RIDGE

SHROPSHIRE & CHESHIRE HOUSE DISPROPORTIONATE COLLAPSE RISK MANAGEMENT REPORT LONDON BOROUGH OF ENFIELD

February 2023

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Prepared for

Enfield Council
Enfield Civic Centre
Silver Street
Enfield
London
EN1 3XA

Prepared by

Ridge and Partners LLP
1 Royal Court
Kings Worthy
Winchester
Hampshire
SO23 7FW

Tel: 01962 834400

Contact

Matt Linney
Senior Structural Engineer
mlinney@ridge.co.uk
07824 373243

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1. INTRODUCTION

1.1. Brief

Ridge and Partners LLP (Ridge) have previously carried out a structural appraisal of the dwelling block, Shropshire House, to assess its structural robustness. The findings of the appraisal showed that the block was insufficiently robust to prevent disproportionate, progressive collapse in the event of an internal gas explosion.

Early investigations into the neighbouring block, Cheshire House, have shown that this block appears to have similar construction details and will therefore have a similar outcome in the assessment. However, this is subject to the completion of the onsite investigations and the subsequent assessment calculations. Provided the ongoing assessment shows that the results are similar, the risk assessments shown within this report will also likely be applicable to Cheshire House.

Ridge and Partners LLP (Ridge) were subsequently appointed by London Borough of Enfield to appraise the risks which may cause a disproportionate collapse event to the block, also considering possible risk-reduction measures.

1.2. Report Contents

The purpose of this report is to provide London Borough of Enfield with the information and tools required to make an informed decision regarding the acceptability of the level of risk and any risk-reduction measures that may be required.

The risk management processes carried out in this report have been carried out based upon the guidance contained within the BRE Report 511 – *Structural Assessment of Large Panel System Dwelling Blocks for Accidental Loading*.

The following risk management process has been undertaken based on the assumption that the piped-gas supply, which was operational during the onsite investigations is to be removed as per the recommendations by Ridge in our earlier LPS assessment report. Ridge have been informed by the client that the piped-gas supply from one of the blocks has already been shut off, and the second will also soon be shut off. The gas supply should therefore be stripped out and replaced with an alternative source. [Note: the outcome of this risk process will not be valid if the piped-gas is retained].

It should be noted that as the risks outlined in this report are carried by London Borough of Enfield, being the duty holder, Ridge will not pass comment upon whether the risks are 'Acceptable' or otherwise. Different organisations have differing views on the acceptability of risk levels, and being an independent body, Ridge believe it would be inappropriate to comment upon what London Borough of Enfield should consider acceptable. Instead, Ridge will assess each risk and provide a commentary compared to various benchmarks. Based on this analysis and associated commentary, London Borough of Enfield will be able to carefully consider whether the assessed level of risk is 'Acceptable' to them.

1.3. Limitations

Whilst a number of likely causes of structural damage/collapse are discussed in this report it should be noted that it is not all encompassing. Some other risks may exist which could potentially lead to structural damage. However, the likelihood, or severity, of these omitted risks is likely to be considerably lower than the main risks discussed.

1.4. Statement

The purpose of the Report is to advise on the risks which may cause a structural failure/collapse of the high-rise LPS block, Shropshire House (likely also for Cheshire House, based on further assessment), together with those related matters specifically referred to therein and it is not intended to be used for any other purposes. The Report is for the sole benefit and may only be relied upon by the addressee, to whom we will owe a duty of care. The Report or any part of it is confidential to the addressee and should not be disclosed to any third party for any purpose, without our prior written consent of Ridge and Partners LLP as to the form and context of such disclosure. The granting of such consent shall not entitle the third party to place reliance on the Report, nor shall it confer any third party rights pursuant to the Contracts (Rights of Third Parties) Act. The Report may not be assigned to any third party.

2. EXECUTIVE SUMMARY

This document presents the risk management process undertaken by Ridge and Partners to assess the risks of disproportionate, progressive collapse in Shropshire and Cheshire Houses, and appraise the options available to reduce these risks, including the previously designed strengthening works. Enfield Council requested that Ridge appraise the risks for 3 timescale scenarios:

- 4 years, sufficient time to mobilise either strengthening or demolition
- 10 years, to enable a phased approach to the works to both blocks
- 30 years, blocks are left long-term without strengthening

The risks have been analysed using qualitative and quantitative risk assessments and the ALARP principle, and the risk-reduction measures have been appraised using an 'options appraisal' and a cost benefit analysis (CBA) for the strengthening option.

The outcome of the risk assessments has shown that the probability of an explosion occurring in a single stack of the block is categorised as 'Improbable'. The probability of a severe explosion occurring in any of the flats for the duration of the three timescale scenarios are as follows:

- 4 Years: 0.41×10^{-4} [1:24510]
- 10 Years: 1.02×10^{-4} [1:9804]
- 30 Years: 3.06×10^{-4} [1:3268]

However, the consequence of an explosion occurring in the upper 8 floors of the block, in its unstrengthened state, could result in **105 fatalities**. This places the risk in the 'Catastrophic' consequence class.

From the probability and consequence calculations, the risk of death to resident in the event of an internal gas explosion was calculated. We compared this to HSE benchmarks to 'tolerable' risks for work and generally to the public, and the risk of death calculated was within both limits.

The ALARP process showed that the risk of collapse required risk-reducing measures to be considered to lower this as low as reasonably possible.

The cost benefit analysis assessed the cost of the proposed strengthening works to the value of preventing a fatality (VPF). From this it was found that the costs associated with the proposed strengthening works were disproportionate to the benefit gained by reducing the risk of fatalities.

However, the HSE states that "A CBA cannot be used to argue against the implementation of relevant good practice, unless the alternative measures are demonstrated unequivocally to be at least as effective." (HSE, 2020). The CBA therefore only suggests that strengthening is the lesser of the attractive options but does not preclude that action is required to be taken and risk reduction measures either short, medium or long term put in place.

Alternative risk-reduction measures were therefore considered and compared against the strengthening works in an options appraisal. An overview can be seen in the following table.

RISK REDUCTION MEASURE	RISK REDUCTION	RESIDUAL RISKS	ASSOCIATED COSTS	TIMEFRAME
Strengthening Proposal	Highest level of risk reduction. Block no longer susceptible to progressive collapse	Localised collapse may occur, but will be proportionate to the cause.	Highest costs. Cost benefit analysis suggests the costs are disproportionate to benefit of risk reduction.	Suitable for long-term retention of the blocks (30-year timescale) [Note: other durability items will be included to attain this 30-year timescale outside the scope of these works]
Administrative Measures	Some risk reduction as probability is reduced, but consequence unchanged.	Block remains susceptible to disproportionate, progressive collapse.	Cost dependent on which measure is implemented, but significantly less than strengthening.	Not suitable for long-term retention of the blocks. To be used as a short term measure (4 or 10-year timescale) to enable either strengthening or demolition
Do Nothing	No reduction in risk	Block remains susceptible to disproportionate, progressive collapse. Risk unchanged.	No cost.	Not suitable for long-term retention of the blocks. Client may consider this if demolition confirmed to commence imminently (4-year timescale, although we would strongly recommend administrative measures are used)

Based on the outcome of the Risk Management process, we would recommend that Enfield Council consider the three following options:

1) If the council wish to retain the block in the short term (4 years or less) then administrative measures should be considered
2) If the council wish to retain the blocks in the medium to long-term (10-30 years), then strengthening works are required.
3) If the council agree that the cost of strengthening works are grossly disproportionate to the benefits of risk reduction, then demolition should be considered.

With either options 2 or 3 it is likely the process to procure, decant (either fully or partially), and complete the works will be over a timeline of 4 years. During this interim period, we would advise that administrative measures are introduced (i.e. security cameras, letter drops etc) to control the risk.

3. METHODS OF ASSESSING RISK

Risk management is a systematic approach which is used to Eliminate, Reduce, Inform, and Control (ERIC). The process initially involves the assessment of the uncertainty by identifying and assessing the hazards to determine the probability and severity, and subsequently the risk associated to each hazard. Once this is understood, each risk can be communicated to the duty holders and suitably acted upon.

The analysis and assessment of risk can be undertaken in two different approaches:

- Qualitative risk assessment,
- Quantitative risk assessment.

Once the risk analysis and assessment, using one or both of the approaches above, a decision can be made by the duty holder as to whether the risks can be deemed 'acceptable' or otherwise. If the magnitude of the risk is considered to be excessive and therefore 'unacceptable' to be directly accepted by the duty holder, the risks are investigated to plan appropriate risk-reduction measures. It should be noted here that the Health and Safety Executive (HSE) guidance states that "duty holders must reduce risks wherever it is reasonably practical to do so, or where the law requires it."

When assessing risk-reduction measures there are several tools available to clients and assessors to ensure that the measures are appropriate, and reasonable for the level of risk reduction achieved.

The outcome of this risk management process is to help protect duty holders and users from various factors such as economic losses, injury and the possibly death.

3.1. Qualitative Risk Assessment

Qualitative risk assessments typically utilise a risk matrix to profile each risk based on their associated probability and severity. This form of risk assessment is significantly simpler than the quantitative approach and can form a basis for decision making. The BRE Report 511 uses the template in Figure 1 to profile the risks into four categories, and also provides a key for the risk categories which can be used to determine the required action based on the outcome of the assessment.

Frequency/probability of occurrence		Severity/Consequence of hazard					
		I	II	III	IV	V	VI
		Catastrophic	Critical	Grave	Serious	Marginal	Negligible
C	Common	UA	UA	UA	UA	T	RAW
D	Likely	UA	UA	UA	T	RAW	RAW
E	Occasional	UA	UA	T	RAW	RAW	RA
F	Possible	UA	T	RAW	RAW	RA	RA
G	Rare	T	RAW	RAW	RA	RA	RA
H	Improbable	RAW	RAW	RA	RA	RA	RA
I	Deliberate Act	RAW	RA	RA	RA	RA	RA

Figure 1 – Risk Assessment – template for risk quantification and profiling (BRE, 2012)

Code	Risk category	Action required
UA	Unacceptable risk	Corrective action essential to reduce the risk
T	Tolerable only if risk reduction impractical	Review required to determine whether a further reduction of the risk is possible – risk reduction required unless cost is grossly disproportional to benefit gained from bearing risk
RAW	Risk acceptable with review	Review required to determine whether a further reduction of the risk is reasonable and practicable – implement if cost of reduction less than benefit gained from bearing risk
RA	Risk acceptable without review	No action required

Figure 2 – Risk Categories (BRE, 2012)

3.2. Quantitative Risk Assessment

Quantitative risk assessments are a more complex form of risk analysis than the qualitative method. This form of assessment utilises information derived from statistics and past events. In the context of the assessment of LPS structure, the statistics are taken from accidental loading and events occurring in the UK building stock, collected by the BRE, and others.

The risk associated with each hazard is estimated by multiplying the probability of the risk occurring by the consequence (number of injuries/deaths) the hazard may likely cause.

The estimated risk level can then be used in the various analysis tools to determine the appropriate response to the risks.

3.3. ALARP

ALARP (As low as reasonably possible) is a principle adopted by the HSE as guidance to duty holders to reduce risks wherever possible provided the reduction measures are reasonable. The ALARP principle for LPS Buildings would be to assess the risks in a systematic manner (using the above two forms of risk assessment) to determine where risks can be eliminated, where practical, or reduced and controlled as far as possible.

The CIB Report: Publication 259 – *Risk Assessment and Risk Communication in Civil Engineering* shows two graphs which are commonly used in the ALARP procedure. Both of the graphs consist of two F-n curve (where F = frequency and n = number of casualties) which correlate to what is considered "*social acceptance of risk to human life*".

The curve to the left of each graph represents the lower risk limit, below which the risk would generally be considered negligible. The curve to the right represents the upper risk limit, above which the risk is not acceptable and remedial action should be sought to reduce this risk. Between the upper and lower bounds is the ALARP region. The risks which fall within this region should be considered for risk reduction measure, and a cost benefit analysis carried out to determine whether the reduction of the risk is worth the cost.

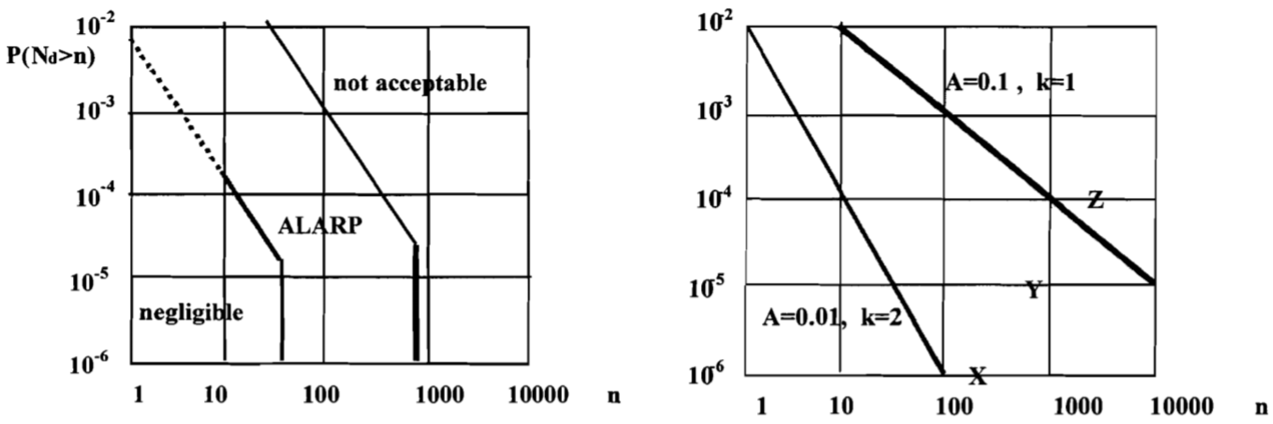


Figure 3 – F-N curves, and the ALARP region. (CIB, 2001)

3.4. Cost Benefit Analysis (CBA)

Cost benefit analyses are typically carried out alongside the ALARP process as a decision tool whether to carry out the proposed risk-reduction measures highlighted in the qualitative risk assessment.

A CBA should take into account all costs and benefits that each remedial action would accrue. The analysis would then compare the two parameters to determine whether the benefits of the risk-reduction measures will outweigh the cost implications.

In Evan's 2005 report *Safety Appraisal Criteria* the below graph has been presented to allow the probability of the hazard occurring can be plotted against the cost of the remedial works. The graph can then be used to indicate whether the benefit of the works would exceed what is deemed as an acceptable cost for preventing a fatality.

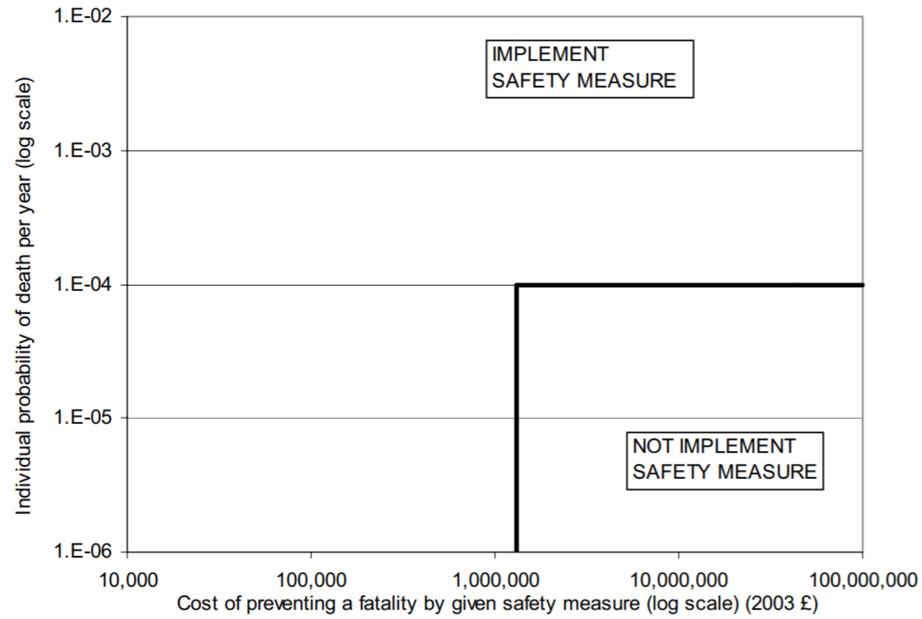


Figure 4 – Individual risk and cost benefit criteria combined (Evans, 2005)

Once the CBA has been carried out, with the potential remedial works assessed, the duty holder will be able to make an informed decision whether to carry out the remedial works, which remedial solution to implement, or whether the risk can be considered as low are reasonably possible.

4. BRIEF OVERVIEW OF LPS STRUCTURES AND INTERNAL GAS EXPLOSIONS

4.1. Ronan Point

On the 11th March 1968 construction was completed on a 21-storey dwelling block in Newham, East London, called Ronan Point. Two months after opening, the block of flats suffered progressive collapse to the southeast corner of the structure. A subsequent Tribunal found that the partial collapse was caused by an explosion of town gas in one of the flats. The explosion had caused the loadbearing flank wall of the flat to 'blow out', thus removing the support to the other loadbearing elements and causing further elements to fail.

Figure 5 – The collapse of Ronan Point in 1968 (The Guardian, 2018)

4.2. Piped-Gas Supply

When Ridge undertook the intrusive investigation into the construction of Shropshire House to determine it's robustness, the block was still served by a piped-gas supply. It is now understood that this has since been shut off (Ridge had recommended a phased removal of this in our assessment report).

The removal of the piped-gas supply reduces the risk of a gas explosion occurring within the block, but it does not eliminate this risk, as non-piped-gas sources, such as LPG canisters, large aerosols etc can still be introduced into the blocks by residents / others which can still cause explosions, albeit it of a smaller magnitude. Through our calculations, based on an overpressure of 17kN/m^2 (which the BRE require in their document BRE511 as the overpressure for non-piped-gas sources), we found that the blocks were still susceptible to disproportionate collapse from these smaller magnitude explosions.

Action was therefore required to control this risk, which we shall discuss in this document.

4.3. Current Climate

As a result of the Grenfell Tower fire where 72 people were killed, a spotlight has been shone on high-rise buildings, including LPS buildings. Duty holders who have these buildings within their housing stock are therefore being required to assess the construction of the blocks and appraise / remedy the risks to the building occupants. With regards to LPS blocks, one of the main areas of concern is their susceptibility to disproportionate, progressive collapse in the event of an internal gas explosion (from both piped and non-piped gas sources)

We have seen in recent times the 'Cost of Living Crisis' which has driven the cost of electricity up, with some unable to pay to heat their homes. As this continues it is likely that people may look to cheaper alternatives to reduce the cost. Some alternatives may include LPG heaters, or oil-filled radiators, which present a risk of fire / explosion. If these sources are brought into the blocks, and an explosion event does occur, this may result in the disproportionate collapse of the block.

It is likely that the London Borough of Enfield already impose a ban on bringing these sources into the high-rise blocks, although we would recommend this is stressed again, due to the current climate, to residents to ensure they are aware of the risks in introducing these into the blocks.

5. SHROPSHIRE HOUSE RISK MANAGEMENT

5.1. Qualitative Risk Assessment

The risk matrix in Appendix A has been prepared to document the outcome of the qualitative risk assessment carried out for the LPS blocks, Shropshire & Cheshire Houses. The risk assessment has considered the likely hazards which may cause structural damage, and the subsequent risks these hazards impose on the residents and others.

The risk matrix also includes possible risk-reduction measure which could be implemented, and how these will impact the risks.

The following outcomes can be drawn from the risk assessment:

- The presence of piped-gas in the block is a Category T risk, meaning the risk should be reviewed and risk-reduction carried out, unless costs grossly disproportionate to the benefit.
    - The removal of the piped-gas supply was one of our recommendations from the assessment report, and one which we would highly advise is undertaken. It is believed that the piped-gas supply has been turned off in Shropshire House, with plans for the same action within Cheshire House, ultimately removing the gas supply from the blocks entirely and replacing with an alternative system.
- After the removal of the piped-gas supply it is still possible to suffer an internal explosion from non-piped-gas sources (i.e. gas canisters). This has been categorised as RAW, meaning the risk should be reviewed and risk-reduction measures implemented provided the benefits of the works outweigh the costs.
    - The strengthening proposals, and the introduction of administrative measures (i.e. 24hr security to prevent residents bringing gas canisters etc into the flats) should be considered.
- Fire causing structural damage has the largest probability of all the hazards included in the assessment.
    - Note: the assessment is for fires causing structural damage, and the injuries/fatalities the structural damage would cause. This does not include the injuries/fatalities from the fire itself.
    - Fires affect concrete by inducing stresses through heating and the subsequent cooling (expansion and contraction)
    - In most cases it is only large, mature fires which cause significant structural damage. Provided appropriate fire evacuation procedures are in place (outside the scope of works), it would be expected that the majority (if not all) residents should be out of the block before the structure is significantly damaged, thus reducing the consequence.
    - Any strengthening works to be employed for the gas-explosion case must be adequately fire protected.
- Inadequately planned structural modifications – the strengthening works should be carried out by a competent and experienced contractor.
- Deliberate acts, such as terrorism, are not within the scope of this report or the BRE Report 511. The incident frequency cannot be confirmed, and the magnitude of this form of event is unpredictable. Risk reduction measures were therefore not considered.

5.2. Quantitative Risk Assessment

The risk of an internal gas explosion was shown in the qualitative risk assessment to be considered a category RAW risk. This category requires the assessor to review the risk to determine whether the potential risk-reduction measures will create sufficient benefit to outweigh the costs.

The risk of an internal gas explosion was therefore calculated using the method shown in BRE Report 511 – Appendix B. The guidance states that the frequency of a severe explosion from a non-piped gas explosion in a dwelling is approximately 0.1 x 10^{-6}. Using this probability of a severe explosion occurring, an estimate of the risk to the dwelling blocks can be derived based on the following site parameters:

- Remaining life of the block assessed for the following:
  - 4 years, sufficient time to mobilise either strengthening or demolition
  - 10 years, to enable a phased approach to the works to both blocks
  - 30 years, blocks are left long-term without strengthening
- The blocks are 18 storeys tall, and each have 6 dwellings per floor (1 x 3 bed, 3 x 2 bed, 2 x 1 bed)
- There are a number of collapse mechanisms which may occur in the event of an internal gas explosion. However, these can typically be categorised into two groups:
  1) Explosion event occurring within the top 8 floors:
     These have the potential to cause significantly more damage to the structure and cause the highest number of potential casualties/fatalities. And explosion in these floors could cause the collapse of three structural bays over the full height of the block (see Figure 7)
  2) Explosion event occurring within the top 8 floors:
     As the cross walls in the lower floors can withstand the overpressure from an explosion at the lower 17kN/m^2 force, the explosion would only cause collapse to the structural bay in which the explosion occurred in. In addition, the collapse would also likely be limited to the floors below the event and one floor above (i.e. an explosion on the 6th floor would cause collapse of floors 1 – 7 in a single bay) (see Figure 8)

[See Appendix B for legend for collapse mechanism diagrams]

Figure 6 – Example explosion event location

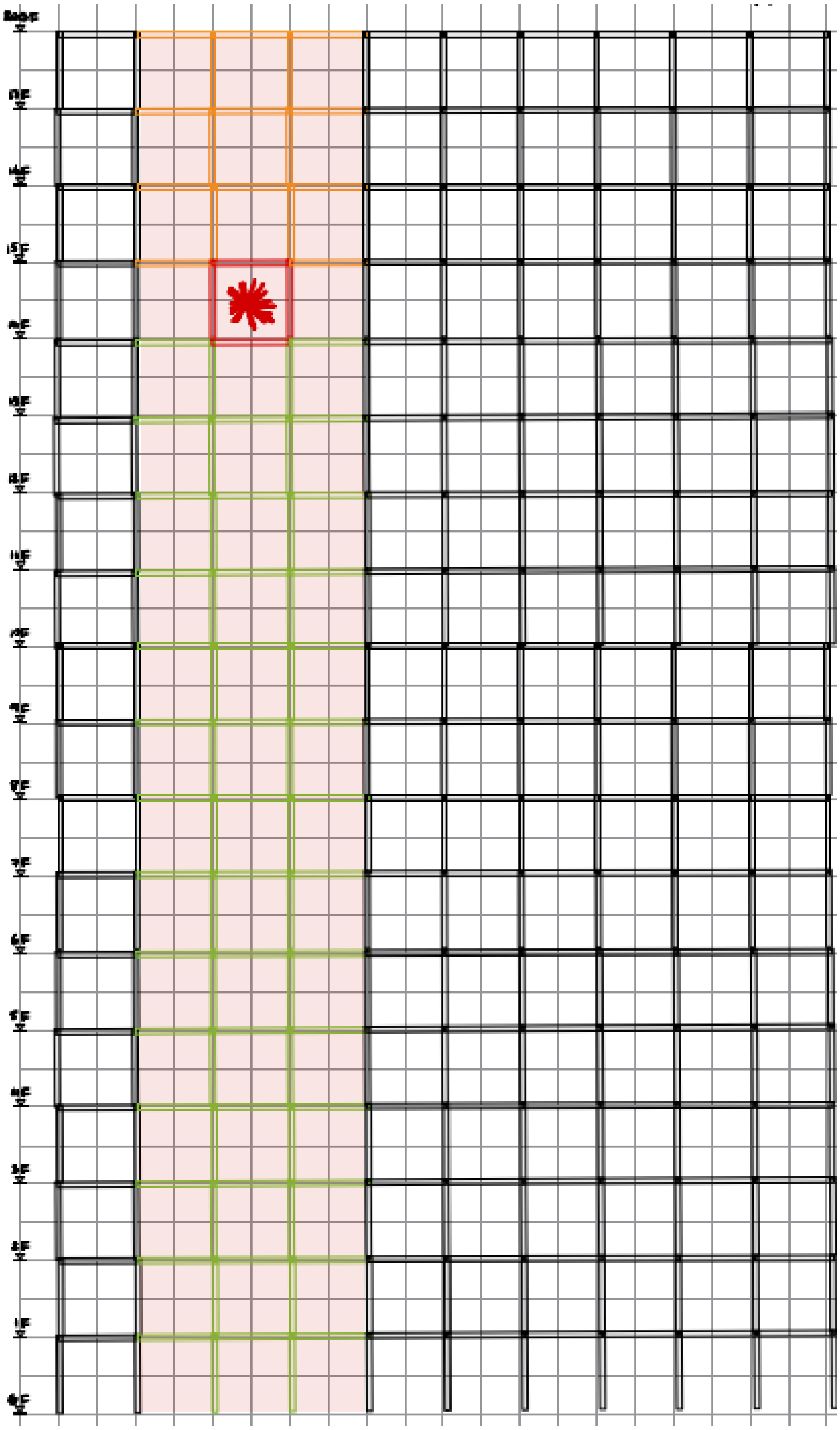


Figure 7 – Collapse mechanism if explosion event occurs in the upper 8 floors (elevation)

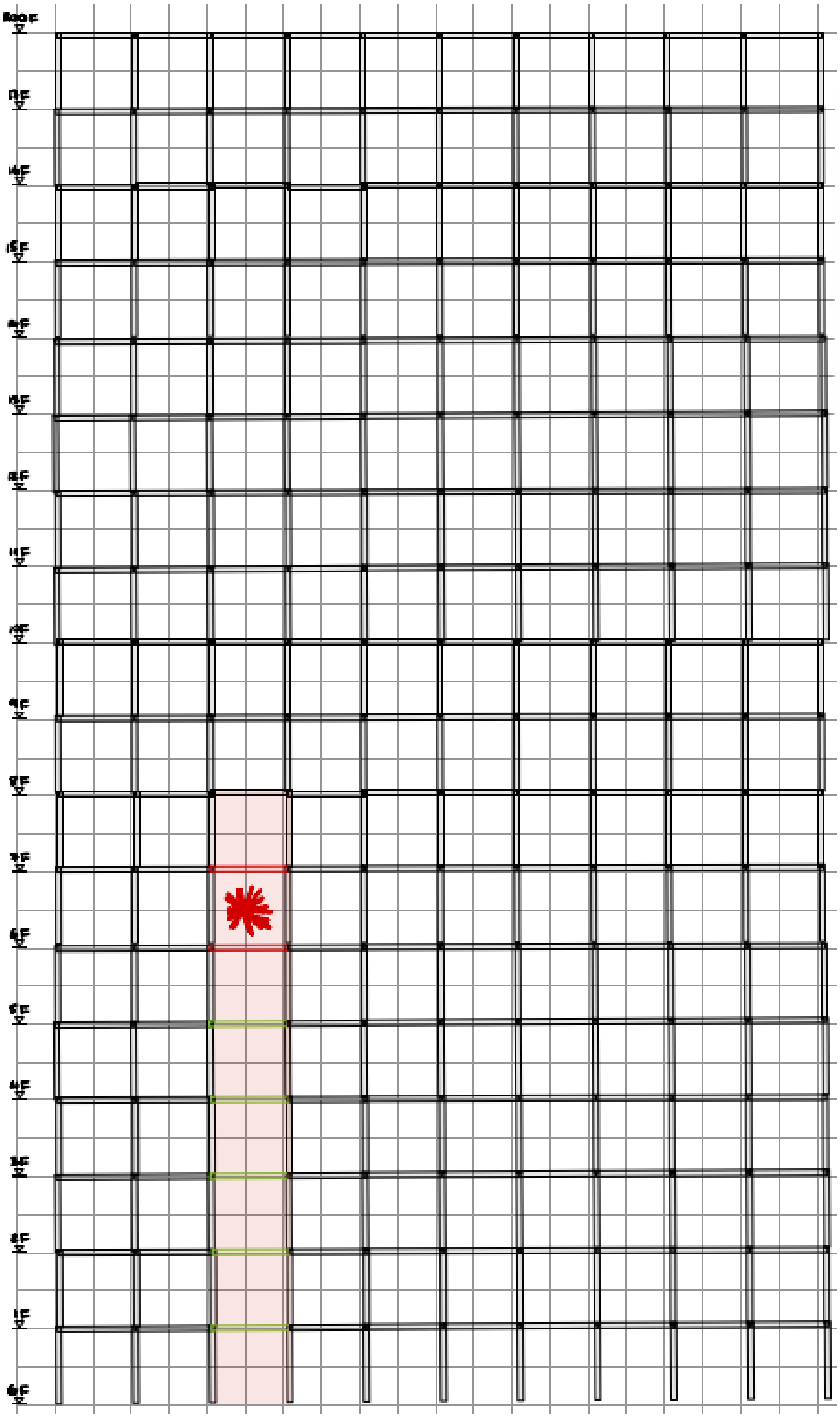


Figure 8 – Collapse mechanism if explosion event occurs in the lower 9 floors (elevation)

Outcome of Quantitative Risk Assessment [Appendix B]

The outcome of the assessment has shown that the estimated probability of a 'severe' explosion from a non-piped gas supply (i.e. gas cannister etc) creating the possibility of a progressive collapse event in one of the blocks is between:

0.16×10^{-6} and 1.7×10^{-6} per annum

The probability of an internal gas explosion causing an progressive collapse event in the proposed remaining life spans of the block:

4-year Remaining Life = 0.41×10^{-4}
10-year Remaining Life = 1.02×10^{-4}
30-year Remaining Life = 3.06×10^{-4}

The consequence of a collapse event, assuming the block is fully occupied at the time of explosion, has been estimated as (upper bound):

105 people

The total risk of death of a resident, has been estimated as:

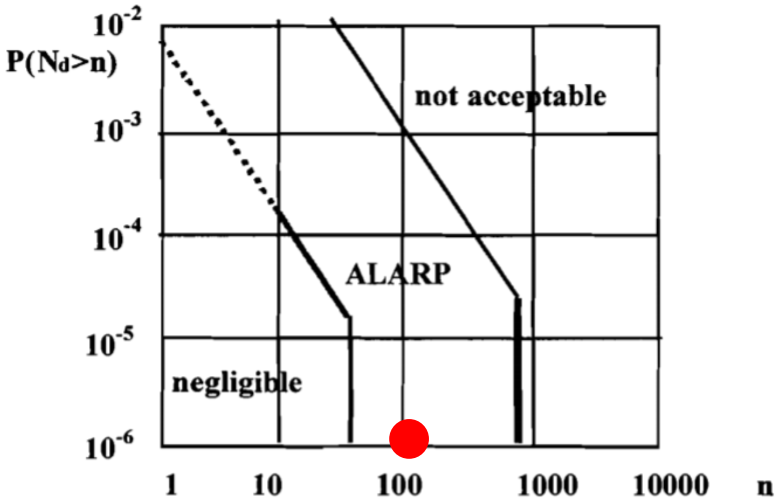
9.48×10^{-5} per annum

Comparison to UK Standard Benchmarks:

- The notional limit for the 'tolerable' limit of risk at work is set at 1×10^{-3} per annum (HSE, 1992)
  - The risk of death from progressive collapse in the event of an internal gas explosion within Shropshire House has been calculated is therefore lower than this notional limit.
- The notional limit for the 'tolerable' limit of risk to any member of the public is set at 1×10^{-4} per annum (HSE, 2002)
  - The risk of death from progressive collapse in the event of an internal gas explosion within Shropshire House has been calculated is therefore lower than this notional limit.

5.3. ALARP

The values obtained from the quantitative assessment (based on the blocks being retained) have been compared against the two ALARP graphs to determine which region the risks fall under.



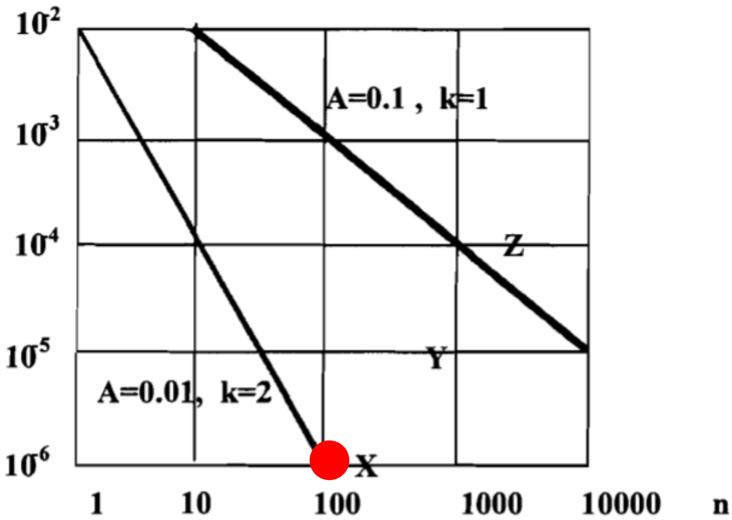


Figure 9 – ALARP analysis for the risk of 'severe' explosion causing progressive collapse to Shropshire & Cheshire House

The ALARP analysis using either of the two graphs above show that the risk of a of a 'severe' explosion from a non-piped gas supply (i.e., gas cannister etc) creating the possibility of a progressive collapse event in one of the blocks lies within the region denoted as 'ALARP'. This outcome suggests that risk-reduction measures should be considered, judged on an economic basis. This appraisal is required under the HSE's requirements, where the duty holder has a responsibility to reduce risks wherever reasonably practical to do so. Strengthening measures should therefore be considered, with a cost-benefit analysis on the risk-reduction works to ensure the amount of expenditure deemed reasonable and cost-effective.

It should also be noted that whilst the F-n curves shown in the graphs above are designed to show what is a 'socially acceptable risk', these graphs were created for the 2001 CIB report, and reproduced later in the 2012 BRE Report 511. The original report is now 20 years old. Therefore, the risk curves differentiating what constitutes an 'socially acceptable risk' may be debatable in the current political climate surrounding social housing in the UK. Particularly with the spotlight placed on LPS blocks, and high-rise blocks in general in recent years. This should be taken into account during the clients decision-making process.

5.4. Cost Benefit Analysis – Value of Preventing a Fatality

The values obtained from the quantitative assessment have been used to carry out a Cost Benefit Analysis (CBA) on the cost estimates for each of the proposed strengthening options. Strengthening will enable the blocks to be retained and therefore the CBA has considered this against the 30-year time frame. [Note: the costs included in the below relate exclusively to the strengthening works, not other maintenance that would be expected to allow the remaining life to meet the 30-years]

- 30 year remaining life
- Total risk of death of a resident = 9.48×10^{-5} per annum

[Values taken from the quantitative risk assessment in Appendix B]

This probability was plotted on the cost-benefit graph produced in Evan's 2005 report *Safety Appraisal Criteria.*

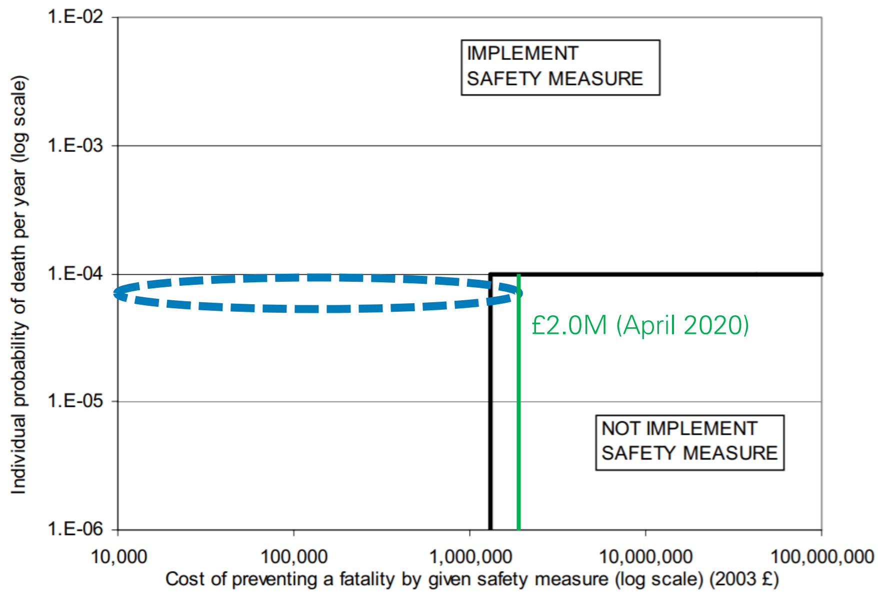


Figure 10 – Individual risk and cost benefit criteria combined for Shropshire and Cheshire Houses (Evans, 2005)

The graph above therefore shows that, based on probability of an internal gas explosion occurring in the block that may cause a disproportionate collapse event, the cost of preventing a fatality by a given safety measure should be between the range £10,000 - £1.31M (The VPF in 2003). Note the Value of Preventing a Fatality (VPF) in this graph is now outdated.

The Value of Preventing a Fatality (VPF) in the UK is currently valued at around £2M (2019) by the Department of Transport. This value is considered to be the maximum reasonable amount to pay to prevent the premature death of one person and is used by numerous UK government agencies (does not just apply to transport).

Therefore, the sum that might rationally be spent to prevent these fatalities, based on the UK governments valuation of VPF is:

$$30 \times 9.48 \times 10^{-5} \times £2{,}000{,}000 = \underline{£5688}$$

However, the validity of the VPF that is used by the UK government is currently under scrutiny, believed to significantly undervalue the cost of life. For comparison, the US Department of Transport's Value of a Statistical Life (VSL) is set at $9.6M [~£7.8M] (2015).

A report published by Professor Philip Thomas from the University of Bristol in Measurement, Volume 150, Jan 2020, concludes that "No confidence can be placed in the figure for the VPF used as a safety yardstick by the UK government because the sample size used in its foundational opinion survey, 167, is less than a tenth of what would be required to give reasonable precision." Instead the report suggests the use of J-value method of analysis which shows the amount that should be spent to preserve the life expectancy of the average person in the UK ought to be £8.59M.

Therefore, the sum that might rationally be spent to prevent these fatalities, based on the J-value method valuation of VPF is:

$$5 \times 9.48 \times 10^{-5} \times £8{,}590{,}000 = \underline{\underline{£24430}}$$

Table 1 shows how the cost estimates for each of the strengthening options compares to the two values of VPF above.
[The cost estimates are taken from Ridge's *'Estimate of Cost for Strengthening Works'* report]

STRENGTHENING OPTION	COST ESTIMATE (PER BLOCK)	COMPARISON WITH VPF	
		VPF £2 M [£5,688]	VPF £8.59 M [£24,430]
Option 1 (Steel Strapping)	£6,379,000	1121 x VPF	261 x VPF
Option 2 (FRP Strapping)	£6,098,900	1072 x VPF	250 x VPF

Table 1 – Comparison of estimated costs for the strengthening options to the value of preventing a fatality (VPF)

The Institution of Structural Engineers' report *Appraisal of existing structures* states that "The factor for 'gross disproportion' is usually taken as at least 2, and can be up to 10 for large risks" (The Institution of Structural Engineers, 2010). The comparison of the cost estimates to the VPF shows that the factor is considerably larger than 10 and therefore may be considered disproportionate to the benefits.

However, it should be noted that cost benefit analysis is an informative tool, rather than a decision-making tool. Other considerations therefore must also be taken into account in the decision-making process. The HSE also states that "A CBA cannot be used to argue against the implementation of relevant good practice, unless the alternative measures are demonstrated unequivocally to be at least as effective." (HSE, 2020)

6. RISK REDUCTION MEASURES

6.1. Overview

In addition to the strengthening works proposed in our earlier work, there is also the option to reduce the risk of disproportionate collapse using other risk-reduction measures. Some possible risk-reduction measures are presented in the following sections. These are then appraised in Appendix C based on the level of risk-reduction achieved once the measure has been installed, and the associated costs of this measure.

6.2. Strengthening Works

As part of previous works, Ridge have designed proposed strengthening works to the blocks which include bolting steel angles to the joints between floors and loadbearing walls to form a cruciform connection, strapping the floor slabs in some areas, and strapping cross walls in the upper 8 floors. These have been designed to limit the amount of strengthening required (by allowing some elements to fail) whilst ensuring that the block does is not susceptible to disproportionate collapse.

These strengthening works offer the greatest risk reduction of all the measures discussed within the document. This eliminates the risk of disproportionate collapse from an internal gas explosion from a non-piped gas source, but does allow for a 'proportionate' failure of some elements.

6.3. Administrative Measures

The alternative to the 'Do Nothing' approach, should the strengthening proposals be found not cost-effective but a reduction in risk required, is to initiate an administrative measure on site to prevent, or at least limit the probability, of gas canisters being taken inside the blocks. This may take the form of security cameras installed around the site with an onsite security office where the live camera feed can be monitored 24/7, or a concierge at the main entrance to the block who is made aware of the risk and remains vigilant. Other options may also be possible, including regular letter drops, posters in communal areas or door-to-door conversations with residents reminding them of prohibited items (such as LPG cannisters) and the risk associated with them.

The installation of administrative measures may reduce the likelihood of an internal gas explosion, although the effectiveness of this form of risk-reduction would largely be dependent on the method employed and the management of this method.

Administrative measures would aim to prevent residents bringing gas cannisters into the flats. However, aerosols also pose an explosion risk and are unlikely to be stopped from entering the properties. A test carried out by the BRE in a maisonette in Sheffield showed that explosions from small aerosol canister (i.e. deodorant cans) can cause an overpressure between 2.6 – 9 kN/m^2. (Note: the higher 9kN/m^2 overpressure was from a 750ml aerosol). Whilst the lower bound of this is unlikely to cause significant structural damage to the block, 9kN/m^2 may cause a structural failure. This failure is likely to cause significant cracking to the panels, but may not cause a collapse, especially if the explosion were to occur in the lower floors where the weight of the floors above reduces the tensile stresses in the panels from the explosion.

The introduction of administrative measures alone will also have no impact on the consequence (number of fatalities) of a progressive collapse event triggered by an internal gas explosion, it will only lower the probability of it occurring.

6.4. Do Nothing

Another possible action is simply to do nothing. Should Enfield Council determine that the risk as analysed in this report is within their limits of being 'acceptable' and consider that the costs associated with the risk-reduction measures are grossly disproportionate to the benefits they would achieve, then it could be argued that the 'do nothing' approach is acceptable and take no further action on the risks.

We would suggest that this would only be appropriate as an immediate/short-term measure, should Enfield decide to demolish the blocks imminently. Although, as noted previously, under the HSE's requirements the duty holder has a responsibility to reduce risks wherever reasonably practical to do so. It would therefore be our recommendation that administrative measures are used in the interim as long as the block remain standing.

6.5. Other Hazards

Fire

The risk assessment for hazards that may cause significant structural damage to the blocks identified Fire as the highest probability hazard. Large, mature fires can induce stresses in the concrete due to expansion during the heating phase, and rapid cooling during the cooling phase (once the fire is extinguished).

The effects of fire may cause local floor collapse, induced movements causing displacement of joints (particularly the flank wall joint) etc. Whilst not designed to resist these induced forces the strengthening proposals for the case of an internal gas explosion may also be sufficient to prevent collapse in a fire, particularly the steel joint angles which would prevent displacement of the joints.

However, to remain effective, and not pose an additional fire risk to the building, the strengthening works must have suitable fire protection. This will likely be in the form of intumescent paint to the required rating.

Inadequately Planned Structural Modifications

As with any construction project, the installation of the remedial strengthening proposals would carry a degree of risk if not the installation is not properly controlled. The strengthening works should therefore be carried out by a suitably competent and experienced contractor to minimise this risk.

The installation of the remedial works must not allow excessive loads to be imposed onto the floor slabs (i.e. storage of materials), and no gas-welding is to be carried out on site, due to the risk of explosion.

Vehicular Impact

The BRE Report 511 states that "overall road vehicle impacts appear to pose a vanishingly small risk of causing structural damage which might lead to progressive collapse or disproportionate damage in an LPS dwelling block."

This being said, the south elevations of Shropshire and Cheshire Houses borders two small car parks and are unprotected by any safety barriers (i.e. Armco). It would therefore be possible for a vehicle to mount the kerb and cause damage to the block. However, given the compressive loading at the lower levels, combined with the short length of the car park (vehicle unlikely to gain sufficient speed for a high-force impact) it is unlikely an impact would cause significant damage to cause progressive collapse of the block.

However, to minimise this risk, an Armco barrier or bollards could be installed along this elevation to prevent vehicle strikes.

7. CONCLUSION

The risk management exercises carried out within this report has made the following findings:

- The qualitative risk assessment has found that the risk is defined as 'Tolerable only if risk reduction impractical'. The BRE 511 report suggests that a review is required to determine whether a further reduction of the risk is possible, and that risk reduction works are required unless the cost is grossly disproportionate to the benefit gained from bearing the risk.
- The quantitative risk assessment calculated that the estimated probability of a 'severe' explosion from a non-piped gas supply (i.e., gas cannister etc) creating the possibility of a progressive collapse event in one of the blocks, in their current un-strengthened state, over the proposed remaining lifespans are:
  - Retained for 4 Years = **4.08×10^{-5}**
  - Retained for 10 Years = **1.02×10^{-4}**
  - Retained for 30 Years = **3.06×10^{-4}**
- The upper bound consequence would be **105 fatalities** if the explosion occurred in the upper 8 floors. This reduces to an average consequence of **12 fatalities** if an explosion occurs in the lower 9 floors. This produces an associated risk of death to a resident as **5.26×10^{-4} per annum**. These results were used in the ALARP and Cost Benefit Analysis.
- The risk of death to a resident was compared against benchmarks for notional limits of risk as set by the HSE. The risk calculated from the quantitative assessment showed that the risk was within the notional limits of risk for both benchmarks.
- Using the ALARP graphs, the risk of fatality from an internal gas explosion from a non-piped gas source causing progressive collapse was found to be in the 'ALARP' zone, which requires risk-reduction measures to be considered and appraised using a cost-benefit analysis.
- Finally, a Cost Benefit Analysis (CBA) was conducted to determine whether the strengthening works were grossly disproportionate to the cost. The analysis used the Value of Preventing a Fatality (VPF) of £2.0M, set by the UK Treasury in April 2020. Comparing the costs of the proposed strengthening works to the estate wide VPF, it was found that the costs associated with the proposed strengthening works were disproportionate to the benefit gained by reducing the risk of fatalities.
- However, we would note that this does not diminish the duty holder's responsibility to reduce risks wherever reasonably practical to do so, under the HSE's requirements. The HSE also state that "A CBA cannot be used to argue against the implementation of relevant good practice, unless the alternative measures are demonstrated unequivocally to be at least as effective"
- Other risk-reduction measures have also been commented upon and appraised, including administrative measures such as the installation of CCTV cameras. These can be effective in the reduction of probability (if residents are stopped from introducing potential sources to the building) but will not reduce the consequence of doing so. This would therefore go against the HSE's statement that alternative measures must be demonstrated unequivocally to be at least as effective. However, could be a useful short-term measure whilst either strengthening or demolition is undertaken.
- Finally, should Enfield Council deem that the level of risk calculated within this document are 'acceptable' and that the cost of risk reduction measures are grossly disproportionate to their benefits, then it could be argued that 'do nothing' is an appropriate response to the risk of progressive, disproportionate collapse. We would suggest, however, that this would only be appropriate as an immediate/short-term measure, should Enfield decide to decant and demolish the blocks imminently. Although, it would still be our recommendation that administrative measures are used in the interim as long as the block remain standing.

8. RECOMMENDATIONS

Based on the outcome of the Risk Management process, we would recommend that Enfield Council consider the three following options:

1) If the council wish to retain the block in the short term (4 years or less) then administrative measures should be considered
2) If the council wish to retain the blocks in the medium to long-term (10-30 years), then strengthening works are required.
3) If the council agree that the cost of strengthening works are grossly disproportionate to the benefits of risk reduction, then demolition should be considered.

With either options 2 or 3 it is likely the process to procure, decant (either fully or partially), and complete the works will be over a timeline of 4 years, the risk of which we have evaluated in our quantitative risk assessment. During this time, it is known that the gas supply has been cut off, and a permanent alternative heating measure has not yet been installed. It is therefore possible that residents of the block may bring bottled gas (i.e. LPG canisters) into the building within this period to provide heating to their flats, increasing the risk of an internal explosion event, leading to a disproportionate collapse event. It is therefore recommended that in the meantime the following preventative measures are put in place to reduce the likelihood of gas being stored within the block:

- 24/7 monitoring of the entrances with CCTV
- Concierge introduced at the main entrance to the buildings who are made aware of the risk and remains vigilant to residents bring in banned sources
- Posters in the communal areas, explaining the prohibited items and the risks
- A letter drop, explaining the prohibited items and the risks
- Door to door conversations – reminding residents of the prohibited items and the risks

9. REFERENCES

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APPENDIX A
Qualitative Risk Assessment

RIDGE

Project: 5020174 - Shropshire & Cheshire House

Note! Refer to footer of last page for legend, exceptional risks only shown within register.

Author: M Linney

CSE: M Linney

ICSE: R Leland

SHROPSHIRE & CHESHIRE HOUSE, ENFIELD - LARGE PANEL SYSTEM - STRUCTURAL ENGINEERING RISK ASSESSMENT

Ref	Hazard	Persons at Risk	Risk Before Mitigation			Design Measures Taken to Eliminate or Reduce Hazard	Risk After Mitigation			Residual Risks	Notes
			Frequency	Severity	Category		Likelihood	Severity	Category		
Accidental Loadings Causing Collapse											
1	Internal Gas Explosion (Piped-Gas Supply)	Residents and the general public	G	I	**T**	Removal of the piped-gas supply from the blocks	H	I	**RAW**	Internal gas explosions from a non-piped gas supply source (ie gas canisters etc).	The frequency and consequence of an internal gas explosion is greatly reduced by the removal of the piped-gas supply.
2	Internal Gas Explosion (Without Piped-Gas Supply)	Residents and the general public	H	I	**RAW**	Administrative risk reduction measures (i.e. 24hour security to prevent tenants bringing gas canisters into the blocks)	H	I	**RAW**	Block remains susceptible to disproportionate, progressive collapse.	High residual risk. Slight reduction in the probability of an internal gas explosion from non-piped gas supply. Same consequence.
						Undertake the proposed strengthening works	H	III	**RA**	Block strengthened to resist overpressure loading to prevent disproportionate collapse.	Residual risk considerably lowered
3	Fire (Causing structural damage) (Excluding the direct hazards of fire)	Residents and the general public	G	I	**T**	Whilst not specifically designed for this purpose, the joint strengthening angles will prevent displacement of joints. Suitable fire evacuation policies should be in place (outside the scope of this report).	G	III	**RAW**	Damage to the concrete members causing spalling etc. Damage to the strapping from the fire.	All strengthening works to be specified with sufficient fire protection (i.e. intumescent paint)
4	Vehicular Impact	Residents and the general public	H	I	**RAW**	Bollards infront of loadbearing members in the areas accessible by vehicles. Ground floor structure is of R.C. construction (more robust than LPS above) therefore less susceptible to impact damage.	H	III	**RA**	None. Risk effectively controlled.	
5	Unauthorised/inadequately planned structural modifications	Residents, general public, contractor and operatives.	H	II	**RAW**	Strengthening works to the blocks to be carried out by an experienced and competent contractor using appropriate RAMS.	H	III	**RA**	Human error during the remedial works potentially causing structural damage	The risk of unauthorised structural modifications by residents is low. The loadbearing walls are 180mm thick concrete panels
6	Exceptionally strong winds	Residents and the general public	H	V	**RA**	None required.	H	V	**RA**	Risk acceptable	Load assessments have shown that the block passes under wind loading. The blocks have also withstood many storms during their 50 year life without significant structural damage.
7	Misuse (i.e. overloading of floors)	Residents and the general public	H	III	**RA**	The steel strapping to the underside of the floor slabs would resist this.	H	VI	**RA**	None.	
8	Deterioration of Structure over time (Concrete testing of 9 samples obtained from loadbearing elements showed that 3 members (33%) were at high risk of corrosion to the embedded reinforcement)	Residents and the general public	F	III	**RAW**	Remedial works required to prevent further deterioration of the concrete and the embedded reinforcement. This may include painting with an anti-carbonation paint, concrete repairs to spalled areas, cathodic protection etc.	H	V	**RA**	An inspection and maintenance procedure should be set in place. Visual inspections should be carried out at 5-year intervals. Durability assessments should be undertaken every 15 years. Full LPS assessments at 30-year intervals	A suitable inspection and maintenance regime will help extend the remaining life of the structure, and reduce the risk of collapse from the effects of deterioration
9	Land movement due to adjacent construction works (i.e. deep excavation)	Residents and the general public	H	III	**RA**	Nearby construction works (particularly from the new development or gas works) should be properly designed, and statutory approval granted prior to works, to ensure works will not impact on the stability of the blocks.	H	III	**RA**	None if properly controlled.	
10	Terrorist Attack	Residents and the general public	I	I	**RAW**	Strengthening options proposed to resist disproportionate collapse from a non-piped gas explosion **may** reduce the impact of a terrorist attack - although this is not what they have been designed for, and is unproven.	I	I	**RAW**	Magnitude of the actions involved in malicious attacks can be unpredictable. If the actions in the terrorist attack exceeds the 17kN/m^2 criteria for an internal gas explosion, the strengthening works will likely not be sufficient to prevent collapse.	Malicious acts/attacks are outside of the scope of this report, and the BRE 511 Report. As the magnitude of explosion forces from terrorist attacks can vary hugely, impractical to design for an upper bound loading.

LEGEND:

***Table C3:* Risk assessment – template for risk quantification and profiling**

Frequency/probability of occurrence	Severity/Consequence of hazard					
	I	II	III	IV	V	VI
	Catastrophic	Critical	Grave	Serious	Marginal	Negligible
C Common	UA	UA	UA	UA	T	RAW
D Likely	UA	UA	UA	T	RAW	RAW
E Occasional	UA	UA	T	RAW	RAW	RA
F Possible	UA	T	RAW	RAW	RA	RA
G Rare	T	RAW	RAW	RA	RA	RA
H Improbable	RAW	RAW	RA	RA	RA	RA
I Deliberate Act	RAW	RA	RA	RA	RA	RA

Key to Table C3: Risk categories

Code	Risk category	Action required
UA	Unacceptable risk	Corrective action essential to reduce the risk
T	Tolerable only if risk reduction impractical	Review required to determine whether a further reduction of the risk is possible – risk reduction required unless cost is grossly disproportional to benefit gained from bearing risk
RAW	Risk acceptable with review	Review required to determine whether a further reduction of the risk is reasonable and practicable – implement if cost of reduction less than benefit gained from bearing risk
RA	Risk acceptable without review	No action required

APPENDIX B

Quantitative Risk Assessment Calculations

RIDGE

Partnership House
Moorside Road
Winchester
SO23 7RX

Tel: 01962 834400
WWW.RIDGE.CO.UK

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SHROPSHIRE & CHESHIRE HOUSE, ENFIELD LPS STRUCTURAL ROBUSTNESS RISK ASSESSMENT	DATE: 25/01/23
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LPS Risk Assessment Calculations

Quantitative Assessment [BRE Report 511 - Appendix B]

Probability of severe explosion from cylinder gas or other gaseous substances = $0 \cdot 1 \times 10^{-6}$

Parameters:

- Remaining life of the blocks:
  - ↳ Scenario 1: 4 years - Block retained long enough to decant + procure for demolition
  - ↳ Scenario 2: 10 years - Phased approach - Demo 1 block at a time, 2nd Block unstrengthened for 10 years
  - ↳ Scenario 3: 30 years - Do nothing approach - Retain blocks long term without strengthening
- Blocks at risk are 18-Storeys tall [17 inhabited floors]
- Total No. Flats in the Block = 102 Flats
  - ↳ 17 x 3-bed Flats
  - ↳ 51 x 2-bed Flats
  - ↳ 34 x 1-bed Flats

Possible Collapse Mechanism:

Whilst there are a large number of possible collapse mechanisms, depending on where the explosion event occurs, they can be categorised into 2 groups:

1) Explosion in top 8 floors. These have the potential to cause significantly more damage to the structure & cause the highest number of potential casualties / fatalities. An explosion in these areas could cause the collapse of 3 structural bays over the full height of the block.

2) Explosion in the lower 9 floors. As the cross walls in the lower floors can withstand the overpressure from an explosion at the lower $17kN/m^2$ force, the explosion would only cause collapse to the structural bay in which the explosion occurred in. In addition, the collapse would also likely be limited to the floors below the event & 1 floor above. (i.e. an explosion on the 6th floor would cause collapse of floors 1-7 in a single bay).

These possible collapse mechanisms are shown on the page over.

RIDGE

Partnership House
Moorside Road
Winchester
SO23 7RX

Tel: 01962 834400
WWW.RIDGE.CO.UK

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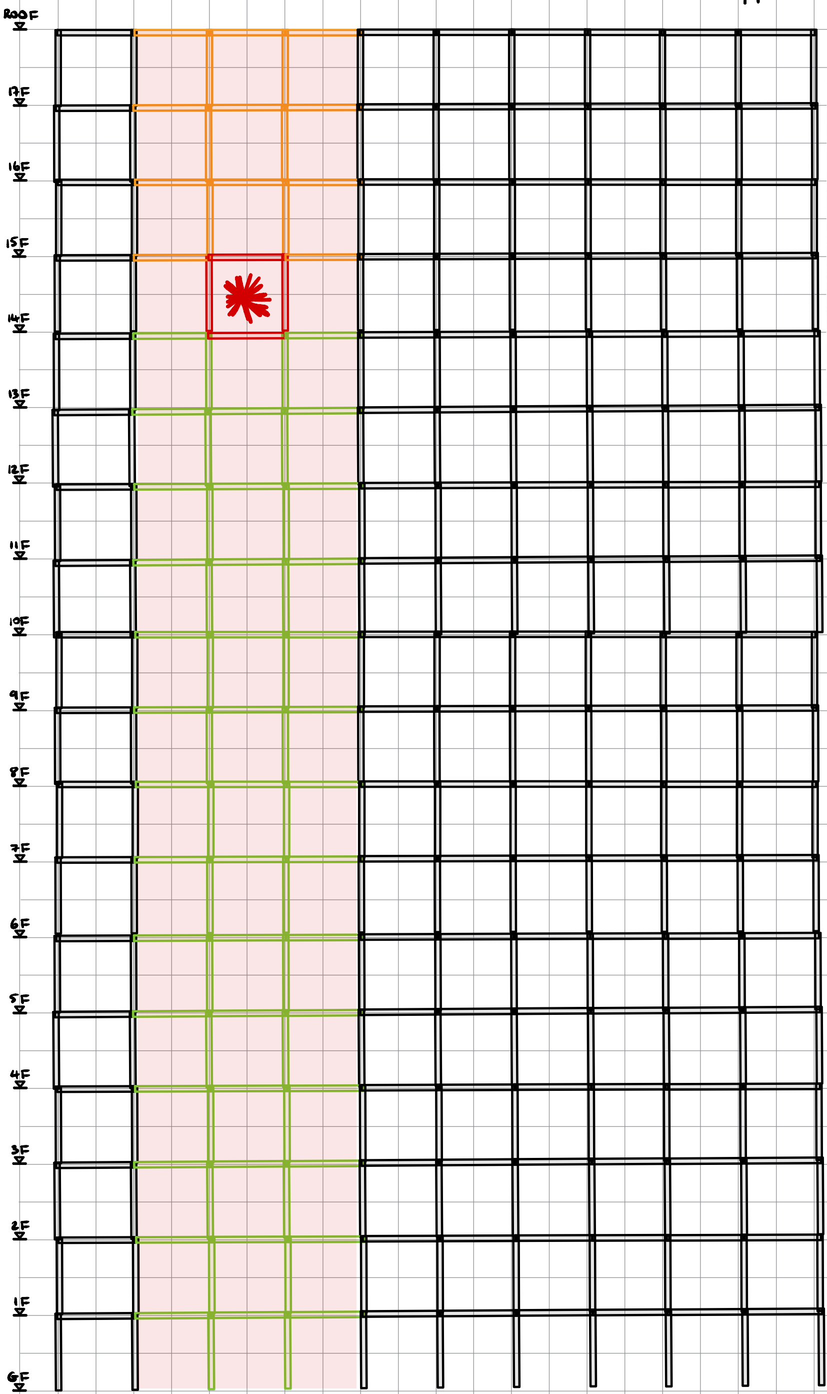
COLLAPSE MECHANISM ① - Event occurs in upper 8 floors



EXPLOSION

STRUCTURE OUTSIDE ZONE OF INFLUENCE, BUT STILL AT RISK OF IMPACT DAMAGE & OTHER FORCES DUE TO THE COLLAPSE OF THE SURROUNDING AREAS OF THE BLOCK

← DIRECT FAILURE FROM EXPLOSION OVERPRESSURE

← FAILURE FROM DEBRIS LOADING.

← INDIRECT FAILURE FROM LOSS OF SUPPORT (FAILURE OF WALLS BELOW)

FLATS AFFECTED.

CALCULATION SHEET

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Moorside Road
Winchester
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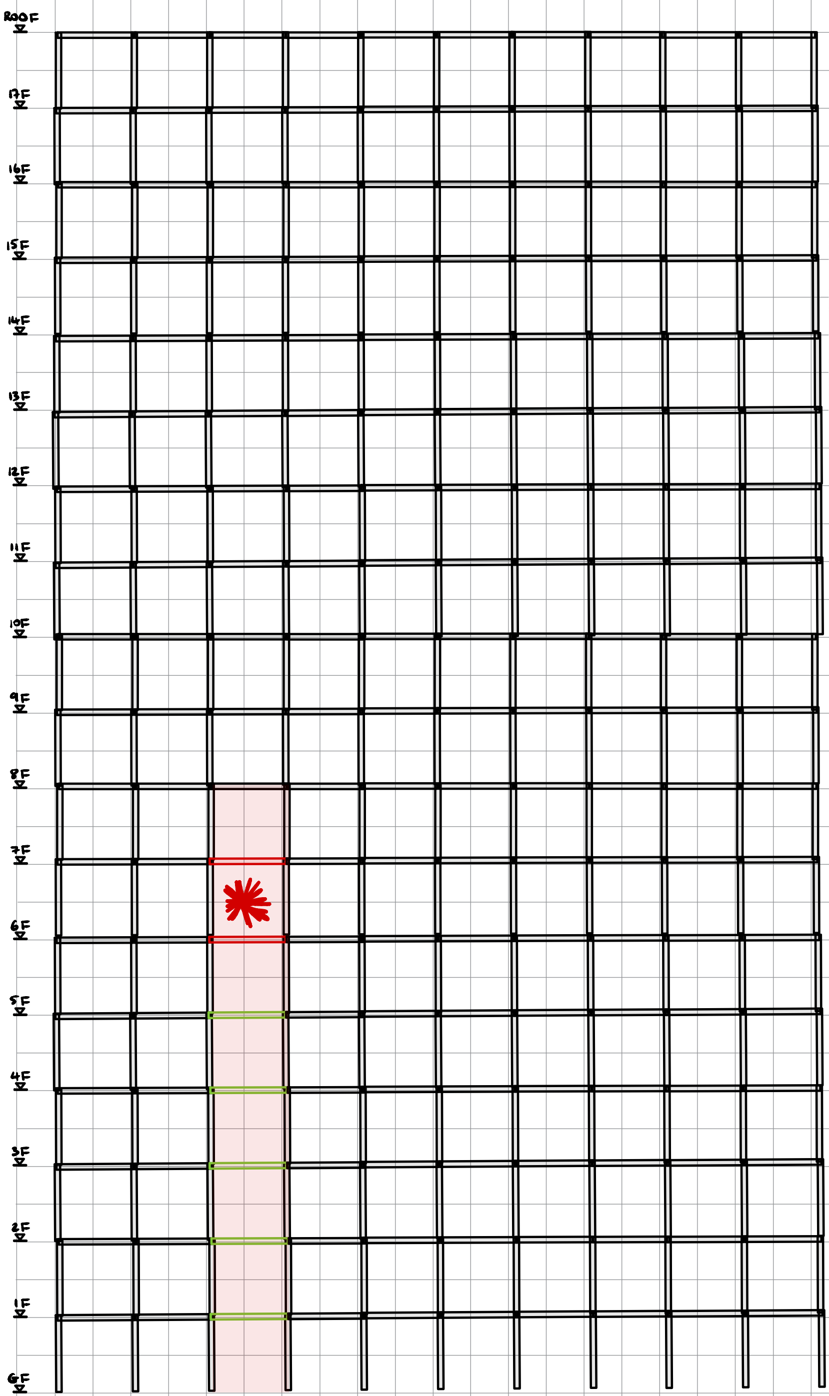
COLLAPSE MECHANISM ② - Event occurs in lower 9 floors



EXPLOSION

STRUCTURE OUTSIDE ZONE OF INFLUENCE, BUT STILL AT RISK OF IMPACT DAMAGE & OTHER FORCES DUE TO THE COLLAPSE OF THE SURROUNDING AREAS OF THE BLOCK

← DIRECT FAILURE FROM EXPLOSION OVERPRESSURE

← FAILURE FROM DEBRIS LOADING.

INDIRECT FAILURE FROM ← LOSS OF SUPPORT (FAILURE OF WALLS BELOW)

FLATS AFFECTED.

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Est. 1 – Probability of a severe explosion occuring in any of the flats over the course of the remaining life

- 4 years : $0.1 \times 10^{-6} \times 102 \times 4 = 4.08 \times 10^{-5}$
- 10 years : $0.1 \times 10^{-6} \times 102 \times 10 = 1.02 \times 10^{-4}$
- 30 years : $0.1 \times 10^{-6} \times 102 \times 30 = 3.06 \times 10^{-4}$

Est. 2 – Probability of a severe explosion occurring in a single stack of dwellings per year

$0.1 \times 10^{-6} \times 17 = 1.7 \times 10^{-6}$ per annum.

Est. 3A – Probability of a severe explosion occurring in the upper 8 floors of a single stack

$0.1 \times 10^{-6} \times 8 = 0.8 \times 10^{-6}$ per annum.

Calculate also probability of a severe explosion occurring in the lower 9 floors of a single stack

$0.1 \times 10^{-6} \times 9 = 0.9 \times 10^{-6}$ per annum

Est. 3B – N/A [For blocks with inadequate concrete compressive strengths – Shropshire cores were typically found to have consistent compressive strength]

Est. 3C – N/A [As above]

Est. 4 – Assuming that only 20% of severe explosion events would exceed the collapse resistance of the LPS dwelling block elements, so that a progressive collapse might occur, the probability of progressive collapse from a severe explosion would be:

$0.1 \times 10^{-6} \times 8 \times 0.2 = 1.6 \times 10^{-7}$ per annum.

Therefore, the probability of a progressive collapse event occurring in the block during the remaining lifespan of the blocks is:

- 4 years : $1.6 \times 10^{-7} \times 4 = 0.64 \times 10^{-6}$
- 10 years : $1.6 \times 10^{-7} \times 10 = 1.60 \times 10^{-6}$
- 30 years : $1.6 \times 10^{-7} \times 30 = 4.80 \times 10^{-6}$

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Winchester
SO23 7RX

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Est. 5 – Risk of death to a resident of the 18-Storey blocks, Shropshire House, assuming block is fully occupied at time of explosion.
A severe explosion occurring in any of the 102 flats in the 18-Storey block on the estate may trigger a progressive collapse event

- Explosion Event in Upper 8 Floors
  [3 structural bays over 17 stories - potentially 2 flats per floor affected - possibly 5 people per floor]
  Probability: 0.8×10^{-6} per annum.
  Consequence: $5 \times 17 = 105$ fatalities
  $\therefore$ Risk $= 0.8 \times 10^{-6} \times 105 = 8.4 \times 10^{-5}$ per annum

- Explosion Event in Lower 9 Floors
  [1 structural bay over between 2-10 floors affected $\therefore$ average = 6 floors, 2 people per floor]
  Probability: 0.9×10^{-6} per annum.
  Consequence: $2 \times 6 = 12$ fatalities
  $\therefore$ Risk $= 0.9 \times 10^{-6} \times 12 = 1.08 \times 10^{-5}$ per annum

$\therefore$ Total risk of death of a resident $= (8.4 + 1.08) \times 10^{-5} = 9.48 \times 10^{-5}$

Comparison to Benchmarks

- 'Tolerable' limit of risk at work $= 1 \times 10^{-3}$ per annum $> 9.48 \times 10^{-5}$ $\therefore$ OKAY
- 'Tolerable' limit of risk to any member of the public $= 1 \times 10^{-4}$ per annum $> 9.48 \times 10^{-5}$ $\therefore$ OKAY

Risk of progressive collapse of the blocks in the event of internal gas explosion is lower than both of the 'Tolerable' limit benchmarks.

APPENDIX C

Risk-Reduction Measures Effectiveness Appraisal

RIDGE

Project: 5020174 - Shropshire & Cheshire Houses

Author: M Linney

CSE: M Linney

ICSE: R Leland

SHROPSHIRE & CHESHIRE HOUSES - LARGE PANEL SYSTEM - RISK-REDUCTION MEASURES - OPTION APPRAISAL

Ref	Risk-Reduction Measure	Proposal Philosophy	Risk Reduction	Risk Associated to Installation	Residual Risks (Upon Completion of Works)	Implications on Residents	Level of Risk Reduction Achieved	Costs to Implement Risk-Reduction Measure
Appraisal of Risk-Reductions Measures for the Risk of an Internal Gas Explosion (From a Non-Piped-Gas Source) Causing Progressive Collapse of the Blocks								
1	Strengthening Option Loadbearing Members Strengthened to Resist 17kN/m^2 Overpressure	▪ The installation of steel angles to the joint between floors and walls. Steel strapping to the top and U/S of floor slabs adjacent to the flank walls. Installation of strapping to / 'blast walls' in front of cross walls in the upper 8 floors. ▪ All loadbearing elements either strengthened to pass an overpressure of 17kN/m^2, or shielded from the explosion. No structural failures occur. ▪ Decision to be made based on cost-benefit analysis.	Progressive Collapse will be prevented in the event of an internal gas explosion (non-piped-gas)	▪ Inherent risks with any construction project if improperly controlled. ▪ Strengthening works to be carried out by a competent and experienced contractor ▪ No gas welding on site ▪ No excessive loads on floors (i.e. material storage)	▪ Floors forming the room in which the explosion occurred will fail, causing a localised collapse (**not** disproportionate to cause)	▪ Strengthening works will be very disruptive to residents. ▪ Will require residents to decant for a period of time during the works. ▪ Requires access to the joint between walls and floors. May require localised strip out (i.e. Kitchen, Artex etc.)	1 The highest level of risk reduction upon completion. Additional risk during installation.	3 £6,379,000 / Block (Ex. VAT)
2	Do Nothing	If magnitude of risk of an internal gas explosion causing a disproportionate collapse is considered acceptably low and that cost of risk-reduction measures would grossly exceed the benefits from strengthening then the duty holder may choose to 'Do Nothing' and directly accept the risk for the duration of the life of the blocks.	No reduction in risk.	No additional risks generated	No risk-reduction measures implemented. Therefore risk of disproportionate collapse remains the same.	▪ Remain living in an LPS block that has been shown to fail assessment.	3 No reduction in risk.	1 £0 (No work carried out, therefore no cost involved)
3	Administrative Measures (i.e. Monitored Security Cameras)	If the magnitude of risk is considered to be unacceptable for direct acceptance, but the cost of the strengthening works is determined to be grossly disproportionate to the benefits provided, administrative measures may be considered to reduce the probability of gas canisters being taken inside the blocks.	The probability of a gas canister being brought into the block may be reduced (dependent on effectiveness of measure employed)	Unlikely to generate additional risks (dependent on measure implemented)	Should an internal gas explosion occur (note: aerosols have been shown to generate 2.6 - 9kN/m^2 overpressure) this blocks may still suffer disproportionate collapse. (No reduction in consequence) Effectiveness of these measures may diminish over time.	▪ Remain living in an LPS block that has been shown to fail assessment. ▪ Site surveillance - privacy issues.	2 Lowest level of risk reduction. Reduction in probability of explosion occuring only. An explosion may still cause progressive collapse. Therefore Consequence remains unchanged.	2 Cost dependent on which measure is implemented (outside scope of works) Will cost more than the 'Do Nothing' approach, but likely significantly less than the strengthening options. Long-term use may be significant cost