during manufacture of some slabs although the higher results were few.

B3.83 The roof slabs were of a voided type and had been subject to water penetration. Reinforcement corrosion and concrete spalling were evident in these components. The concrete cover to the reinforcement was between 6 and 12 mm, and the average depth of carbonation was 7.5 mm with a maximum of 28 mm in one instance. The average chloride content in the roof slabs was 0.2% with a maximum value of 0.59%. It would seem therefore that the deterioration was mainly due to corrosion of reinforcement following carbonation of the concrete.

B3.84 Delta bronze cladding ties were identified and as a result additional fixings were provided[3].

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

B3.85 The overall conclusion of this report was that the remaining life of the structure was likely to be determined by the durability of the black cladding panels and the condition of the roof. On this basis it was estimated that the structure had a minimum further life of 20 years.

Site CB17
B3.86 This site contained five estates providing a total of 792 dwellings. The buildings were Bison Wallframe 3- and 4-storey flats and maisonettes and 2-storey terraced houses built between 1966 and 1968. All had piped gas supplied. The report covered one of the estates on which 98% of the dwellings were inspected. None of the buildings were showing significant signs of structural distress.

B3.87 Opening up the joints between components revealed significant shortcomings in the construction.

B3.88 There was inadequate bearing of the floor and roof planks on the loadbearing walls. Spalling was occurring at the wall/floor joints and excessive movement was taking place at these locations. A party wall/floor connection had insufficient bearing and no mechanical linkage provided.

B3.89 Linkage between spandrel panels and floors was absent in maisonettes and only partially in evidence in the flats. However the dry pack was generally in sound condition in all the dwellings inspected.

B3.90 The report concluded that the lack of tying raised doubts about the factor of safety in all the dwellings under normal loading and it recommended that all dwellings should be strengthened.

B3.91 Carbonation depth was found to be between 2 and 5 mm in general with isolated depths of 10 mm. Chloride contents were generally low with a few results in the medium category. Component durability was therefore not considered to be a major problem.

B3.92 It was further recommended that piped gas should be removed from dwellings and heating provided using a district system.

Site CB18
B3.93 This site contained two 5-storey and two 4-storey blocks of Bison Wallframe construction.

B3.94 External examination revealed only isolated cases of cracking or spalling except for the balcony slabs of which approximately 50% had localised spalling. The concrete cover to the reinforcement in these slabs was usually 25 mm but in some cases covers as low as 10 mm were recorded.

B3.95 Internal inspection showed that the dry pack had been properly compacted in the external walls in general but that it tended to be less good towards the outer face of the wall and not in place to the full depth of the horizontal joint. The nuts on the levelling bolts had not been wound down during construction and showed signs of corrosion.

B3.96 The in-situ joints between the wall panels and the ceiling panels were found not to be tying the components together effectively since at some locations the reinforcement was surrounded by polystyrene.

B3.97 The report concluded that there were no significant structural or movement problems but that the incomplete dry pack should be grouted in all joints supporting more than three storeys.

B3.98 Since the depth of carbonation varied between 5 and 25 mm and chloride contents were low, it was concluded that there was no immediate risk of widespread deterioration but that coatings should be used to ensure a reasonable future life for the components.

Site CB19
B3.99 This site comprised one 19-storey block built in 1969 and 32 low-rise blocks. The report covered the 19-storey block only. External inspection identified a number of defects which were not structurally significant, such as diagonal cracking at the corners of window openings, spalling of concrete due to corrosion of reinforcement around openings, and movement of parapets.

B3.100 Extensive opening up of all types of joint was carried out and in all instances the joints were found to be as detailed on the drawings and to be well constructed.

B3.101 Samples were analysed for chloride and only one showed a chloride content in the medium category, the rest being in the low category.

Site CB20
B3.102 The report concerned a 12-storey Bison Wallframe structure built in 1964 which had been partially strengthened on the 8th, 9th, 10th and 11th floors only. Piped gas had been removed.

B3.103 The joints exposed were found to be in satisfactory condition but it was recommended that the lower floors should also be strengthened.

B3.104 Carbonation depths had been assessed, although they were not quoted in the report. Predictions of the future life of the cladding panels were 8 to 10 years for the upper storeys, 15 years for the middle storeys and 25 years for the lower storeys. Coatings were recommended in order to extend the life of all panels.

Site CB21
B3.105 At this site three 11-storey blocks of an early type and two 19-storey blocks of Bison Wallframe construction were present. They were all constructed between 1963 and 1965 and no major defects were

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

apparent although a number of superficial defects were present. These defects were:

(a) Downward nibs on gable panels broken off or cracked, sometimes exposing the reinforcement

(b) Columns at roof levels spalled due to corrosion of the main reinforcement resulting from inadequate cover and poor-quality concrete

(c) Stirrups to beams at roof level corroding due to little or no concrete cover

(d) Bowing of spandrel panels due to differential shrinkage of the two types of concrete used in their construction

(e) Damage to corners of panels and their edges due to poorly made factory repairs or due to reinforcement corrosion resulting from the addition of chlorides to the repaired areas

• • • • • • •

B4 The Camus system

B4.1 Five reports were received on the Camus system describing the condition of buildings at three sites.

B4.2 The Camus system is similar to most other large panel systems in its general construction. It employs 6 inch solid concrete cross walls, with two layers of reinforcement, as the main loadbearing elements and sandwich panels, with a 5¾ inch loadbearing inner skin and a 3 inch outer concrete skin giving a 10 inch thick overall construction for the outer envelope. It differs from other systems in two respects. First, the floor slabs span in two directions and are therefore supported on all four sides. Second, connection between the inner and outer leaves of the sandwich panels is provided by two ferrous lattice connectors at each end of the panel and not by wall ties.

Site CCA1

B4.3 At this site the estate comprised eleven 20-storey blocks built approximately 20 years ago. Five of these blocks were inspected both internally and externally. The external inspections revealed a high incidence of rust staining and spalling due to low concrete cover where carbonation had reached the reinforcement.

B4.4 Although no materials data are given in the report, chloride contents were reported to be in the medium category which indicates that calcium chloride may have been added during the casting of some components.

B4.5 It was noted that cracking was present at the ends of the panels where the ferrous lattice connectors were present and it was thought that corrosion of this lattice may have accounted for the cracking.

B4.6 The internal investigation included opening up in-situ joints between components. They were reported to have been well constructed with reinforcement in good condition. There were no signs of structural distress.

B4.7 The report concluded that the blocks were structurally sound and met the 2.5 psi tying requirement but did not meet the full 5 psi design standard. It was decided that the blocks would need to be strengthened with angle connectors between floors and walls in view of possible use of liquefied petroleum gas by the occupants. In addition, stainless steel ties were to be provided to augment the ferrous lattice connections between the inner and outer skins of the cladding, and all spalled areas were to be repaired. It was felt that no guarantee of long-term repair was possible because of the chloride contents, and continued monitoring and repair was recommended in the report.

Site CCA2

B4.8 Three reports were received from this authority on the condition of buildings at three locations. At the first location three 22-storey blocks built in the late 1960s were examined. They had been strengthened with angles after construction.

B4.9 External examination revealed a number of superficial defects:

(a) Areas of cracking and spalling exposing the reinforcement and giving rise to loose concrete and mosaic finishes

(b) Cracking in the tops and bottoms of panels ranging from hair-line width to 3 mm in thickness

(c) Voiding at the edges of panels which had given rise to corrosion of reinforcement

(d) Ends of bars exposed at the edges of panels and the outer faces of balcony slabs

(e) Hair-line cracking at the wall/floor junctions within balcony areas

B4.10 No opening up of joints was undertaken and no materials data were included.

B4.11 It was concluded that the blocks were structurally sound but that repair should be carried out to rectify the superficial deterioration on the cladding panels in order to avoid hazards from falling concrete and mosaic tiles.

B4.12 A total of six 16-storey blocks were present at the other two locations. The conditions reported in the six blocks were very similar to those at the first

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

location with the exception that cracking around window reveals was more prevalent. Similar conclusions were drawn for these two locations as for the first.

Site CCA3

B4.13 This site contained three types of Camus construction; 2-storey houses, 3-storey flats and 5-storey flats designated as types 2M, 3M and 5M respectively. In total 70 blocks were built between 1966 and 1968 providing 607 dwellings. Ninety-eight dwellings were inspected and a detailed study of one type 2M, four type 3M, and two type 5M dwellings was made. In addition one link block was inspected in detail.

B4.14 Few defects were found and the structures were reported to be in good condition. Some minor cracking was present but this was attributed to shrinkage and lack of provision for movement at some locations. In some instances expansion joints had not been constructed according to the original design and in others insufficient allowance had been made for movement.

B4.15 Details of the findings of the joint inspections were not given in the report but a statement was included to the effect that all the joints were constructed according to the design, with good workmanship, and the reinforcement contained was found to be in good condition. No materials data were reported. The overall conclusion of the report was that the construction inspected was structurally sound and in good condition.

• • • • • • •

B5 The Cebus system

B5.1 BRE received four reports on the Cebus system of construction. These reports described conditions in six 23-storey blocks which were constructed in two phases between 1966 and 1968.

Site CCE1

B5.2 Phase 1 comprised two blocks, one flat being investigated in each block. The findings from each flat were generally similar with the exception of the quality of the in-situ concrete in the joints which was good in one flat and poor in the other.

B5.3 Tie bars between floors and panels were often found to be of a smaller diameter than specified, with concrete cover of the order of 20 mm instead of the specified 100 mm. In addition the bars had frequently been bent out of position and had not been embedded in the in-situ joints. There were a number of instances where tie bars had been omitted entirely from the joints.

B5.4 At the corner panel/panel junction the interconnecting bars did not extend fully into the in-situ concrete. Lightweight concrete had been used in the construction of one of the panels instead of normal dense concrete as specified.

B5.5 The vertical joints between adjacent panels had projecting reinforcement but this had been bent down along the face of the panel so that no mechanical linkage was provided between adjacent panels.

B5.6 Externally the blocks were showing signs of corrosion of the reinforcement in the panels which was causing spalling of the mosaic finish. This deterioration was reported to be affecting a significant proportion of the Phase 1 blocks. The Phase 1 blocks have subsequently been strengthened as was recommended.

B5.7 The construction in Phase 2 was a modified version of the Phase 1 construction with more tying bars specified and joint details amended to make them easier to construct. The outer skin of the panels was also made thicker to provide more concrete cover to the reinforcement, and all concrete was specified as normal dense concrete.

B5.8 The structures in three of the four blocks built in Phase 2 were found to be in significantly better condition than those found in Phase 1. Tie bars between floors and walls were of the correct diameter and formed proper interconnecting joints, and the concrete cover and embedment of the reinforcement was as specified. Similar sound construction was found at the vertical corner joints between panels.

B5.9 The vertical panel/panel connections were still not constructed as specified but the detail provided was considered to be an improvement on the Phase 1 joint. The report concluded that this joint was satisfactory.

B5.10 The quality of the in-situ concrete was found to be good and no corrosion of reinforcement in the panels was evident. As a result three Phase 2 blocks were assessed as structurally satisfactory and not requiring remedial measures.

B5.11 In the remaining block constructed in Phase 2, two flats were examined and shortcomings were discovered that were similar to those encountered in Phase 1. There were no loop bars provided at the floor/panel connections and in general the tying between components was very sporadic and poor. The in-situ concrete in the horizontal joints was poorly compacted and in some instances had shrunk away from the precast components.

B5.12 Most of the components were found to be poorly tied and strengthening of the block was recommended.

B5.13 A further two flats in this block were inspected by opening up as a check on the conditions found. This second inspection revealed exactly the same shortcomings and it was therefore concluded that the defects discovered in this Phase 2 block were likely to obtain throughout the structure.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

B6 The HSSB system

Site CH1

B6.1 BRE received four reports on the HSSB (High Speed System Build) system which were concerned with a series of investigations into the condition of 2-storey houses and 3-storey flats. Approximately 800 dwellings were provided on the site constructed 20 years ago. The investigations were carried out in conjunction with researchers from BRE.

B6.2 Results of BRE's investigations are reported in Appendix A. The following is a summary of the consensus arrived at between BRE and the buildings' owners.

B6.3 It was established that chlorides were present to some extent in all types of components and all areas of the estate. The worst affected areas were the stairs in the 3-storey flats where very high levels of chloride (in excess of 1.5%) were frequently found.

B6.4 In addition 24% of the precast concrete floor panels tested were shown to contain over 1% chloride, 40% had values between 0.4 and 1.0%, and only 20% contained less than 0.4% chloride. The precast wall components were occasionally found to contain in excess of 1.0% chloride but more often contained medium levels in the range 0.4 to 1.0%.

B6.5 Carbonation depths in the floor slabs were also high, typically 25 mm, but in some cases they were in excess of 40 mm. Fewer measurements of carbonation were made in the wall panels but carbonation depths between 5 and 10 mm were recorded, indicating a better quality of concrete than that used in the floors.

B6.6 In view of the materials data the conclusion was reached that the long-term durability of the estate could not be assured.

B6.7 Investigations of the connections between wall panels and floor panels revealed that the degree of tying was unsatisfactory although no signs of structural distress had occurred under normal loading.

B6.8 It was concluded that strengthening should be carried out to improve the tying of structures and that it was appropriate to design the tying to withstand the 2.5 psi standard of equivalent static pressure. It was not considered necessary or practical to strengthen to the full 5 psi standard even though gas was supplied, since horizontal progressive collapse could be prevented by a number of measures to ensure lateral stability, such as the provision at intervals of solid buttress walls.

• • • • • • •

B7 The PAC system

B7.1 This system is a low-rise cross-wall system with spandrel panels to the front and rear elevations. BRE received one report on the PAC system. The report had been commissioned to investigate extensive dampness and lack of weathertightness of the dwellings, which were built in 1966. It did not address the structural condition nor the quality of the materials.

Site CPAC1

B7.2 The only information relevant to this review was an observation that some of the beams over garage areas were cast using high alumina cement concrete. It is not known if this is a general feature of the system. It seems more likely that it was a local variation introduced because of the particular architectural configuration at this site.

• • • • • • •

B8 The Reema system

B8.1 BRE received 15 reports giving information on the Reema system of construction. Six of these contained information relevant to the assessment of the condition and durability of Reema construction. The six reports described conditions at four separate sites.

Site CR1

B8.2 This site comprised several 4-storey blocks of flats of the Reema type and had no piped gas supplied. No structural distress nor signs of instability were reported and apart from some minor cracking in the outer faces of some wall panels the buildings had performed satisfactorily. Examination of the floor/loadbearing panel connections and the vertical continuity reinforcement between panels showed that the floor/wall joints had not been constructed in accordance with the design and the joint provided little horizontal fixity at each floor level. The continuity steel in the in-situ columns had been omitted and it was reported that the 'Reema' company had confirmed that this may be normal in some later types of low-rise designs.

B8.3 No materials data were contained in the report.

B8.4 The main conclusion of the consultant was that the construction did not comply with current standards of resistance to instability and that the tying between floors and walls was unsatisfactory. It was recommended therefore that lateral tying in the structures should be increased.

Site CR2

B8.5 The three 12-storey blocks on this site were supplied with piped gas at the time the consultant's report was compiled. Piped gas has since been removed from these blocks.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

B8.6 No drawings were available of the construction but the consultant reported that no connections were found at the base of panels or between the in-situ columns and panels. Concern was also expressed about the length of span of the hollow precast concrete floor components.

B8.7 It was observed that the general quality of the precast panels and floor units was satisfactory but that some external faces were showing signs of spalling. This was attributed to low concrete cover to the reinforcement (10 mm or less) in some instances. It was also noted that there was a lack of vertical continuity steel in the walls between storeys.

B8.8 The in-situ columns and beams showed local honeycombing but in general had been cast satisfactorily especially where the detail made casting easy. Casting at some of the more difficult locations had been executed less well.

B8.9 The deterioration found consisted of local cracking and spalling around windows and door openings, spalling to supports of balustrades, bars exposed due to low concrete cover, and some bottom corners of panels missing.

B8.10 Analyses of only five concrete samples were reported. They showed that the depths of carbonation varied from 12 to 15 mm in the in-situ concrete samples, with chloride levels low at 0.1%; the single result from the precast panels gave a carbonation depth of 30 mm and a chloride level of 0.7% indicating that chlorides may have been added to the precast components during manufacture.

B8.11 The report concluded that the structure did not comply with the Building Regulation criteria for buildings containing piped gas and could not be strengthened to the 5 psi standard. It further concluded that the structure did not at present fully meet the current 2.5 psi design requirement but that it could be strengthened to this level relatively easily. Proposals were included for such strengthening.

Site CR3

B8.12 The three 16-storey tower blocks at this site had been inspected and assessed against current Building Regulation requirements for resistance to progressive collapse.

B8.13 The standards of construction and workmanship encountered in each of the tower blocks differed considerably from one block to another although none of the structures had shown any sign of significant structural distress during their service life. The main comments from the reports are summarised below.

Tower block 1

B8.14 The joints between the floor and loadbearing walls had been made well and the correct steel was present. The same situation was found at the base of the gable and intermediate walls. The vertical joints between panels in end flats had in some instances steel arrangements different from those shown on the drawings. Hoop bars projecting from the ends of walls had been bent back in some cases during erection and not straightened afterwards. This had resulted in a loss of mechanical interlock between some components.

B8.15 There were signs of cracking on the underside of some floor units which occurred more frequently in the upper floors. The in-situ concrete was generally found to have been placed and compacted satisfactorily although some areas of voiding were found.

Tower block 2

B8.16 In this block the reinforcing bars projecting from the precast floors did not engage with the hoop bars provided in the loadbearing walls. The in-situ concrete was poorly compacted and the in-situ packing at the base of the cross walls was voided. It was reported that there were signs of movement in the external corner junctions of the gable wall and non-loadbearing cladding panel.

Tower block 3

B8.17 As in the previous block, no physical connection was found between the floor reinforcement and the wall reinforcement, and the vertical joints between wall panels had not been built in accordance with the details shown on the drawings. In addition there was no connection between individual floor panel components.

B8.18 No materials data were included in the report although it was stated that the maximum carbonation depth measured was 7 mm.

B8.19 The consultants' conclusions on the three blocks were:

(a) The overall structural condition of the blocks was satisfactory although some joints had been badly constructed.

(b) The connections between intermediate and loadbearing gable wall panels and between floor and loadbearing wall panels had not been carried out in accordance with the design intention. The workmanship in these joints was variable.

(c) The strengthening to the 2.5 psi standard carried out previously had not been executed well and, as a result of poor workmanship and a 'slim design', the structure required further work to bring it fully to the current tying requirement for buildings without piped gas.

Site CR4
B8.20 At this site there were over 800 dwellings in 2- and 3-storey terraced buildings. A limited inspection was carried out involving visual examination of the external faces only. No major faults were reported and the only defects apparent were minor cracking and corrosion around window openings and one instance of corrosion causing a 450 mm spalled length of concrete. No materials sampling was undertaken.

B9 The Skarne system

B9.1 BRE received two reports on the Skarne system, one an inspection carried out on three 4-storey blocks of maisonettes, the other describing an inspection of a 16-storey tower block, both being constructed in 1967 – 68.

B9.2 The inter-component connections in the Skarne system are slightly different from those used in most other systems in that steel sections are used to form the mechanical linkage. These angles and straps are either bolted to sockets cast in the concrete panels or project out of panels and are joined by site welding.

Site CSK1
B9.3 At this site the three blocks of flat-roofed 4-storey maisonettes were being assessed for conversion into 2-storey houses incorporating pitched roofs. The access to each dwelling was by external precast stairways and walkways.

B9.4 All the panels in the maisonette construction were solid, the external walls being dry-lined to provide insulation.

B9.5 External inspection showed the panels to be in good condition, the instances of reinforcement corrosion being few and of a superficial nature. Where corrosion had occurred it was in the main due to low concrete cover to the reinforcement or where lifting eyes in the components had been poorly grouted after erection.

B9.6 The internal inspection revealed no major defects or signs of structural inadequacy. No signs of movement at joints were apparent and corrosion of reinforcement was only observed where roof leaks had occurred.

B9.7 When the steel joint connections were exposed they were found to be in good condition with only surface corrosion present. A number of connecting bolts to the angle cleats had not been fully tightened. The dry pack between loadbearing walls was in place and in good condition.

B9.8 The materials data were reported in terms of ranges in relation to the limits given in *Code of Practice* CP 110[4]. The results for the panels showed that the depth of carbonation ranged from 0 to 25 mm and that chloride contents ranged from 0.16 to 1.36%, with 59% of results below 0.35% chloride, 15% of samples between 0.35 and 0.5% chloride, and 26% of samples above 0.5% chloride.

B9.9 The results from concrete samples from the access stairs showed carbonation depths between 0 and 28 mm, and chloride contents between 0.16 and 2.96%, with 11% of samples in the range less than 0.35% chloride, 61% of samples between 0.35 and 0.5% chloride, and 28% of samples in excess of 0.5% chloride. It can be concluded therefore that calcium chloride had been added during manufacture of all types of components at times.

B9.10 The overall conclusion of the report was that no structural inadequacies of any significance had been found but that long-term durability was in question as a result of the high chloride in some components. It was therefore suggested that a more thorough materials survey should be conducted before definite recommendations were made concerning the future conversion of the dwellings.

Site CSK2
B9.11 The 16-storey block examined at this site employed the same steel fixings as the lower-rise blocks at Site CSK1, the main difference in construction being the use of 'sandwich' panels for the external wall envelope. The staircases and lift shafts were all constructed using solid precast components.

B9.12 In 1969 strengthening was recommended to the wall/floor and floor/floor joints. The inspection showed that only the wall/floor joints had been strengthened. It was subsequently recommended that tying between adjacent floor panels should be carried out according to the original recommendations.

B9.13 External inspections revealed a number of non-structural defects, the most common of which were: corrosion of reinforcement and spalling at corners and edges in panels, insufficient concrete cover to the reinforcement in faces of ribbed panels, repaired areas of panels failing resulting from corrosion, and some misalignment of panels leading to unequal joint thicknesses.

B9.14 Internal inspections were carried out in 71 unoccupied flats and in 15 of the 27 occupied flats. These revealed minor cracking at many joints between components but only a few of these were of sufficient size to be of concern.

B9.15 Dampness due to condensation, rain penetration and isolated cases of damage such as flooding caused by blocked drainage and water ingress through roof leaks, had resulted in corrosion or spalling at some locations.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

B9.16 The joints exposed were in good condition and little corrosion of the steel was evident. It was noted that most of the cracking due to movement between components was associated with the bolted connections rather than the welded type. In some cases the bolts were not fully tightened.

B9.17 The horizontal joints between floor panels were often cracked and further examination showed that this was due to poor and incomplete filling of the joints with in-situ concrete.

B9.18 The block had balconies at its corners which were supported on two sides, the outer corner being completely free. Attention was drawn in the report to inadequacies in their performance. All the balconies had deflected which had resulted in water ponding at the outer edges and penetrating the joint between the balustrade and the balcony slabs. There was also cracking on the slab soffits.

B9.19 The materials data from the wall panels showed that carbonation had penetrated between 0 and 30 mm, with the higher values occurring on the inner faces of the panels. Chloride contents were reported to be in the range of 0.2 to 1.47% with 24% of samples in excess of 0.5% chloride.

B9.20 The concrete samples from the floor panels indicated that they contained an average of only 8% cement and some had high chloride levels (2.03% in one case). These results indicate that calcium chloride had been added to many components during manufacture, which, together with the low cement contents, put their long-term durability into question.

B9.21 The overall conclusion of the report was that the block was performing satisfactorily under normal loading but that the original strengthening measures recommended should be implemented immediately and that the long-term durability of the block could not be assessed without a comprehensive survey associated with a continuing maintenance programme.

• • • • • • •

B10 The Tracoba system — Scotland

B10.1 The one report received on the Tracoba system summarised an extensive survey of 14 high-rise blocks constructed in Scotland. It is not known if the specification and practices used in these blocks were the same as those in the rest of the United Kingdom.

Site CT1

B10.2 The blocks were constructed between 1968 and 1970 and comprised five 19-storey blocks and nine 8-storey blocks, providing a total of 850 dwellings.

B10.3 The construction is similar in principle to other large panel blocks, using solid internal loadbearing walls and concrete floor panels with concrete sandwich panels forming the external envelope. The main difference between the Tracoba system and other large panel systems is the method of connection between the two leaves of the sandwich panels. They are connected by reinforced concrete bridging strips around the edges and along the horizontal centre line of the panels and not by isolated ties.

B10.4 The blocks were visually inspected internally and externally, concrete samples were taken and analysed, and joints between the precast components were opened up. In addition cores were taken from the precast panels. The main findings of these investigations were:

(a) Some spalling was present due to shallow repairs being carried out using grout. The spalling was not due to corrosion of reinforcement.

(b) Some rust staining was present due to reinforcing bars protruding from the ends of panels.

(c) Hair-line cracks were present in some panels, and coring showed that carbonation had penetrated down the cracks and in from the surface of the cracks to a depth of about 1 mm.

(d) Corners and nibs of panels had been repaired at the time of construction. These repairs were failing, sometimes due to the presence of chlorides causing reinforcement to corrode.

(e) Carbonation depths in the concrete were in general 3 to 4 mm throughout. Where wide cracks had occurred, carbonation had penetrated 4 mm in from the face of the crack.

(f) Chloride contents were generally low with occasional high values. These high values were usually associated with repaired concrete.

(g) Joints inspected had been constructed well and in accordance with the drawings and all the panels had an even bearing on the panels below.

B10.5 The overall conclusion of the report was that no problems were found with respect to the performance of the structures or their durability, but that some secondary hazard may result from falling pieces of concrete due to the localised defects described above. There is a continuing commitment to maintenance and inspection of the structures.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

B11 The Wates system

B11.1 BRE received five reports on inspections of Wates dwellings covering two sites. The Wates system comprises precast floors and solid precast internal walls, with precast sandwich panels forming the outer envelope. The inner leaf of the sandwich panels supports the floors at the loadbearing peripheral walls of the building. The condition of low-rise prefabricated reinforced concrete houses was investigated earlier[5].

Site CW1

B11.2 The report from this site describes the condition of buildings at two locations.

B11.3 At the first location, inspections were carried out on one 16-storey block built in 1965 – 66. The block was appraised in 1970 after the partial collapse at Ronan Point and, because of the lack of physical connections at the base of the Wates panels, strengthening was recommended. The strengthening adopted took the form of dowel bars grouted into holes formed by drilling upwards through the floor slab from below into the inner loadbearing leaf of the sandwich panels.

B11.4 Internal inspection of the floor/wall joints was carried out and the report made the following observations:

(a) The in-situ concrete surrounding the levelling bolt was in place and complete but was friable in nature.

(b) No bedding mortar had been used at one location, resulting in the upper panel bearing unevenly on high spots at the top of the lower panel.

(c) Vertical cracking between panels occurred frequently at the higher levels in the building but less often with reducing height. No cracks were present below fourth-floor level.

(d) A strengthening bar exposed was not properly embedded in the concrete and was considered to be ineffective.

(e) Chloride contents in all samples were in the low category.

B11.5 External inspection of the cladding panels was carried out and the following observations were made:

(a) Repaired areas were evident, many of which were now failing.

(b) Inadequate concrete cover to the reinforcement in the mullions of windows and to the edges of balconies had resulted in numerous rust stains and exposure of some reinforcement due to spalling of the concrete cover.

(c) Water penetration at some joints had occurred especially on the south face.

(d) Chloride contents in the panels were in the low category but chloride contents in the repair materials were often high.

B11.6 The overall conclusion of the report was that the structure was behaving satisfactorily under normal loading and most of the problems with the structure were due to minor spalling, low concrete cover to the reinforcement, and water penetration at the structural joints.

B11.7 The estate at the second location comprised five 10-storey blocks built in 1964 – 66 which had been strengthened in the early 1970s.

B11.8 The inspections of the floor/wall joints in one flat showed that the dry pack and in-situ concrete around the levelling bolts were in good condition and there were no signs of movement between panels. In one instance the nut of a levelling bolt had not been slackened off and one strengthening bar which was exposed did not penetrate into the inner leaf and was therefore not effective.

B11.9 Examination of the cladding panels showed defects similar to those at the first location. Several corners of panels were cracked or broken, early repairs to the panels were failing and the concrete cover to the reinforcement, although generally satisfactory, was low in the window mullions and was giving rise to corrosion of the reinforcement and spalling.

B11.10 Chloride levels were again low in the panels.

Site CW2

B11.11 Several blocks were inspected at this estate and a comprehensive list of defects and incorrect non-structural design details was given in the report. Those relevant to this review are:

(a) Deterioration of the roof structure due to water penetration through cracks in the waterproof asphalt surface and in the underscreed to the asphalt

(b) Water penetration of the structural joints in the balcony walkways due to defective skirting joints and defective movement joints in the structure

(c) Spalling and cracking of beams supporting access walkways

(d) Poor-quality concrete in the cladding panels due to an excessive amount of sand in the mix resulting in a poorly graded porous concrete. It was also believed that excessive shrinkage in the panels may have accounted for a number of the cracks

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

(e) Reinforcement exposed and cracking around the window openings

(f) Main concrete mullions showing signs of compression failure at their base

(g) Apparent use of incorrect panels in some locations

B11.12 The report also contained the results of a comprehensive experimental and theoretical investigation into the adequacy of the fixings of some panels. As a result it recommended that the window panels should be tied back to the structure and that a programme of monitoring and repair should be implemented since the long-term durability of the structural connections could not be assured.

• • • • • • •

B12 The YDG system

B12.1 This system evolved through a different history from that of most of the other large panel structure systems. Several local authorities combined together to form the Yorkshire Development Group which devised the concept of a large panel housing scheme for their common use and then employed the Shepherd Building Group to design and construct the system.

B12.2 BRE received seven reports on the YDG system, describing conditions at two sites. Four of these reports contained information relevant to this review.

Site CYDG1

B12.3 The structural system is one of loadbearing cross walls supporting the floors and roof panels, with the front and rear elevations infilled with non-loadbearing concrete spandrel panels and glazing. Lateral stability is provided by the cross walls, and longitudinal stability is provided by short stub walls at right angles to the party cross walls.

12.4 The reports for this site described conditions at two estates, Estate 1 comprising 15 blocks providing 558 dwellings and Estate 2 comprising 18 blocks providing 627 dwellings. All the blocks were medium-rise construction in the form of flats and maisonettes. The approximate date of construction of the blocks was 1970.

B12.5 After the partial collapse at Ronan Point, piped gas had been removed from all the blocks and some strengthening had been carried out.

B12.6 All the blocks were inspected visually from the outside and two blocks were examined in more detail, including testing of concrete samples for carbonation and chlorides. A design check was also carried out on the system of construction.

B12.7 The following conclusions were made in respect of the design of the YDG system:

(a) The overall concept and structural arrangement was satisfactory.

(b) The longitudinal stability of the construction was satisfactory provided the connection between the party walls and the stub buttress walls was effective. It was later concluded that this connection was not adequate and strengthening was recommended.

(c) The long-term strength of the balconies was suspect due to under-design.

(d) The factor of safety against overturning of the lift, stair-well and refuse tower was less than would normally be required.

(e) Some of the link bridges forming the deck access were unable to carry present-day loading requirements and some needed propping for safety reasons due to deterioration of the reinforced concrete.

B12.8 The site inspections of the two blocks revealed the following defects in their construction. They are expressed as a percentage of components inspected.

(a) Structural cracks in balcony slabs: Estate 1, 39%; Estate 2, 44%

(b) Insufficient concrete cover to the reinforcement in balcony slabs: Estate 1, 24%; Estate 2, 15%

(c) Insufficient concrete cover to the reinforcement in voided slabs: Estate 1, 36%; Estate 2, 50%

(d) Excessive joint movements in balustrades: Estate 1, 29%; Estate 2, 26%

(e) Shear cracking and other defects in cantilever beams supporting deck access: Estate 1, 20%; Estate 2, 61%

B12.9 No materials data were included but a summary of findings in the text indicated that chlorides had been added in some instances and this combined with low concrete cover was likely to lead to a reduced structural life. Most components had an estimated further life of 25 years or less based on the chloride contents recorded. Carbonation, although significant, was not considered to be the governing factor with respect to the life of the structural components.

B12.10 The overall conclusion was that there were many defects and shortcomings in the construction due to poor workmanship and poor supervision. The report concluded that most of these defects could be

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

put right and that there was no immediate structural problem with the basic fabric of the structures.

Site CYDG2

B12.11 Conditions at this site were very similar to those of the previous site. Here, 23 blocks of 6 to 7 storeys provided 647 flats and maisonettes. All the blocks had a history of water penetration. Their piped gas had been removed after the partial collapse at Ronan Point. The block had also been strengthened with angles and wall cleats at the floor/gable connection above deck access level.

B12.12 The panels had been cast on the site in a special temporary precasting yard.

B12.13 Initially one block was inspected but because of the deterioration found the inspection was selectively extended to other blocks.

B12.14 External inspections revealed three main areas of deterioration. First, severe corrosion of the supporting nibs to the walkways had occurred to the extent that immediate propping was necessary to restore the safety of the access bridges.

B12.15 Secondly, severe corrosion of the support to the balconies had occurred at two locations on the first block and at six other locations on the other blocks. This deterioration also required immediate remedial action. Extensive corrosion was also found on the soffits of the balcony slabs themselves.

B12.16 Lastly, it was observed that the stair and lift tower areas were showing signs of corrosion of the reinforcement and these are to be the subject of a further investigation.

B12.17 Internal inspections of the panel/panel joints showed that these joints had no interlocking reinforcement and the system relied on cast-in-situ concrete shear keys for its connections. Generally they showed no signs of movement or distress but occasionally the in-situ concrete had shrunk away from the surface of the precast component.

B12.18 The data from the analysis of the concrete showed that approximately 30% of the samples contained very high levels of chloride. It appears that the worst deterioration occurring in spandrel panels, walkways and balconies was associated with these high levels of chloride. The concrete samples taken from the loadbearing panels did not contain significant amounts of chloride. In addition, four carbonation depths were recorded ranging from 1 to 9 mm.

• • • • • • •

B13 References

1 **Building Research Establishment**. *The structure of Ronan Point and other Taylor Woodrow-Anglian buildings*. BRE Report. Garston, BRE, 1985.

2 **Reeves B R**. *Large panel system dwellings: preliminary information on ownership and condition*. BRE Report. Garston, BRE, 1986.

3 **The Institution of Structural Engineers, Scottish Branch**. *Guidance note on the security of cladding on large panel concrete construction*. September 1984.

4 **British Standards Institution**. The structural use of concrete. *Code of Practice* CP 110:1972. London, BSI, 1972 (Now withdrawn and replaced by BS 8110).

5 **Building Research Station**. *The structural condition of Wates prefabricated reinforced concrete houses*. BRE Report. Garston, BRE, 1983.

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

Licensed Copy: KLatimer, London Borough of Tower Hamlets, 30/08/2007 15:49:42, Uncontrolled Copy, © IHS BRE Press

ISBN 0 85125 251 6

OBC