Southwark Council

Ledbury Estate

Structural Robustness Assessment for Large Panel System Tower Blocks with Piped Gas

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1 Introduction and Brief

In July 2017, Arup was appointed by Southwark Council to carry out a visual investigation into the structure of four tower blocks on the Ledbury Estate, after residents reported cracks appearing in the ceilings, floor and walls. This investigation concluded that these cracks were gaps between the non-load bearing concrete panels. No gaps were found between load-bearing elements and therefore the loadpath as intended by the original design is unchanged.

The Estate comprises of four geometrically identical 14-storey precast concrete Large Panel System (LPS) tower blocks. The buildings were built for the Greater London Council by Taylor Woodrow Anglian (TWA) between 1968 to 1970. Southwark Council's asset list records Bromyard (1968), Sarnsfield (1969), Skenfrith (1969) and Peterchurch House (1970). All four towers have piped gas.

The blocks at Ledbury are of similar construction and were built by the same contractor who built the 23-storey flats at Ronan Point, one of which suffered a partial collapse due to a gas explosion in 1968. The collapse led to immediate and significant change to structural engineering design and regulatory standards. A Government circular issued in 1968 [4] in response requested that all blocks of similar construction be assessed and set out a method for assessment.

Ledbury Estate was transferred over to Southwark Council in the 1980s following the dissolution of the GLC. Unfortunately, a great deal of information was lost during this transitional process, meaning that Southwark Council have no information on record that documents this issue.

A BRE report dated 1985 titled "The Structure of Ronan Point and other Taylor Woodrow – Anglian buildings" [1] examined the reasons for the collapse at Ronan Point. This report identified that there were two types of TWA buildings, "Type A" which was identical to the towers at Ronan Point and then "Type B" which BRE report to have a different means of connecting the precast panels. Contained within Appendix A of this report is a list of the Estates where TWA buildings were constructed. Ledbury Estate is listed in this report (named Commercial Way) and is identified as being a "Type B" building. The report concludes "*There are 43 'Type B' buildings. Their flank wall joints are bigger than those in Ronan Point, containing interlocking reinforcement and are less likely to have been poorly constructed. Their design was checked and construction supervised by independent consultants. These factors all suggest that the design is likely to be adequate and construction for good quality. Confirmation of the design and construction quality should be considered only if additional assurance of adequacy is desired*".

In the absence of documentation on record specifically relating to Ledbury Estate, Southwark Council asked Arup to check whether the four tower blocks at Ledbury Estate satisfy the Government recommendations for robustness of Large Panel System tower blocks with piped gas. Specifically, Southwark Council requested that Arup undertake a rapid assessment of whether a gas explosion could lead to progressive and disproportionate collapse.

A full assessment of the blocks, in the absence of construction details on record, requires extensive exploratory investigations that would take considerable time and would cause significant disruption to the residents. Southwark Council advised that there were two vacant flats immediately available. Given the urgency of assessing the risk from a gas explosion with occupied blocks the assessment was broken up in to a number of stages.

Stage 1 – Rapid structural appraisal to determine if the building should have gas.

Stage 2 – If it is found that the building should not have gas, then with piped gas turned off, are there any structural strengthening measures needed to enhance the margin of safety to the full level expected for this type of building, to bring within required limits the extent of damage that would be caused in the event of accidental damage to the structure?

A specialist investigation contractor, Martech [7], with significant experience in high-rise concrete tower blocks was appointed to carry out the investigations. At short notice, they were able to move existing contracts to undertake two days of testing to gather information for the Stage 1 assessment.

The availability of the specialist contractor, access to only two flats and the requirement to reach a rapid opinion on piped gas meant that investigations were targeted to parts of the structure known to be most critical based on engineering experience and with the information and guidance in the two BRE documents [1] and [2].

This report summarises Stage 1.

Following the completion of Stage 1 and with agreement from Southwark Council we will move into Stage 2 the steps for which are discussed in more detail in Section 5.

2 The Buildings

2.1 Description of Building

There are four geometrically identical tower blocks on the Ledbury Estate; Bromyard House, Peterchurch House, Sarnsfield House and Skenfrith House, each are 14 storeys high, with a floor to floor height of approximately 3m (Figure 1). Each has a 'H-shaped' floorplan, with two sets of flats on each floor separated by a lift and stair core at the centre, see Figure 2.

Figure 1 Peterchurch House on Ledbury Estate

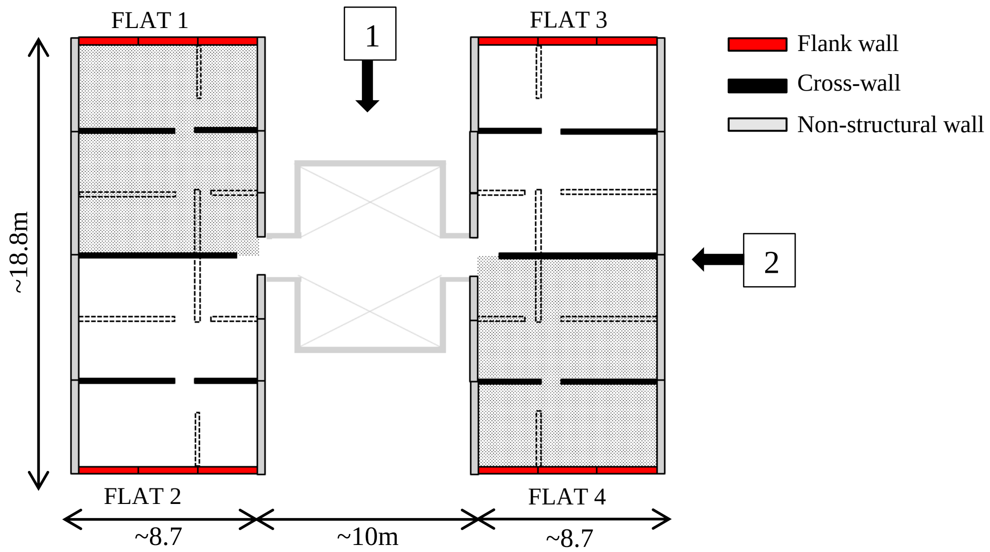

Figure 2 Approximate floorplan of the Ledbury Estate tower blocks

2.1.1 Structural form

The tower blocks were constructed using a precast concrete Large Panel System (LPS), where the panels were built in factories and assembled on site. The floor slabs span one-way onto the internal cross-walls and the outer flank walls. The concrete non-structural wall panels are designed to carry no vertical load other than their own self-weight, they are stacked upon each other and are tied back to the floor slabs via structural steel ties. The approximate floor plan of a single flat can be seen in Figure 3.

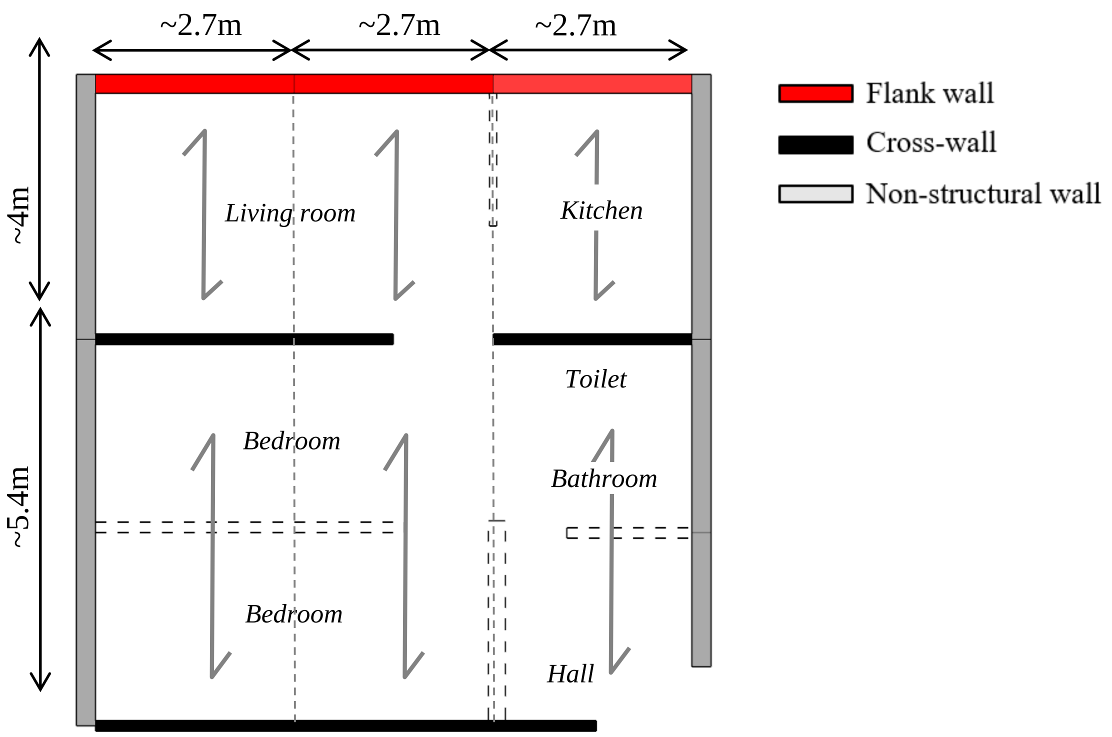

Figure 3 Approximate floorplan of a single flat

2.2 History of Ledbury Estate and LPS buildings

Ledbury Estate was originally commissioned by the Greater London Council (GLC) in the 1960s and transferred over to Southwark Council in the 1980s following the dissolution of the GLC. Unfortunately, a great deal of information was lost during this transitional process.

The buildings were built by Taylor Woodrow Anglian (TWA) between 1968 to 1970. Southwark Council's asset list records Bromyard (1968), Sarnsfield (1969), Skenfrith (1969) and Peterchurch House (1970). All four towers have piped gas.

The Large Panel System used is also known as the Larsen- Nielson design.

It is understood that Ledbury Estate was formally known as Camelot Street and also Commercial Way.

The following sources were thoroughly searched for any information related to Ledbury Estate:

- Southwark Council archives
- London Metropolitan archives
- British Research Establishment (BRE) archives
- Taylor Woodrow archives

No information in any form was obtained from the Southwark Council archives, British Research Establishment (BRE) archives nor the Taylor Woodrow archives. A limited number of planning and architectural drawings, showing only basic building outlines, but no technical details, were located at the London Metropolitan archives, as were receipts for a total of £53,700 "remedial" works between 1968-1969 which would have been during the period of construction and following the collapse at Ronan Point. However, no details or description of what "remedial" works were carried out exist. No construction drawings were located.

In May 1968, Ronan Point tower block, built by Taylor Woodrow using their 'Anglian system', suffered a partial collapse as a result of a gas explosion. The damage caused by the gas explosion was considered to be more extensive (causing more parts of the building structure to collapse) than should have occurred following an explosion of that magnitude. This led to the reappraisal of Large Panel System blocks throughout the UK. The Ministry of Housing and Local Government issued Circulars 62/68 [4] and 71/68 [5] in response.

Circular 62/68 required that all LPS blocks over six storeys in height were to be appraised by a structural engineer and their ability to withstand a force equivalent to a static pressure of 34kPa without incurring disproportionate collapse be assessed. If this requirement was not met, the blocks were to be strengthened or gas removed. Additionally, all new LPS blocks were to be built to these same standards.

Circular 71/68 maintained that LPS blocks with piped gas should be assessed against a pressure of 34kPa, however if removed, this figure could be reduced to 17kPa.

Minimum requirements for robustness in any buildings of five or more storeys were also introduced at this time, outlined in an Amendment to the Building Regulations in 1970 [6]. Subsequent revisions to structural codes and replacement codes have since incorporated the principle of robustness and avoiding disproportionate collapse, in general by providing effective horizontal and vertical ties. Requirement A3 in current building regulations *"The building shall be constructed so that in the event of an accident the building will not suffer collapse to an extent disproportionate to the cause"* applies to all buildings, however buildings are now placed into classes and additional measures in relation to the prevention of disproportionate collapse apply to the higher classes. The higher the class, the more stringent the rules [3].

BRE also published a number of reports following the partial collapse of Ronan Point, including a report in 1985 [1], which specifically reviewed the Taylor Woodrow Anglian form of construction; Ledbury Estate was referenced in this report. This report states the tower blocks on Ledbury Estate (unlike Ronan Point) used a Type B H2 flank wall joint which were "*designed to resist forces equivalent to a standard static pressure of 5lbf/in^2* [34kPa]".

In relation to the flank wall to slab H2 joints in 'Type B' buildings, the report stated the following *"the in-situ flank wall joints are much bigger, contain interlocking reinforcement connecting the units and vibrated concrete was specified and practical. Such joints will accept eccentric loading and are less sensitive to any deficiencies which may exist in the hand-packed joints, providing that the in-situ concrete is confirmed to be solid. The condition of the joints should be checked."*

However, this report provides no drawings of the Type B H2 joint nor any evidence that Ledbury Estate was assessed on an individual basis.

In 2012 BRE published the "Handbook for the structural appraisal of Large Panel System (LPS) dwelling blocks for accidental loads" [2]. This document was written in order to update the Governments 1968 guidance to take into account all of BRE's subsequent research, the general development of assessment methodologies and to align with current structural design codes. The document continues to recommend assessing LPS blocks with piped gas for a pressure of 34kPa or 17kPa if bottled gas is used.

This document is still considered the Industry best practice guidance for the appraisal of Large Panel System buildings.

3 Investigations

3.1 Description of investigations

In the absence of any construction drawings, all structural information in relation to the Ledbury Estate tower blocks, used in this report, has come from visual and intrusive investigations completed as part of this scope of work. This section describes the intrusive works that were undertaken on 1 and 2 August 2017, by concrete investigation specialists Martech [7], in the presence of an Arup engineer.

The investigations took place in two vacant flats; one on the 7th floor of Bromyard House and one on the 6th floor of Skenfrith House. The surveys included electromagnetic and radar scans to non-destructively locate steel reinforcement and connection details, followed by careful exploratory works to validate the scans and to gather further information.

The 1985 BRE report [1] (which references Ledbury Estate) identified the flank wall to slab H2 joint (described in Section 2.2) as being the most vulnerable location to failure resulting in disproportionate or progressive collapse, in the event of a gas explosion. Therefore, given the limited timescale available, we focussed on finding and exposing this joint, to check the condition of the in-situ concrete and the reinforcement and to record the spacing and dimensions of the interlocking rebar, so that strength of this joint could be assessed.

Other critical connections, when looking at the risk of disproportionate or progressive collapse are the flank wall panel to flank wall panel, cross-wall panel to cross-wall panel and cross-wall to slab joints; these were also investigated.

The dimensions and reinforcement details of the vertical load bearing elements; the flank walls, cross-walls and slabs, were also investigated, so that the strength of these elements and their ability to withstand a gas explosion could be assessed.

3.2 Findings of investigations

The locations of the investigation works undertaken are shown in Figure 4. While the two flats have the same general layout, the flat in Bromyard House has two bedrooms, while the flat in Skenfrith has one bedroom (the room shaded grey in the sketch below is the third bedroom to the neighbouring flat). This sketch is referred to throughout the following Section.

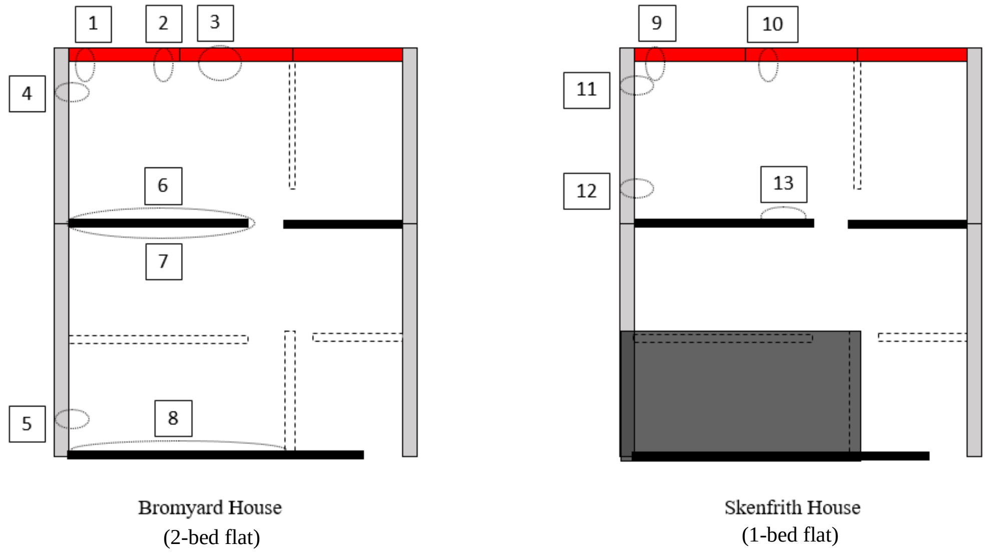

Figure 4 Floorplans of the two flats showing the locations of the intrusive investigation works

3.2.1 Flank wall

The flank wall panels are approximately 2.7m wide and 3m high. They are located on the outer end of the building with the floor slabs spanning onto them (see Figure 3). An exploratory hole drilled through one of the panels was used to determine the approximate thickness and make-up of the wall. In addition, all flank wall panels, in both flats were scanned from the inside for the presence of reinforcement using an electromagnetic scanner and radar.

A sketch of the cross-section of a flank wall panel, based on the investigation findings, can be seen in Figure 5. The panels consist of two concrete leaves separated by an insulation layer. The inner leaf of the panel bears all of the vertical load provided by the slabs (i.e. the weight of the building goes through the inner leaf). The outer leaf simply provides the weather proofing skin. As a result, our investigations focussed on the inner leaf.

Access constraints and time limitations focused the investigations on the inner leaf of the flank wall panels because the inner leaf is the part of the panel which is responsible for carrying vertical loads and for withstanding lateral loads. No reinforcement was detected in the inner concrete leaf of the flank wall. The outer leaf was not investigated in full, however it is likely that it contains a light reinforcement similar to the non-structural wall panels, which have the same cross-sectional dimensions and which were exposed during previous investigation works, see Figure 6.

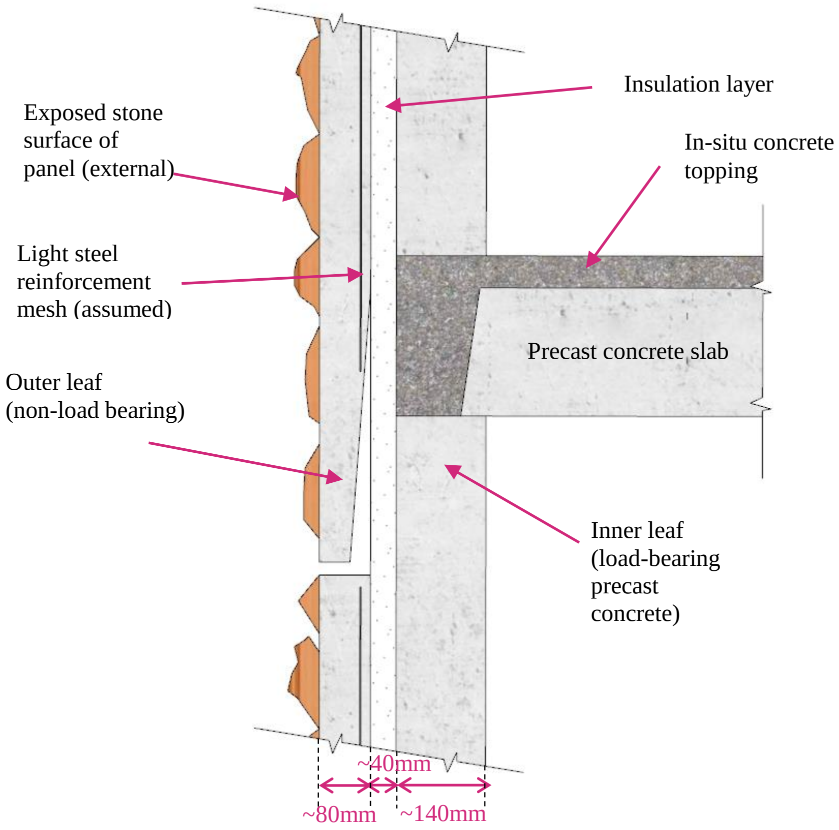

Figure 5 Cross-section of the flank wall panel

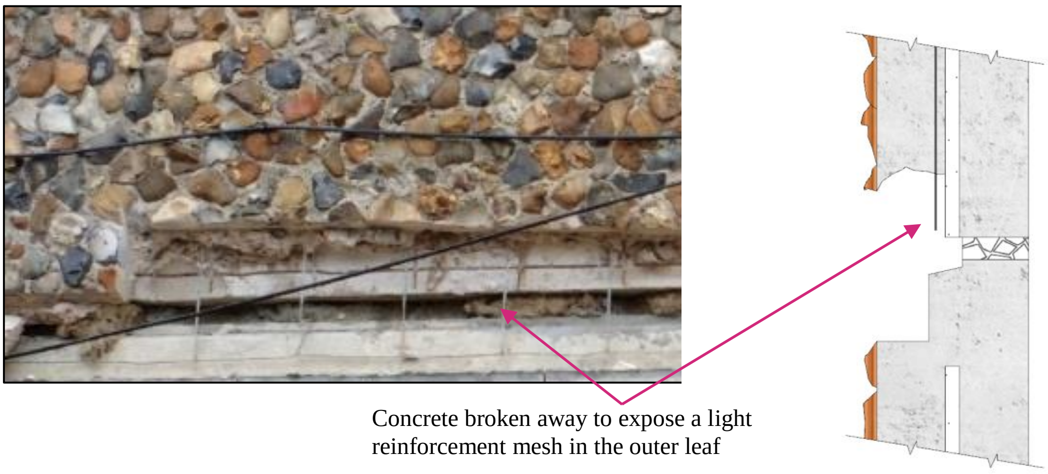

Figure 6 Light reinforcement mesh in the outer leaf of a non-structural wall panel. Photograph looking straight at the panel (LHS). Sketch showing a section through the wall panel, demonstrating the extent to which the concrete was broken away (RHS)

3.2.2 Cross-wall

Covermeter and radar scans indicate that there is no reinforcement present in the cross-walls. Where possible wall thicknesses were measured at door openings and were found to be approximately 150mm thick. It was not possible to measure the thickness of the cross-wall which separates neighbouring apartments.

3.2.3 Slabs

Covermeter and radar scans indicated a regular pattern of reinforcement at 150mm centres. No holes were drilled through the slab to measure the overall thickness, however it is estimated to be 300mm based on floor to floor and floor to soffit measurements.

There is an in-situ concrete topping on top of the precast floor slabs. Localised breakouts found the topping to be 50mm thick and no reinforcement was discovered in the topping.

3.2.4 Connection details between precast concrete units

3.2.4.1 Flank walls to floor slab

Interlocking reinforcement between the top of the flank wall panels and the floor slabs was found; located at 300mm centres. A sketch of this detail (based on the investigation findings) can be seen in Figure 7. Three fixings were exposed; two at location 3 and one at location 10 (seen in Figure 4).

10mm diameter plain hooped bars extend from the top of each flank wall panel and from each slab. These hooped bars are linked by a horizontal ribbed 'lacer' bar. These lacer bars were observed to be 12mm in diameter in Skenfrith House (location 10) and 16mm in diameter in Bromyard House (location 3). At location 3, two bars were discovered indicating a position of a lap. The voids between the precast panels are filled with in-situ concrete.

Plain bars circa 1968 suggest 'R' type bars with a characteristic yield strength of ~250MPa. Ribbed bars suggest 'T' type bars with which typically had a characteristic yield strength of ~410-450MPa.

This fixing detail connects the top of the flank wall to the floor slab only. The base of the wall is restrained horizontally by the wall to wall vertical bars, described in Section 3.2.4.2.

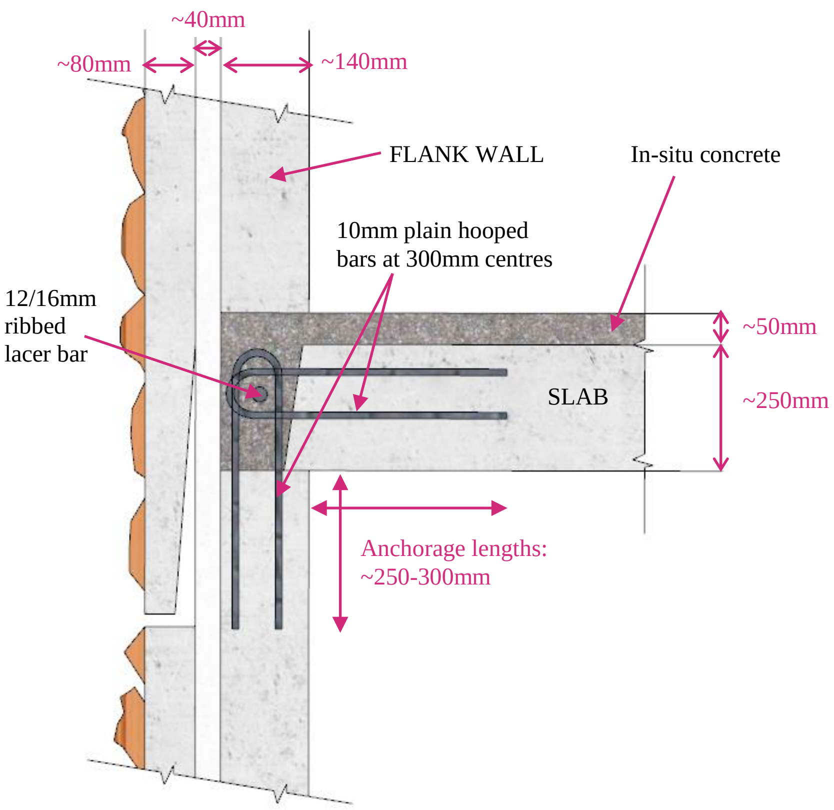

Figure 7 Flank wall panel to floor slab fixing detail

3.2.4.2 Flank walls to flank wall

Each flank wall panel is connected to the flank wall directly above and below by two vertical 16mm diameter ribbed steel reinforcement bars at either side of each panel. These bars are contained within 45mm diameter metal sheaths which were fully grouted at the exposed locations. The non-destructive scanning tools detected that the sheaths extend the full height of the panel and local break-outs revealed that the vertical steel bars extend into the in-situ concrete joint (between the wall and slab). The extent to which the base of the fixings were exposed at the base of the wall panels can be seen in Figure 11. Sketches of this fixing detail (based on the investigation findings) can be seen in Figure 9 and Figure 10. A photograph showing locations 1, 2 and 3 (Figure 4) can be seen in Figure 8.

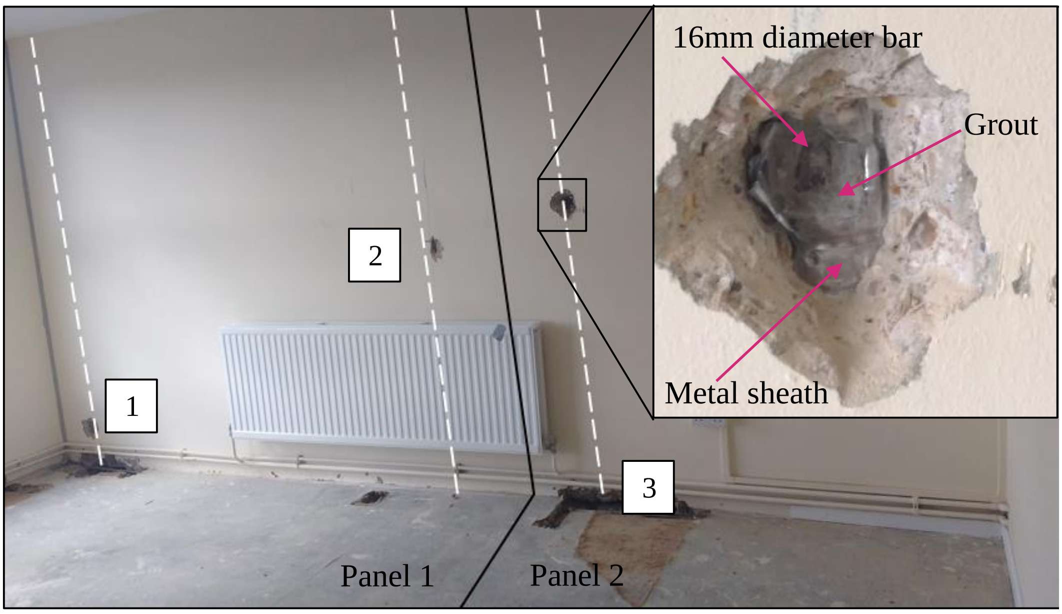

Figure 8 The locations of the vertical bars in the flank wall panels (located by electromagnetic scanner), are shown in white. The close-up photo shows an exposed metal sheath and bar at mid-height

The location of each vertical joint was initially located using the non-destructive scanning tools and four locations were subsequently intrusively investigated; locations 1, 2, 3 and 9, as seen in Figure 4. At location 1, the base of the joint was exposed and two steel bars were observed, this is assumed to be the lapping of the vertical bars, one bar ends just below the bottom of the sheath and one bar extends into the in-situ joint. At location 2, the sheath and bar were exposed at mid-height – a single bar was found. At location 3, both the base and top of the joint was exposed. In both instances a single bar extending into the in-situ joint was observed. The bar and sheath was also exposed at mid-height at this location; again revealing a single bar. At location 9 the base of the joint was exposed and a lapped detail similar to that at location 1 was observed.

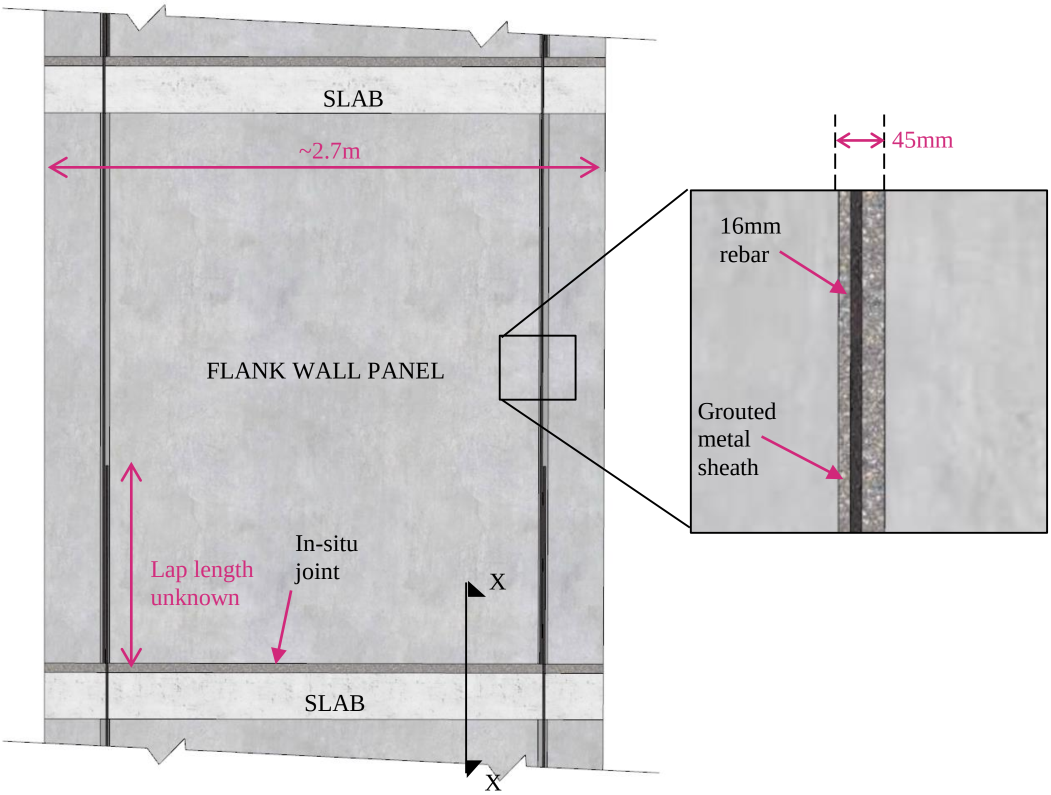

Figure 9 Flank wall to flank wall fixing. One flank wall panel is shown

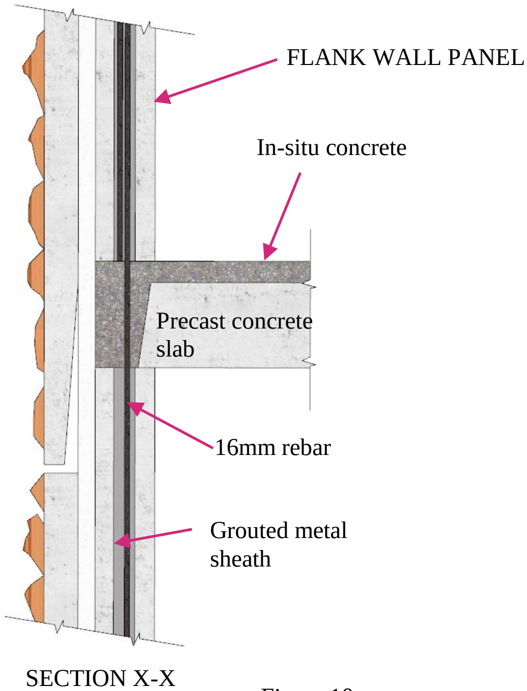

Figure 10

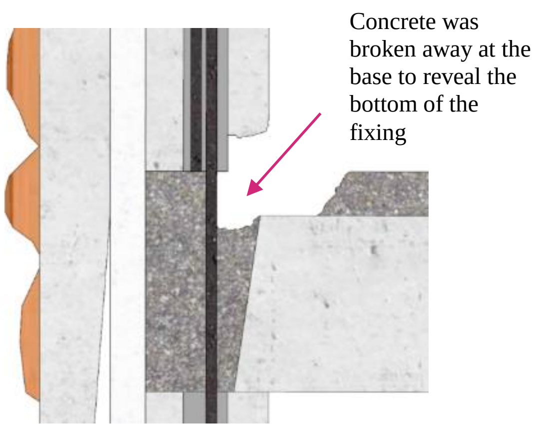

Figure 11

Figure 10 Flank wall to flank wall fixing, Section X-X (taken through the joint)

Figure 11 Flank wall to flank wall fixing, illustration of extent of break-out

3.2.4.3 Cross-walls to floor slab

Bromyard House

Removing the skirting boards along the base of the load-bearing cross-walls in Bromyard House revealed 10mm thick, steel L-brackets (see Figure 12) bolted to floor slabs and walls at locations 6, 7 and 8 (Figure 4). Four brackets are spaced along a length of ~5m at location 8 (Figure 12), while three brackets are spaced along a length of ~4m at locations 6 and 7. No L-brackets exist at ceiling (soffit) level. No further investigations were undertaken on these cross-walls.

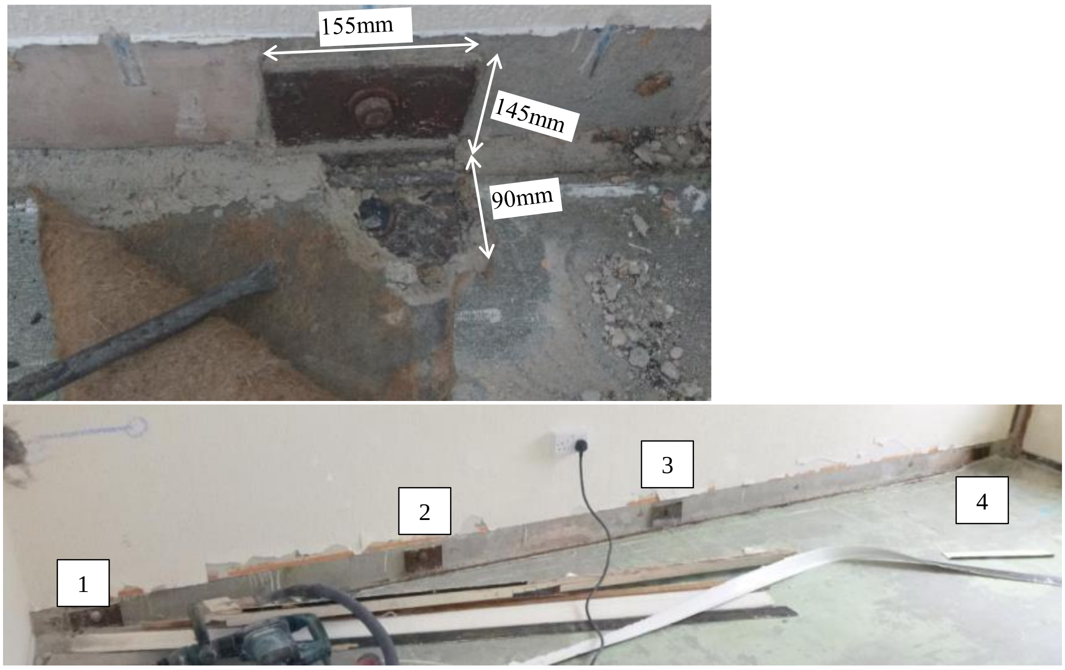

Figure 12 Bromyard House – L-brackets were found along the length of the cross-walls (location 8)

Skenfrith House

No L-brackets are present along the cross-walls in Skenfrith House. However, interlocking reinforcement at 300mm centres tying the top of the cross-wall panels to the floor slabs (similar to the flank wall fixing described in Section 3.2.4.1) was found at location 13 (Figure 4). The extent to which the joint was exposed can be seen in Figure 13. The joint was only exposed from one side, the dotted outline of Figure 13 was not investigated.

3.2.4.4 Cross-walls to cross-wall

Vertical steel bars housed in grouted metal sheaths, similar to the fixing described in Section 3.2.4.2 were located in Skenfrith House. However, unlike the flank walls, the bars and sheaths only extend ~400mm above and below floor level (Figure 14), an electromagnetic scanner was used to locate the vertical bars and determine the anchorage lengths.

Only one joint was exposed, at location 13 (Figure 4), two 8mm plain vertical bars extending down into the in-situ concrete joint were found. It is unknown if the two bars extend the full height of the joint or if the bars are lapped.

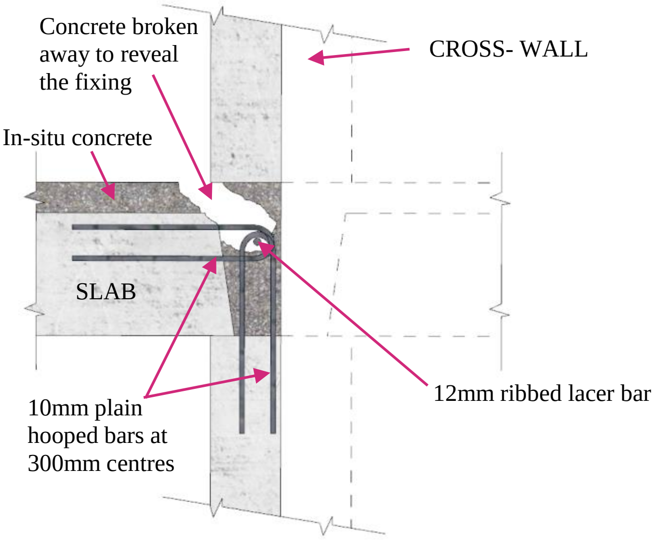

Figure 13 Skenfrith House: cross-wall to slab fixing, illustration to show extent of break-out. Only one side of the cross-wall was investigated

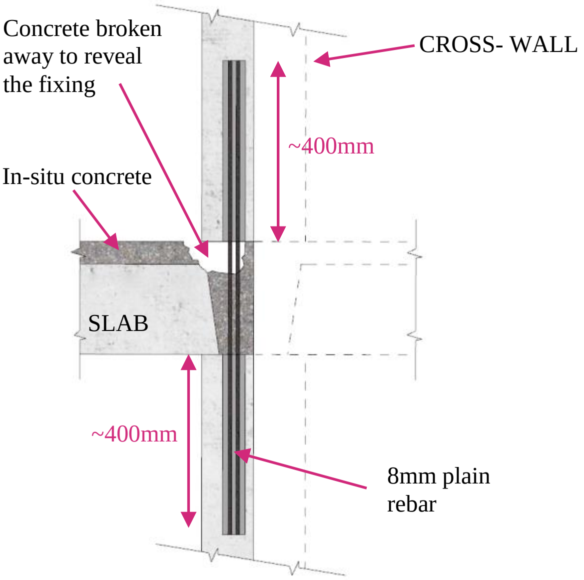

Figure 14 Cross-wall to cross-wall vertical fixing. Only one side of the cross-wall was investigated

3.2.4.5 Non-structural walls to floor slab

The non-structural wall panels are stacked upon each other and were not originally designed to carry vertical load, other than self-weight. They are tied back to the floor slabs with two ties per panel. Electromagnetic scans were used to locate the fixing details and two fixings (at locations 4 and 5 - Figure 4) were exposed. Different details were found at each locations (Figure 16), however the general principle is the same; the ties loop around a bolt (connecting adjacent non-structural wall panels) and are restrained via bolts to the top of the slab. The floor screed was broken away to reveal the ties from the inside and concrete was also broken away to reveal the bolt from the outside (Figure 15).

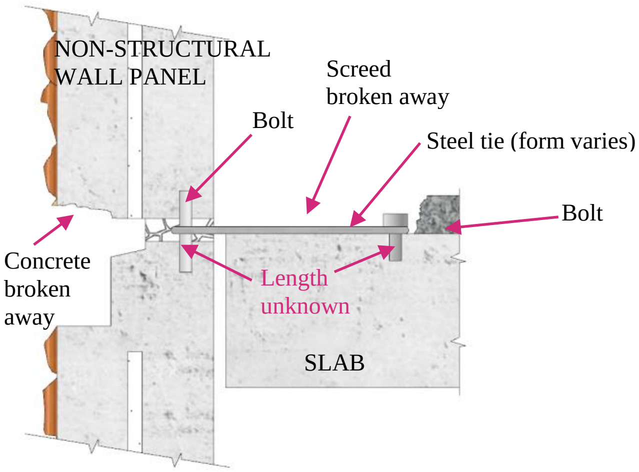

Figure 15 Non-structural wall panel to slab fixing

Figure 16 Non-structural wall panel to floor slab fixings exposed at locations 4 (LHS) and 5 (RHS). Chalk outline shows what the electromagnetic scanner located

3.3 Limitations of investigations

A full assessment of the blocks, in the absence of construction details on record, requires extensive exploratory investigations that would take considerable time and would cause significant disruption to the residents. Southwark Council advised that there were two vacant flats immediately available. Given the urgency of assessing the risk from a gas explosion with occupied blocks the assessment was broken up in to a number of stages.

The availability of the specialist contractor, access to only two flats and the requirement to reach a rapid opinion on piped gas meant that investigations were targeted to parts of the structure known to be most critical based on engineering experience and with the information and guidance in the two BRE documents [1] and [2]. This is deemed to be the Stage 1 investigations.

Stage 2 investigations are explained in more detail in Section 5. The extent of these investigations will depend on the number of additional vacant flats made available.

Whilst the four buildings are geometrically identical, the investigations so far have found some differences in the same connections on Bromyard House and Skenfrith House. Investigations in Peterchruch House and Sarnsfeild House are essential.

It will never be practical to investigate every connection in all four blocks and thus it will never be possible to have 100% certainty. That said this is true of any existing building where physical investigations are required to build up as full a picture as possible because as-built drawings have been lost or destroyed. The practicalities of the residual risk in relation to the ownership and management of this particular building should be investigated by Southwark Council.

4 Assessment

4.1 Assessment Criteria

BRE Large Panel System (LPS) Assessment Guide

The BRE document "Handbook for the structural appraisal of Large Panel System (LPS) dwelling blocks for accidental loads" [2] clearly defines three criteria for the assessment. If the building can be proven to satisfy any one of the three criteria, then it is considered to satisfy requirement A3 of the Building Regulations [8] (which is the requirement to avoid disproportionate collapse) in accordance with Approved Document A [3]. The following is an extract from the BRE assessment guide:

LPS Criterion 1: Determine if there is adequate provision of horizontal and vertical ties to comply with the current requirements for Class 2B buildings as set down in the codes and standards quoted in Approved Document A – Structure [3] as meeting the requirements set down in the Building Regulations.

LPS Criterion 2: Determine whether an adequate collapse resistance can be demonstrated for the foreseeable accidental loads and actions, which is defined as 34kPa for a block with piped gas or 17kPa for a block with bottled gas.

LPS Criterion 3: Determine whether there are alternative paths of support that can be mobilised to carry the load, assuming critical section of the load bearing wall in the manner defined for Class 2B buildings in Approved Document A – Structure [3] or alternatively assuming the removal of adjacent floor slabs (taking the floor slabs bearing on one side wall at a time) providing lateral stability to the critical section of the load bearing wall being considered.

Current Building Regulation requirements

Approved Document A – Structure [3] defines building consequence classes. Depending on the consequent class different measures must be taken to prevent disproportionate collapse occurring. The Ledbury Estate tower blocks are classified as a Consequence Class 2b Buildings (Upper Risk Group) as they are blocks of flats greater than 4 storeys but not exceeding 15 storeys.

According to The Building Regulations Approved Document A – Structure [3] Consequence Class 2b buildings must comply with the rules as defined in BS EN 1990 [9], 1991 [10] and 1992 [11] and provide effective horizontal ties together with effective vertical ties in all supporting columns and walls.

Alternatively, upon the notional removal of each supporting wall (one at a time in each storey of the building), the building should remain stable and that the area of the floor at any storey at risk of collapse must not exceed 15% of the floor area of that storey or 100m^2, whichever is smaller, and must not extend further than the immediate adjacent storeys.

4.2 Assessment Discussion

In the event of an explosion in the kitchen in one of the tower blocks at Ledbury Estate the flank wall and first internal wall could experience a pressure of 34kPa (piped gas). Two failure mechanisms have been considered.

- Failure of the wall panel
- Failure of the joint at the head or base of the wall which ties it back to the floor or to the wall panel above or below

Our investigations indicate that the flank and cross-walls are unreinforced concrete. As such the walls do not have sufficient capacity to resist 34kPa (accidental load requirement for a block with piped gas) or 17kPa (accidental load requirement for a block with bottled gas) and as such the walls surrounding the explosion will fail. This has consequences to the floor immediately above which relies on the walls for support.

There is likely to be significant damage to the floor slabs in the room where the explosion occurs. The walls and floors that that would be affected by an explosion in the kitchen can be seen in Figure 17.

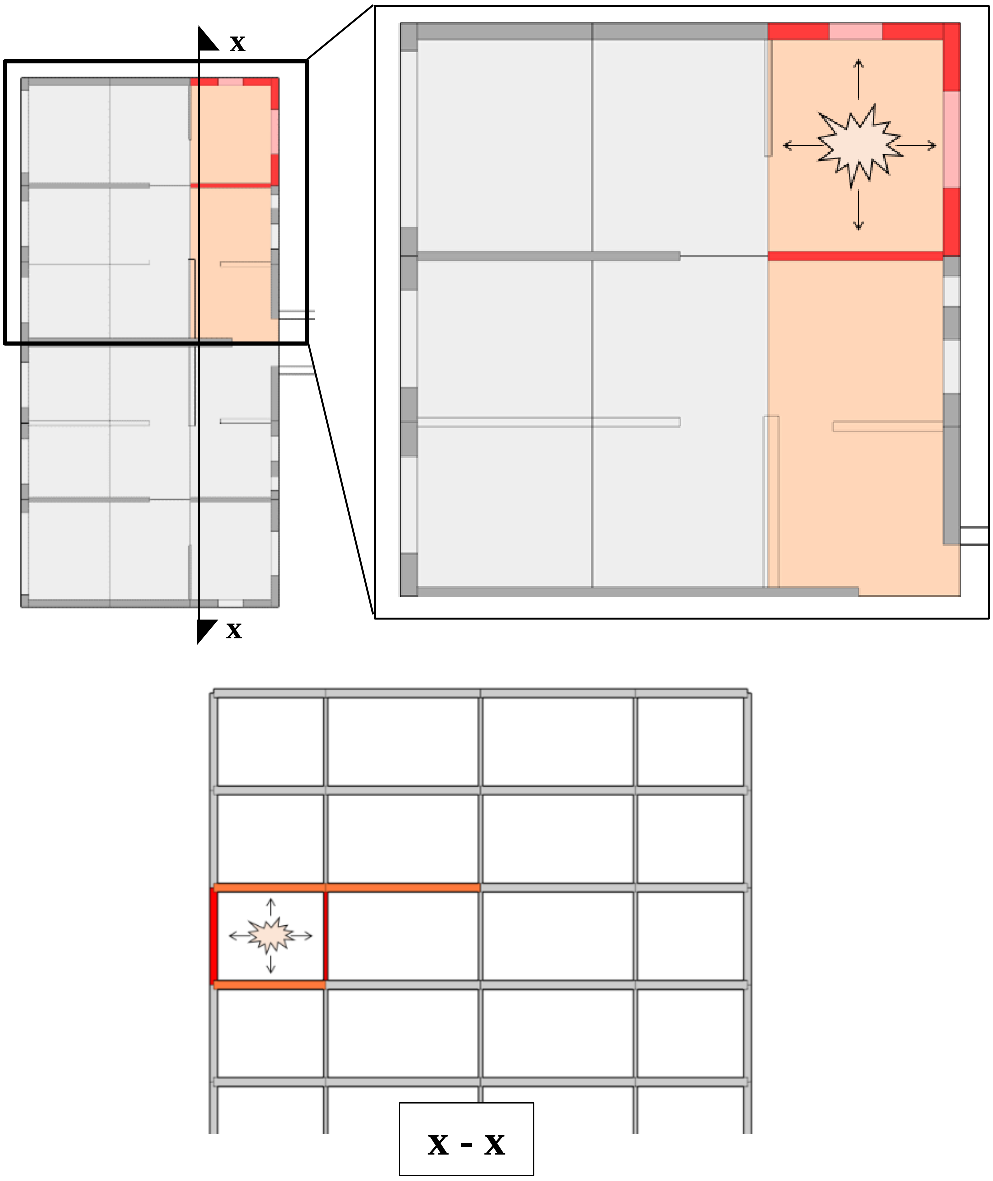

Figure 17 Plan view (above) and section view (below). The walls affected by an explosion occurring in the kitchen are highlighted in red. The affected floor slabs are highlighted in orange.

With the loss of the flank wall and the first internal wall, the floor on the level above the explosion will no longer have support from below and will try to vertically suspend from the wall above. Our investigations indicate that the floor slabs are connected to the wall below but are not directly connected to each other or to the wall above. Our investigations indicate that there are only two vertical bars per wall panel which continue from the wall panel to the wall panel above. The vertical bars are not capable of supporting the weight of the slab in tension and as such in the event of the wall failing below, then the floor previously supported by that wall would also collapse, see Figure 18. The area of the floor that would fail is greater than 15% of the total floor area (at that level) which is not compliant with the regulations for disproportionate collapse, see Figure 19.

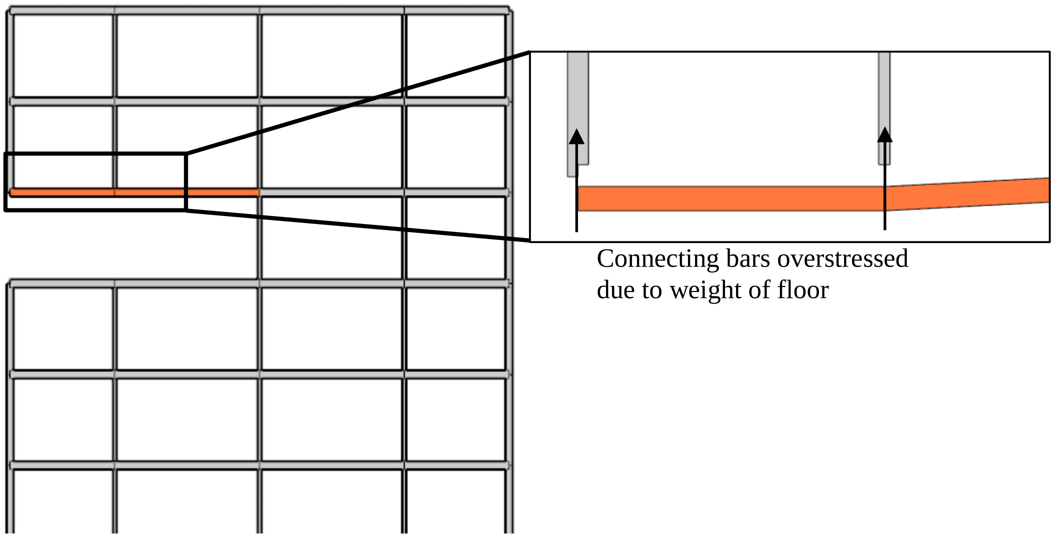

Figure 18 With the loss of the flank wall and the first internal wall, the floor on the level above the explosion will no longer have support from below and will try to vertically suspend from the wall above. The connecting steel reinforcement bar would become overstressed due to the weight of the floor, leading to the tensile failure of this connection.

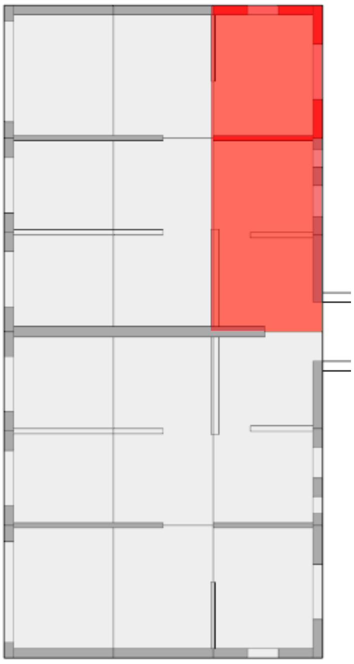

Figure 19 The area of the floor that would fail (highlighted in red) is greater than 15% of the total floor area (at that level)

There is a possibility that such a failure would propagate to the failure of additional elements, causing progressive collapse such as was the case at Ronan Point, but without a fuller understanding of the structural details it is not possible at this time to conclusively conclude the full extent of damage.

Therefore, as described above, in the event of a gas explosion the walls are not able to resist the blast load of 34kPa (for piped gas) or 17kPa (for bottled gas) and therefore would fail the LPS Criterion 2 (as defined by BRE [2]). With the flank wall and/or the first internal wall removed, the floor slabs of the level above are not adequately tied to the walls above or to each other and thus there is no reliable alternative path of support and therefore cannot be shown to meet LPS Criterion 3 (as defined by BRE [2]).

Some of the tying details discovered during our investigations, specifically the vertical ties between floor panels and walls and horizontal internal ties do not comply with Approved Document A – Structure and thus fail LPS Criterion 1 (as defined by BRE [2]).

In conclusion, based in the information available from the Stage 1 investigations the building does not appear to be sufficiently robust to resist a gas explosion without incurring disproportionate collapse.

These investigations showed that the flank walls and vertical (tension) ties between the floors and walls are not robust enough for buildings with piped gas (using the BRE assessment criterion).

5 Future actions

As discussed in Section 1, a full assessment of the blocks, in the absence of construction details on record, requires extensive exploratory investigations that would take considerable time and would cause significant disruption to the residents. Southwark Council advised that there were two vacant flats immediately available. Given the urgency of assessing the risk from a gas explosion with occupied blocks the assessment was broken up in to a number of stages.

Stage 1 – Rapid structural appraisal to determine if the building should have gas. This is now complete and as described in this report, we have found that the buildings are not robust enough for buildings with piped gas.

Stage 2 – If gas is turned off, are there any structural strengthening measures needed to enhance the margin of safety to the full level expected for this type of building? For buildings of this type, the main risk of accidental damage is damage caused by gas explosion. However, regulations require structural elements in buildings to be able to withstand additional stress, at a certain level beyond the stress the building will experience in its everyday circumstances, even if there is no gas in the building. This provides an additional degree of comfort, such as if there is some other type of accident that damages the building.

The following steps are required for stage 2:

Step 2.1 – Undertake further intrusive investigations to understand if the details already investigated are consistent in the other two buildings and also in other flats throughout the two blocks already investigated. The amount of opening up will need to be sufficient to achieve a representative sample, but the precise extent will depend on the number of vacant flats available. Material testing will also be required to understand the concrete durability (i.e. petrographic tests, carbonation and chloride tests).

Step 2.2 – Considering all forms of accidental loading other than a gas explosion, undertake an engineering assessment to understand where there are structural deficiencies and assess if it is feasible to practically strengthen the tower blocks to enhance the margin of safety to where it needs to be for this type of building for future use, to bring within required limits the extent of damage that would be caused in the event of accidental damage to the structure.

Step 2.3 - If it is considered feasible to strengthen the building then conceptual structural remedial designs will be produced for high level costing enabling Southwark Council to assess in conjunction with the other works (such as fire safety and waterproofing).

6 Conclusions

The tower blocks on Ledbury Estate have been assessed against current building regulations [3] [8] and government guidance [2] for LPS blocks with piped gas.

The BRE report dated 1985 [1] found that Ledbury (then Commercial way) was a Taylor Woodrow Anglian 'Type B' building and that "The flank wall joints in 'Type B' TWA buildings are likely to be adequate" in the event of a gas explosion of magnitude 34kPa.

In the absence of documentation on record specifically relating to Ledbury Estate, Southwark Council asked Arup to check whether the four tower blocks at Ledbury Estate satisfy the Government recommendations for robustness of Large Panel System tower blocks with piped gas. Specifically, Southwark Council requested that Arup undertake a rapid assessment of whether a gas explosion could lead to progressive and disproportionate collapse?

Physical investigations were carried out in the two available (vacant) flats, one in Bromyard and one in Skenfrith House. No reinforcement was detected in the internal (cross) loadbearing walls or the internal leaf of the external (flank) loadbearing walls, as such the walls would fail under a 34kPa and also a 17kPa blast load (blast pressures for piped and bottled gas as defined by BRE [2]). The loss of walls would undermine the support to the floor slabs immediately above and investigations of the connection between the floor slabs and wall above show that the connection is incapable of supporting the weight of the floor in tension. The extent of the loss of the floor slabs in the floor above is likely to be greater than 15% of the total floor area at that level which fails to satisfy the Building Regulations Approved Document A – Structure. The buildings fail to satisfy the three criterion as defined in BRE's Handbook for the Structural Assessment of Large Panel System (LPS) Dwelling Blocks for Accidental Loading.

It is recommended that piped gas is turned off from the tower blocks on Ledbury Estate. Note: at the time of finalising this report, the gas has already been turned off. Based on the findings of the investigations undertaken, it would be impractical to strengthen the building to accommodate piped gas. The assessment also shows that the wall panels would fail under blast pressures defined by BRE [2] for non-piped gas. It is therefore recommended that gas is not re-introduced in any form. It is further recommended that the gas pipes be removed, to ensure there will be no future use of piped gas.

As discussed in the previous sections of this report, at this particular time, the assessment that we have carried out is not a full assessment. The assessment has focused on the areas of the building known to be most vulnerable when considering the effect of a gas explosion. This limited assessment has identified connection details that would require strengthening in order to enhance the margin of safety to where it needs to be for this type of building for future use, to bring within required limits the extent of damage that would be caused in the event of accidental damage to the structure.

With gas turned off from the blocks the immediate and main risk will be removed.

7 References

[1] The structure of Ronan Point and other Taylor Woodrow – Anglian buildings, Building Research Establishment, Department of Environment, 1985

[2] Handbook for the Structural Assessment of Existing Large Panel (LPS) Dwelling Blocks for Accidental Loads, Stuart Matthews and Barry Reeves, Building Research Establishment, Communities and Local Government, 2012

[3] Structure: Approved Document A, The Building Regulations 2010, Department for Communities and Local Government

[4] Circular 62/68, Flats constructed with pre-cast concrete panels. Appraisal and strengthening of existing high blocks: Design of new blocks, Ministry of Housing and Local Government, 15 November 1968

[5] Circular 71/68, Flats constructed with pre-cast concrete panels. Appraisal and strengthening of existing high blocks: Design of new blocks, Ministry of Housing and Local Government, 20 December 1968

[6] Statutory Instruments 1970 No. 109, Building and Buildings, The Building (Fifth Amendment) Regulations 1970

[7] Martech Technical Services Ltd, 21 Church Street, Sawtry, Huntingdon, Cambridgeshire, PE28 5SZ

[8] The Building Regulations 2010, Building and Buildings, England and Wales

[9] Eurocode 0: Basis of structural design, BS EN 1990

[10] Eurocode 1: Actions on structure, BS EN 1991

[11] Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings, BS EN 1992-1-2004+A1:2014

Appendix A - TWA buildings with ‘Type B’ H2 Joint

TWA buildings with ‘Type A’ H2 joint [1]

Buildings	Council	Storeys
Abraham’s Point	LB. Newham	22
Ronan Point, Merrit Point, Gannon Point, Dobson Point	LB. Newham	22
Bauckham Point	LB. Newham	22
Crowhall Tower	Gateshead M.B.	17
Broadwater Farm	L.B. Haringey	17
Aden Tower, Amble Tower, Altringham Tower, Australia Tower, Aberdeen Tower, Aldinham Tower, Amalfi Tower, Gilley Law	Sunderland M.B.	16
Lannoy Point, Hartopp Point, Aintree Est	L.B. Hammersmith & Fulham	14
Barley Mow, Ropemakers Field	L.B. Tower Hamlets	14
Morris Walk	L.B. Greenwich	10
Argyle St	L.B. Wandsworth	10
Ocean Estate	L.B. Tower Hamlets	10
Alpha Grove	L.B. Tower Hamlets	10
Jefferson Estate	L.B. Tower Hamlets	10
Heathcote Pt, Vanner Pt, Ravenscroft Pt, Hensley Pt, Gascoyne Estate	LB. Hackney	10
St Matthew Estate	L.B. Lambeth	7

TWA buildings with ‘Type B’ H2 joint [1]

Buildings	Council	Storeys
Ault Point, John Sopp Point, Hume Point	LB. Newham	22
Goscote House	City of Leicester	22
Broadwater Farm	L.B. Haringey	17
Commercial Way	**L.B. Southwark**	**14**
Lisson Green	City of Westminster	8
Lisson Green	City of Westminster	7
Lethbridge Close	L.B. Lewisham	7