Please note the contents of these documents contain detailed descriptions and diagrams of Grenfell Tower. This could be upsetting for some.

This version of the document has therefore been created with any photographs of fire damage or the interior of the Tower removed to minimise the amount of potentially upsetting or distressing information within it. A copy of the original documents with photographs can be provided on request.

Please take care when reading or circulating these documents.

The Grenfell Health & Wellbeing Service is a free and confidential local NHS service for children and adults affected by Grenfell. To talk to someone, you can get in touch by phone on 020 8637 6279 or by e-mail Grenfell.wellbeingservice@nhs.net.

This document and its contents have been prepared for the Ministry of Housing, Communities, and Local Government. For further information, please contact GrenfellTowerSite@communities.gov.uk

Grenfell Tower

Final Design Validation

Ministry of Housing, Communities, and Local Government

05 May 2021

5186876-ATK-XX-XX-RP-SE-000003

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Contents

Introduction

This report documents the Final Design Validation carried out on Grenfell Tower

Executive Summary

This report documents the findings of the Final Design Validation (FDV) carried out by Atkins and the information on which those findings are based.

Key findings

The global stability of the building was assessed and found to be within the acceptable lateral movement limits of current practice.

With respect to structural strength under the effects of dead load, areas of the floor slabs are typically overstressed on most floors. This is due to the significant fire damage and the resulting spalling of the concrete. Such zones require propping and where the Stage 3 propping would be expected to be designed to actively carry the slab dead load in addition to any live load component.

The significant damage to the corner column in Flat 5 between Level 13 and level 14 at the time of the fire would have resulted in the load being redistributed to adjacent parts of the structure. This alternative load path has been examined and found to be adequate to resist the loads in question.

The reinforcement amounts in the columns at lower levels is not known and as such the adequacy of several the columns cannot be demonstrated based on the assumptions of minimum reinforcement. However, this is a particularly onerous assumption and it would be expected that the reinforcement in the columns would be increased in the lower levels. Further, this would have been the case before the fire and no evidence has been found that shows the columns and supported structure were not performing satisfactorily.

Recommendations

The recommendations drawn from this report are as follows:

Further analysis and design

The FDV is based on the Stage 3 propping being installed over the entire height of the building from Basement Level.

If the propping strategy changed such that propping started on a suspended slab level rather than at Basement Level, a high-level investigation of the consequence of this change could be carried out through modification of the analysis model used for the FDV.

Flat 5 corner column C10 between Level 13 and level 14

Given the severity of the damage to this column, repairs/encasement should be considered to make it safe. Further, the propping in this corner must be retained to mitigate against the risk of further deformation of the damaged column.

Propping

The basis of the Temporary Works Designer’s design for the proposed Stage 3 propping is that no load from the propping is shed into any of the suspended slabs, rather the full load is carried to foundation level.

The consequence of this is that the FDV does not consider any applied load from the propping onto the suspended slabs.

It is expected that the CAT 3 checker for the temporary works will confirm that this is correct as it is the basis of the loading assumptions used in the FDV.

Access

To control the level of risk associated with site operatives and visitors to the site being inside the structure, only essential access to the scaffolding and inside the building should be permitted; essential being prop tightening and maintenance, monitoring, and critical structural repairs.

Repair

Repairs should be carried out to the roof waterproof membrane, or that it be replaced, in order to prevent water ingress to the structure.

For the structure generally, it is recommended that exposed reinforcement and spalled concrete faces be painted with suitable protective compound. Whilst the extent of such repair measures may be limited to those areas deemed to be the worst affected, a residual risk would remain in that untreated areas may suffer further deterioration; regular inspections will partly mitigate this risk.

Further investigation works

In order to better understand the resistance of the slabs and columns to load, it is recommended that:

- Local opening up of the top of a slab at a support, e.g. fire wall, be carried out in order to understand the reinforcement size and spacing used. Alternatively, it may be possible to carry out a ferroscan to obtain this information and avoid opening up works.
- The reinforcement in the columns at the lower levels in unknown. In order to better understand how they have been reinforcement, it should be determined whether a ferroscan type survey would allow the reinforcement amounts to be established and if yes, such a scan carried out.
- The reinforcement spacing appears variable based on the zones exposed. To have a better record of both reinforcement spacing and bar sizes a ferroscan type survey, supplemented by local opening up works, would facilitate this.

1. Introduction

This Report documents the findings of the Final Design Validation (FDV) and the information on which those findings are based.

1.1. Purpose of the FDV

The FDV is a design verification of the damaged primary structure and accounts for the proposed Stage 3 propping proposal being developed by the Temporary Works Designer (TWD). The Stage 3 propping replaces the majority of the currently installed Stage 1 and Stage 2 propping for the purposes of providing a propping solution for the short-to-medium term whilst the future of the structure is determined.

The FDV is based on the Stage 3 propping scheme only with the overall aim being to provide the necessary assurance for MHCLG related to the building's primary structure.

For the FDV an inspection driven detailed analysis has been carried out. This means that a qualitative structural damage assessment of every flat was carried out relating to the primary structure (i.e. the structural concrete members) and a bespoke approach to analysis and modelling adopted dependant on the actual damage and loss of cover.

The FDV has been carried out by means of a global analysis model and local cassette models of each floor in accordance with relevant design standards and good practice. The analysis accounts for the non-uniformity of the structural behaviour due to fire damage by adjusting slab stiffnesses associated with the observations made during the inspection.

Based on work carried out during the FDV, the following topics are addressed:

- The current condition of the structure with respect to its stability and strength
- The structural load path/load sharing between primary structure and the proposed Stage 3 propping
- An assessment of where propping is required to provide an independent means of cross-checking the TWDs proposals
- The likely structural degradation of the primary structure in the short-term – defined as being to the end of December 2021 – and recommendations for appropriate remedial work if necessary

1.2. Relationship to the Initial Design Validation (IDV)

Atkins have previously carried out an Initial Design Validation (IDV) as reported in Atkins Report Ref 5186876-ATK-XX-XX-RP-002 *Grenfell Tower – Initial Design Validation*, July 2019.

The IDV was a high-level review of the structure of Grenfell Tower to examine the structural performance of Grenfell Tower and the associated temporary works.

The FDV develops the work done at the IDV stage and is a more detailed assessment of the structure. However, the base datasets from the IDV, such as the assessment of the material properties, have not changed. As such, where no new information has been provided, or is required for the purposes of the FDV, the data analysis carried out for the IDV is adopted and included herein such that the FDV Report acts as a single standalone document.

1.3. FDV Assumptions

The following assumptions have been made in carrying out the FDV:

- The FDV only relates to the primary building structure and not the internal proprietary propping system or external perimeter scaffolding. The design of the internal propping system for Propping Stages 1, 2, and 3, is the responsibility of the TWD, Cantillon.
- No assessment of the scaffolding design, or the connection of scaffolding to primary structure will be made as part of the FDV.
- The propping layout assumed for the FDV is that issued by Cantillon on 28 March 2020. It is recognised that the propping design and layout has continued beyond this date and on its completion the impact of any changes on the FDV will be reviewed.

- The Stage 3 propping design by Cantillon, the TWD, is based on all load being carried by the propping system being transmitted to foundation level. Cantillon have confirmed that no load is shed into any suspended slabs; such slabs acting as a rigid sandwich layer.
- No assessment was made of the adequacy of the building's foundations. However, as there is no indication that this was affected by the fire, it is considered unlikely that this part of the structure would be a cause for concern. Similarly, whilst the wind catchment area has increased, it is unlikely that this will have a significant effect on the foundations.
- In the absence of construction or contractors as-built drawings the following will be assumed and will be in accordance with the assumptions made in the IDV where appropriate:
  - Material strengths
  - Bar sizes and arrangements based on site observations and an understanding of design and construction practice at the time of the building's design

1.3.1. FDV Exclusions

The following have been excluded for consideration as part of the FDV:

- This report is not intended to inform the design of the propping system, the analysis and design of which is independent of the FDV and the responsibility of the TWD. However, the FDV findings may be used as a cross-check against the provision of the Stage 3 propping.
- The design of the proprietary propping system has not been reviewed as part of the FDV process.
- The TWDs design assumption that no load is shed into any of the suspended slabs is not investigated/validated as part of the FDV.
- Consideration of future deconstruction issues is excluded from the work carried out on the FDV.

2. Sources of information

The primary sources of information used in developing the FDV are as follows:

- *Grenfell Tower – Fire-damage investigation of key structural concrete elements*, ref 1280180-01, RSK, 5 Feb 2019
- *Grenfell Tower, Deliverable 4b – Technical Due Diligence Report*, ref 5186876-ATK-XX-XX-RM-0001, Atkins, London, 30 April 2019
- *Grenfell Tower – Initial Design Validation*, ref 5186876-ATK-XX-XX-RP-002, Atkins, London, July 2019
- The propping layout issued by the TWD, Cantillon, on 28th March 2020
- Atkins visual structural survey findings of 18th and 20 February
- *BS CP 114 Structural use of reinforced concrete in buildings (metric)*, British Standards Organisation, London, 1972
- *Report CS 030 Formwork. A guide to good practice'*, 3rd Edition, The Concrete Society, Camberley, 2012
- *Technical Report No 68 Assessment, design and repair of fire-damaged concrete structures*, The Concrete Society, Camberley, 2008

3. Basis of Design

The purpose of the Basis of Design is to set out the design criteria used in the FDV.

3.1. Context of original design

To put the design, construction, and the fire, of Grenfell Tower in context the key dates are presented in Table 3.1 and what they mean in terms of the assessment carried out.

Table 3.1 - Timeline

Date	Event	Implication
1967	Design of Grenfell; Tower commences	The Code of Practice current at the time were CP 114 *Structural use of reinforced concrete in buildings*; the metric version of this code was published c.1969. Based on this code, it is anticipated that a permissible stress design or a load factor approach would have been used. Limit state design was introduced in 1972 with the publication of CP110, *The structural use of concrete*, and it is therefore considered unlikely that a Limit State Design approach would have been adopted in the design of Grenfell Tower.
1968	Ronan Point disproportionate collapse event	The disproportionate nature of the Ronan Point collapse would have been understood during the design of Grenfell Tower and it is assumed that tying requirements were addressed in accordance with the changes to the Building Regulations of that time.
1970	Approval of Grenfell Tower structural design	–
1972 - 1974	Construction	As of June 2019, this makes Grenfell Tower ~45 years old. Prior to the fire, it could reasonably have been assumed that the full effects of shrinkage and creep would already have been experienced by the structure. Also prior to the fire it is likely that the building's design life would be approaching or possibly have passed.
14 June 2017	Fire	–
June 2017 to present	Emergency propping installed during this time with monitoring/adjustment carried out over time.	The fire damage such as spalling, heating of reinforcement, large deflections, etc would have occurred pre-installation of the propping system. It is assumed that the propping system is therefore supporting any residual load or newly applied load.
July 2019	IDV completed by Atkins.	-
May 2020	FDV completed by Atkins	-

3.2. Assumed structural action

In-situ reinforced concrete construction, particularly flat slab type construction, has a high degree of redundancy inherent in this form of construction. This is evidenced by the robustness of the building's frame during and following the fire, in that whilst there were large deformations of the structural slabs, there was no collapse of the primary structure reported.

To assess the structure, the original design intent, and the structural system following the fire, are postulated. This assumed behaviour is the basis of the analytical assessment carried out and documented in Section 5.

Note that the post-fire structural performance of the concrete and steel reinforcement in the primary structure is a function of the exposure to fire and the heating effect within a member. The depth into a member that temperature will have affected the structural performance is termed the heat affected zone (HAZ) and is referred to throughout this Report.

3.2.1. Pre-fire structural system

The original design calculations and associated drawings are not available and as such the original structural system is based on engineering judgement for a building of this scale.

Stability, lateral and rotational, is assumed to be provided by the concrete walls around the central core. Whilst several walls connect the core to the perimeter columns, for a building of this height and plan size, it would be unusual to have required these walls to act as outriggers to mobilise the perimeter columns. As such these walls are assumed to be fire walls, i.e. their purpose is to separate adjacent flats, and that they were not intended to be part of the stability system.

The floorplates are traditional slabs (however see Section 3.2.1.1) without perimeter stiffening beams and it is assumed that they act as flat slabs spanning between the stability cores, walls, and the perimeter columns. The screed on the floor slabs is assumed to be non-structural.

The columns are octagonal and in the order of 790 mm square; there is no evidence that they reduce in size at the upper storeys. It is assumed that the columns resist the gravity loading only and do not form part of a sway-frame type construction.

In summary this appears to be a traditional building utilising a simple structural system in order to provide stability and to support the design loading.

3.2.1.1. Perimeter spandrel panels

A spandrel beam runs along the outer perimeter of the floorplate and from limited photographic information from the time of construction, appear to be precast members. Whilst the original design intent may have been to mobilise this as an edge support, in effect creating a two-way slab rather than a flat slab, this cannot be established.

The approach taken in the FDV is to ignore any benefit from the spandrel beam, which is conservative, whilst still accounting for the spandrel beam self-weight.

3.2.2. Post-fire structural system

Whilst there has been some fire damage to the fire and core walls, and spalling of the columns, the main impact has been to the floor slabs which have suffered significant damage due to spalling and subsequent deflection.

With respect to stability, it is assumed that the central areas of slab in each bay are ineffective as diaphragms with the less damaged zone around them acting as a 'picture frame' or horizontal vierendeel for the purposes of lateral load transfer. The clad scaffolding is also connected directly to the fire walls between flats and given the relative increase in stiffness it is likely that this is the primary means of transferring lateral load to the stability core.

With respect to vertical load, several load paths are in effect. Prior to the introduction of the Stage 1 and 2 propping being introduced the slabs were self-supporting under their self-weight plus the fire damaged building contents. Given the magnitude of the deflections at mid-span of a bay and the significant spalling, tensile membrane action was likely to be the main load carrying system. This also implies that the reinforcement in the un-spalled zones retained enough anchorage to mobilise this load path.

Following the fire, temporary propping was installed throughout the building in two stages: Stage 1 immediately following the fire and Stage 2 sometime after that. Whilst it is understood that these props are not actively stressed beyond hand tightening, it is likely that the residual loading is being shared between several floors. It is understood that the majority of these props are to be replaced as part of the Stage 3 propping installation, the design of which is currently being undertaken by the TWD.

Except for the column in the northwest corner – the corner column of Flat 5 – the columns appear to have retained much of their integrity with respect to load transfer. For the northwest column, extensive propping has been introduced around it to create an alternative load path.

3.3. Referencing system

The referencing system adopted in this report follows that set out in RSK's Survey report, Figure 3.1.

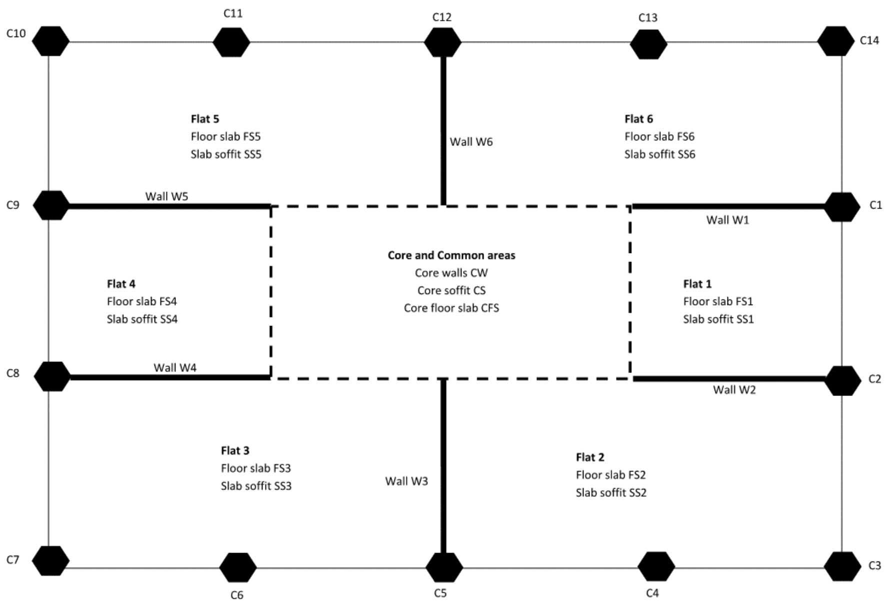


Figure 3.1 - Referencing system (diagrammatic plan)

3.4. Geometry

The geometry of the building globally, and members locally, are detailed in this section.

3.4.1. Plan dimensions

The plan dimensions of the building are shown in Figure 3.2. These are based on record drawings of the structure. The dashed line in the figure represents the extents of the scaffolding around the building and are based on Mattison Scaffolding drawing A/MS 6250-15C.

As impermeable sheeting is used to clad the scaffold, the dashed outer perimeter represents the wind catchment length for the purposes of the applied wind pressure.

3.4.2. Slabs

Based on the through thickness core samples taken, the structural slab thickness is 200 mm with 50 mm of screed over. The screed is assumed to be non-structural for the purposes of calculating section resistance. However, in addition to the load it applies, the insulating effect of the screed to the top face of the slab is considered in the assessment carried out.

At roof level the slab is typically 450 mm with localised 150 mm high plinths acting as plant support.

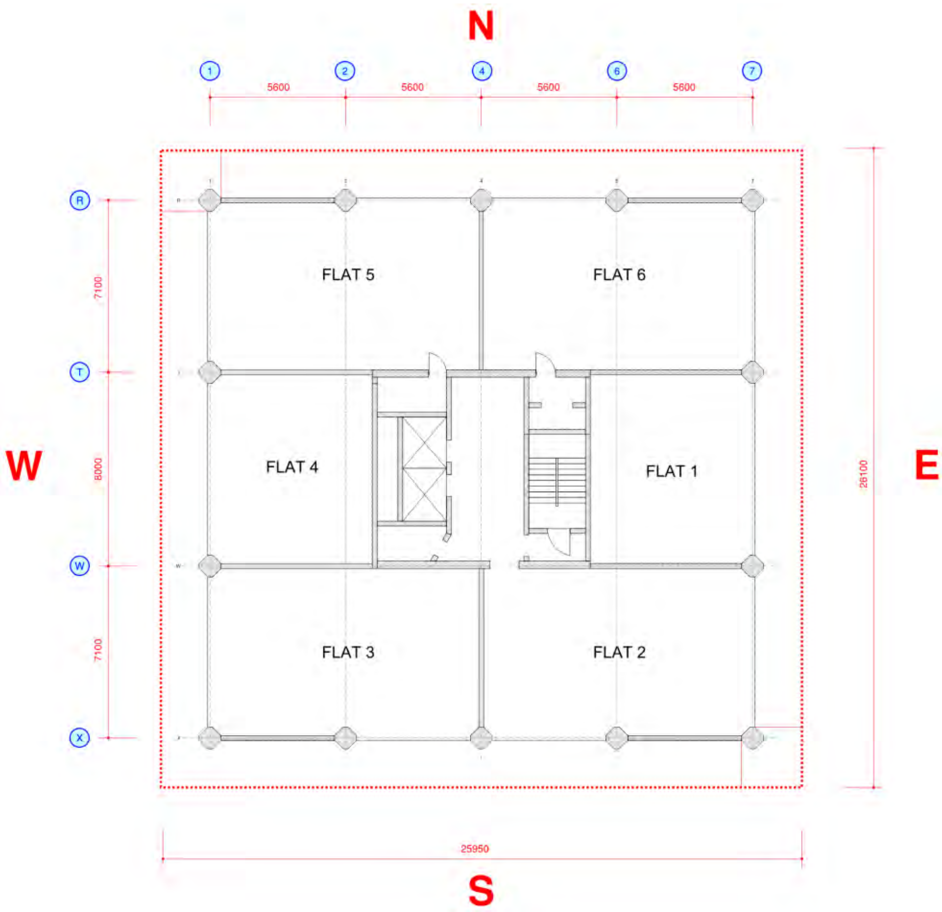
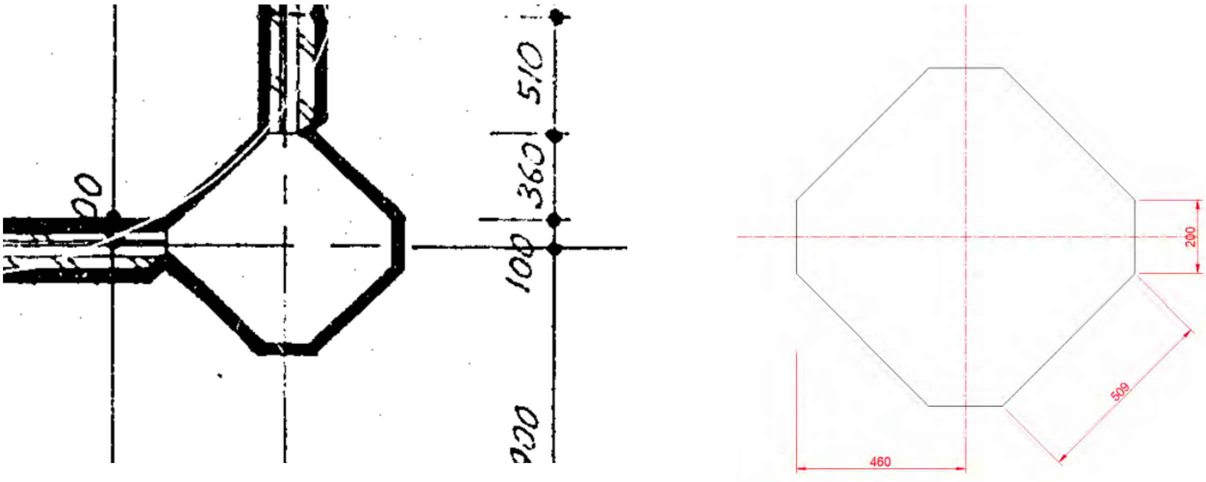


Figure 3.2 - Plan dimensions

3.4.3. Columns

In section the columns are octagonal. Based on the available record drawings, it has not been possible to locate an explicitly dimensioned column and as such the column size has been estimated based on the available information.

Figure 3.3(a) shows an extract from Drawing 1 of Project 1343/C1 *Grenfell Tower Deck 2 Play Centre Lower Level Plan* dated August 1979. The originator of this drawing is unclear – the title block notes RBKCs Department of Architecture and Planning although it is unclear if this simply signifies RBKC as client. It is noted that the grid dimensions on this plan tie in with other available sources of information giving the information some degree of credibility. The section size used in the analysis is shown in Figure 3.3(b).



(a) Record drawing extract at Column C2 (b) Idealisation

Figure 3.3 - Column dimensions

3.4.4. Walls

Within the building, the walls assumed to be part of the primary vertical load carrying structure are those on the perimeter of the stability core and the dividing fire walls between flats.

3.4.4.1. Stability (core) walls

The structural core is formed in reinforced concrete. Based on an original record drawing the perimeter walls of the structural core vary in thickness as follows:

- North wall 330 mm
- East wall 320 mm
- South wall 350 mm
- West wall 320 mm

Whilst there are internal concrete walls within the core, the philosophy adopted in the FDV is that they do not contribute to either the building strength or stiffness.

3.4.4.2. Fire walls

The fire walls between flats, W1 to W6, are formed of reinforced concrete. These walls are not founded at basement level.

Based on an original record drawing and through thickness cores taken of the walls, their thickness is 200 mm.

3.5. Material properties

The data obtained from the limited testing carried out on the structure has been used to establish the material properties used in the FDV; the derivation of these is also set out in this section.

3.5.1. Concrete

RSK took concrete cores from walls, columns, and slabs, within the building and these were used for strength testing and petrographic analysis. The RSK results summary table is reproduced in Table 3.2; for ease of reference the rows of the table have been shaded to indicate similar element types, e.g. slabs.

The three test results for Level 4, boxed at the start of the table, are considered by RSK to be a ‘control sample’ as no fire damage was exhibited on those floors.

The in-situ cube strength, $f_{,is,cube}$, has been determined in accordance with BS EN 12504-1. Based on expressions NA.1 and NA.2 of this code, the ratio of cylinder to cube strength, $f_{,is,cyl}$ / $f_{,is,cube}$ = 0.8

For assessment purposes the RSK test results are re-expressed in terms of cylinder strengths and from this a characteristic concrete strength, f_{ck}, is determined.

Approach B of BS EN 13791 is used to convert in-situ strengths to in-situ characteristic strengths and from this the general characteristic strength determined from: $f_{ck} = f_{ck,is} / 0.85$

The calculation of characteristic strength is a function of the number of samples being considered. Whilst the samples have differing HAZ over the height of the building, the test results for a given member, e.g. slabs, have been taken outside of these zones and as such they are considered to form a single population.

The member groupings and calculated characteristic strengths are presented in Table 3.3.

Table 3.2 - RSK Summary of concrete test results (reproduced from RSK Table 4.6)

RSK Ref	Floor	Flat	Element ref	Depth of fire alteration from outer end surface	Portion testing, mm	In-situ cube strength, MPa
17878/C4	4	1	Column C1	0	5-80	60.1
17878/C5	4	1	Wall W1	0	70+140	38.7
17878/C6	4	1	Soffit SS1	0	10-110	39.8
17878/C7	5	6	Soffit SS6	0-25	70-135	56.4
17878/C8	6	6	Wall W6	0-15	70-145	44.3
17878/C9	6	6	Soffit SS6	0-20	70-135	36.6
17878/C10a	8	5	Soffit SS5	0-30	40-140	29.9
17878/C11	9	4	Column C8	0-35	50-125	32.5
17878/C12	9	6	Column C13	0	5-80	39.8
17878/C13	11	4	Wall W5	0-50 + 205-230	50-125	24
17878/C14	12	6	Wall W6	0-20 + 140-190	60-135	19.2
17878/C15	13	1	Core Wall CW	0-50	2-74	40.4
17878/C16b	14	2	Soffit SS2	0-40	10-110	37.6
17878/C17	14	Core	Core Soffit	0-45	65-130	31.6
17878/C18a	16	3	Soffit SS3	0-70	65-130	43
17878/C19	18	6	Column 14	0	15-90	28.4
17878/C20	19	4	Soffit SS4	0-40	65-130	32
17878/C21	20	4	Core Wall	0-110	35-130	27.5
17878/C22a	21	2	Column 3	0-35	40-115	34
17878/C23	21	2	Wall 2	0-190	50-125	26.2
17878/C24a	22	4	Soffit SS4	0-55	60-125	24.1
17878/C25b	23	6	Wall 6	0-25 + 170-190	50-150	26.2

Table 3.3 – Characteristic concrete strengths

RSK Ref	Floor	Flat	Element ref	$f_{ck,is,cube}$ MPa	$f_{ck,is,cyl}$ MPa	f_{ck} MPa
17878/C4	4	1	Column C1	60.1	N/A	
17878/C5	4	1	Wall W1	38.7		
17878/C6	4	1	Soffit SS1	39.8		
Slabs						
17878/C7	5	6	Soffit SS6	56.4	23	27
17878/C9	6	6	Soffit SS6	36.6		
17878/C10a	8	5	Soffit SS5	29.9		
17878/C16b	14	2	Soffit SS2	37.6		
17878/C17	14	Core	Core Soffit	31.6		
17878/C18a	16	3	Soffit SS3	43		
17878/C20	19	4	Soffit SS4	32		
17878/C24a	22	4	Soffit SS4	24.1		
Columns						
17878/C11	9	4	Column C8	32.5	20	23
17878/C12	9	6	Column C13	39.8		
17878/C19	18	6	Column 14	28.4		
17878/C22a	21	2	Column 3	34		
Walls						
17878/C8	6	6	Wall W6	44.3	15	18
17878/C13	11	4	Wall W5	24		
17878/C14	12	6	Wall W6	19.2		
17878/C23	21	2	Wall 2	26.2		
17878/C25b	23	6	Wall 6	26.2		

RSK Ref	Floor	Flat	Element ref	$f_{ck,is,cube}$ MPa	$f_{ck,is,cyl}$ MPa	f_{ck} MPa
Core walls						
17878/C15	13	1	Core Wall CW	40.4	Insufficient samples to determine a characteristic strength. Conservatively the core wall concrete strength shall be assumed to be equal to that of the fire walls.	
17878/C21	20	4	Core Wall	27.5		

3.5.2. Reinforcement

RSK took samples of reinforcing bar from walls, columns, and slabs, within the building and these were used for strength testing. The key data from the RSK summary table is reproduced in Table 3.4; for ease of reference the rows of the table have been shaded to indicate similar element types, e.g. slabs.

As with the concrete cores, a 'control sample' was taken from the 4th Level as being representative of reinforcement in a floor without fire damage; this is the boxed value in the first row of the table.

Table 3.4 - Reinforcement tensile strength test results (reproduced from RSK Table 4.3)

RSK Ref	Floor	Flat	Element ref	Bar type	Size mm	CSA mm^2	0.2% proof stress	Tensile strength MPa
17878/SS1	4	1	Soffit SS1	PR 16mm Ø	9.87	76.51	297	454
17878/SS2	8	5	Soffit SS5	PR 16mm Ø	9.96	77.91	306	494
17878/SS3	11	1	Soffit SS1 (buckled bar)	PR 14mm Ø	9.96	77.91	258	428
17878/SS4	12	6	Column C13 Tie bar	PR 8mm Ø	5.07	20.19	362	531
17878/SS5	13	1	Core Wall CW	PR 8mm Ø	4.96	19.32	331	482
17878/SS6	14	Core	Soffit CSS (buckled bar)	PR 12mm Ø	5.08	20.27	297	419
17878/SS7	18	6	Soffit SS6 (buckled bar)	PR 16mm Ø	9.94	77.6	271	440
17878/SS8	21	2	Wall W2 (exposed bar)	PR 8mm Ø	4.91	18.93	347	483
17878/SS9	22	2	Column C4 Tie bar	PR 8mm Ø	5.07	20.19	347	516
17878/SS10	23	2	Soffit SS2	SqT 16mm Ø	9.91	77.13	358	503

Note. PR:= plain round; SqT:= square twisted

The tabulated values represent the strength of the reinforcement post-cooling.

It is assumed that the 'Size', and associated 'CSA', columns of the table are based on the machined test specimen dimensions.

If the main plain round bars, i.e. excluding links, are considered to be a single population then adopting a log normal distribution gives a characteristic reinforcement strength of ~241MPa, Table 3.5.

Table 3.5 - Calculation of characteristic reinforcement strength

	#	**test result, MPa**	**ln(test)**	**(ln x - m_y)^2**	
	1	297	5.694	0.000	
	2	306	5.724	0.000	
	3	258	5.553	0.022	
	4	331	5.802	0.010	
	5	297	5.694	0.000	
	6	271	5.602	0.010	
	7	347	5.849	0.022	
n	7				
1/(n-1)	0.1667				
		Mean of ln values	5.703		
		$\sum$ (ln x - m_y)^2		0.06	
		1/(n-1)		0.1667	
		UNKNOWN V_x => s_y		0.104	= $[1/(n-1) * \sum (\ln x - m_y)^2]^{0.5}$
		k_n		2.09	
		m_y-k_n·s_y		5.486	
		characteristic value = exp(m_y-k_n·s_y)		**241.24**	

3.6. Reinforcement arrangements and cover

Cover to reinforcement is given in the RSK report; similarly, the HAZ is based on the RSK condition survey and associated petrographic analysis.

3.6.1. Slabs

Based on site observations of the bottom mat of reinforcement, the outer layer spans in the north-south direction in Flats 2,3,5, and 6, whilst in Flats 1 and 4 the outer layer of reinforcement spans in the east-west direction; this is shown in Figure 3.4. Whilst not observed, it is assumed that the layering arrangement is reflected for the top reinforcement.

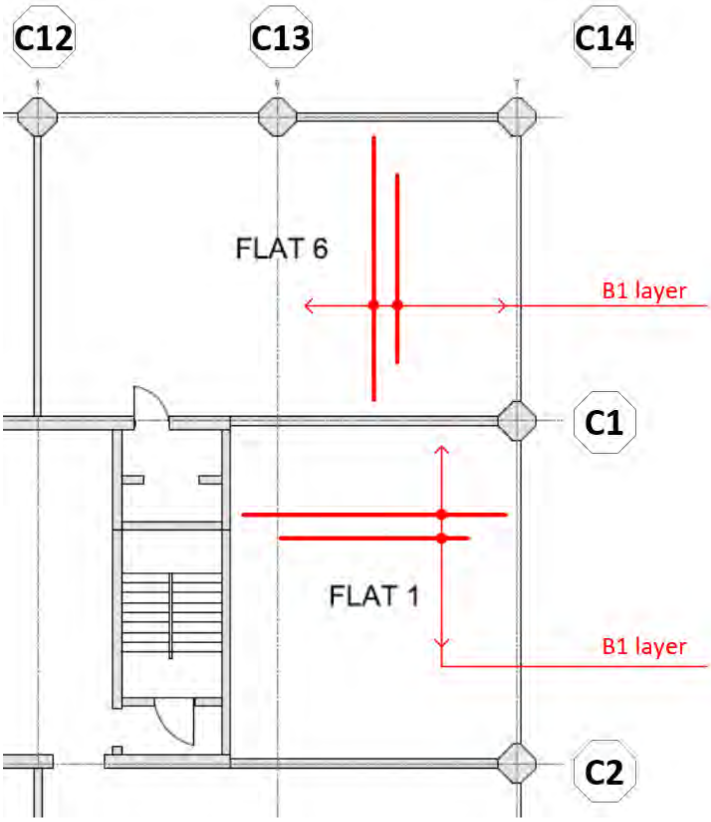


Figure 3.4 - Reinforcement layering

3.6.2. Columns

The columns are octagonal and based on site observation it is assumed that a reinforcing bar is placed in each corner and at the mid-point on each side, Figure 3.5.

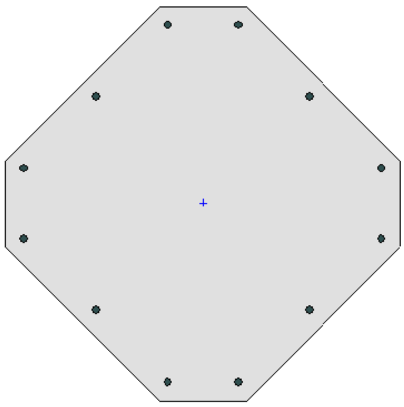


Figure 3.5 - Main reinforcing bar placement in octagonal column

Enclosing links, not shown in the figure, are also present and are in the order of 8 mm diameter according to the RSK inspection report.

Note that the actual amount of reinforcement in the columns and how that varies over the building height is unknown. The calculations of column capacity consider what resistance is required and from that conclusions drawn as to the likelihood of the required amount of reinforcement being present.

3.6.3. Walls

The core walls and fire walls are assumed to be traditionally reinforced with the outer layer of bars being placed horizontally.

No main bars in the walls were tested; the reinforcement size used for the purposes of analysis shall be based on the RSK inspection reports for the walls.

3.7. Loading

The loading post-fire to be used in carrying out the analysis is set out in this section.

The fundamental assumption being made in the application of load is that in accordance with Cantillon's Basis of Design for their propping system, no load is shed into any suspended slabs with these slabs simply acting as a rigid sandwich layer. Therefore, only the effect of live load being applied to the slabs post-prop installation, is considered.

3.7.1. Gravity loads

The characteristic gravity loading considered in the FDV is set out in this section.

3.7.1.1. Dead and superimposed dead load

The dead load of structural concrete members shall be based on a density, $\rho = 25\ kN/m^3$. For a 200 mm thick structural slab this gives an area load of 5 kPa.

The superimposed dead load comes from the 50 mm screed @ $\rho = 24\ kN/m^3$ giving an area load of 1.2 kPa. It is conservatively assumed that all of the pre-fire screed is still in-place.

As part of their design, the TWD has proposed local grouting under prop positions to address the possible occurrence of voids between the floor screed and the primary slab due to debonding as the slab deflected. Whilst this will locally induce a component of additional SDL this is not included in the SDL allowance as it is considered to be more than compensated for by neglecting the reduction in slab thickness due to the widespread spalling to many of the slab soffits.

During the Atkins visual structural survey in February 2020, it was noted that many of the flats contain debris stacked on the perimeter of the flats, a typical example is shown in Figure 3.6. It has been confirmed by the MHCLG that this is to be removed from all flats prior to the installation of the Stage 3 propping installation and as such is not considered in the loading used in the FDV analysis.

Figure 3.6 - 20th Floor – Flat 3 taken on 18th February 2020

3.7.1.2. Live load

The imposed loading condition is based on the TWD's Design Basis statement where a characteristic live load of 1.5 kPa on any six floors is adopted. Whilst the TWD considers no other floors to have imposed load applied, the Atkins analysis always assumes a minimum characteristic imposed load of 0.6 kPa and in current design practice this is equivalent to the load allowance for a roof with only maintenance access.

3.7.1.3. Façade loading

The concrete spandrel beams are modelled with zero stiffness in the analysis such that their self-weight is accounted for in the dead load gravity loading case.

3.7.2. Lateral loading – wind

The wind loading shall be determined in accordance with the Eurocodes and applied to the wind catchment area represented by the perimeter of the scaffold cladding, i.e. an increase from that the building would originally have been designed for.

For London, the wind speed is taken as v_b = 21.4m/s

3.7.3. Load factors and material factors

For the purposes of the FDV, the following load and material factors are use in the analysis unless noted otherwise:

- Load factor (gravity), γ_f = 1.2
- Load factor (wind), γ_f = 1.2
- Concrete material factor γ_C = 1.25
- Reinforcement material factor γ_S = 1.15

Whilst the testing of the concrete has been used to justify a reduced material factor of 1.25 versus the codified base value of 1.5, the reinforcement material factor has not been reduced due to the uncertainties surrounding the effect of heating during the fire.

3.8. Design codes for the purposes of assessment

Eurocode 2 combined with the UK National Annexe and other sources of Non-Contradictory Complimentary Information *(NCCI)* have been used as the basis of the design validation.

Whilst it is recognised that in assessment work newer codes are often more onerous, e.g. for shear in concrete, the use of modern codes captures current best practice and in the case of shortcomings in design resistance, engineering judgement shall be applied to evaluate the consequence and risk in such instances.

The concrete design code assumed to have been used at the time the building was designed, BS CP 114, has also been used to establish minimum reinforcement amounts and concrete covers that – in the absence of construction or reinforcement drawings – can reasonably be expected to have been provided.

3.9. Analysis software

The software used in the FDV for the purposes of analysis is as follows:

- OASYS General Structural Analysis (GSA)
- OASYS Analysis and design of sections (AdSec)
- Microsoft Excel

4. Damage classification

The damage to a given part of the structure, whether concrete spalling from the slab soffit or from the face of a column, informs the assessment and analysis of the structure with respect to the load paths formed within the structure and the ability of a damaged part of the structure to resist the applied loads.

In February 2019, RSK issued their report, *Grenfell Tower – Fire-damage investigation of key structural concrete elements*, ref 1280180-01, detailing their assessment of the structure. Whilst in February 2020 Atkins carried out a visual survey of the primary structure in order to better understand the damage, and its locations within a given area with the primary purpose being to inform the analysis of the structure.

The findings of the RSK work are summarised in Section 4.1 whilst the Atkins survey findings are reported in Section 4.2.

In terms of context, the RSK damage assessment can be considered as a global assessment of damage whilst the Atkins survey is a more granular assessment of the damage to the structure in order to refine the structural analysis model for the FDV.

4.1. RSK damage classification

The damage classification of slabs, columns, and walls, as defined in RSK's report have been used as the basis for the analysis carried out for the purposes of this Report.

The RSK damage assessment and member damage classification was carried out in accordance with the recommendations of Concrete Society Technical Report No. 68 *Assessment, design and repair of fire-damaged concrete structures*. Whilst the damage classification is to some degree subjective, the assessment is rigorous and consistent.

As a means of presenting the RSK damage classification and the internal propping, the building has been unwrapped along the cut-line shown in Figure 4.1.

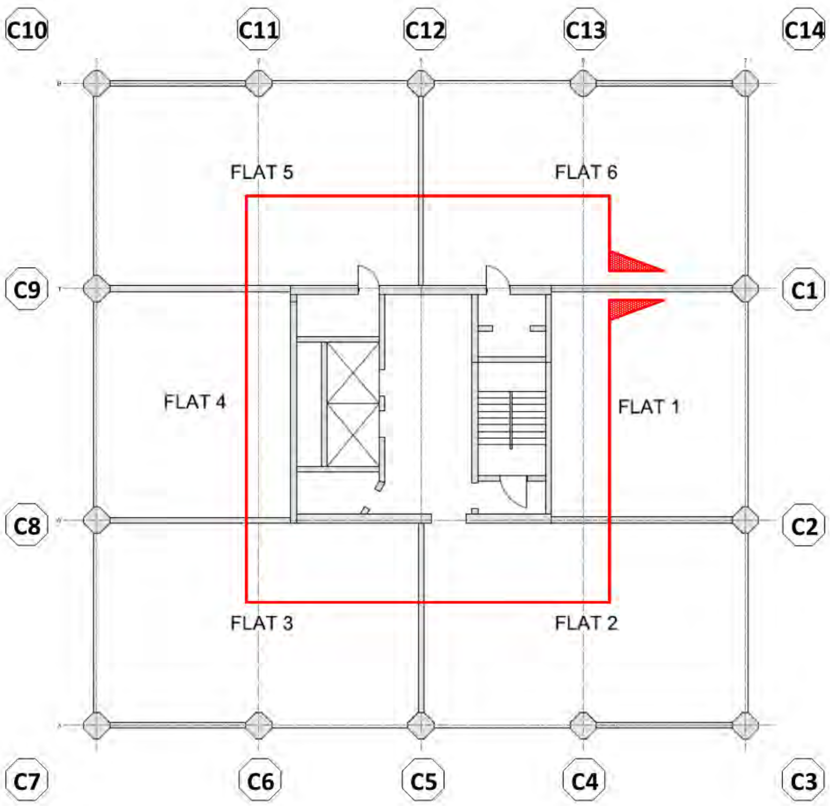


Figure 4.1 - Cut-line for unwrapped section

The unwrapped section is shown in Figure 4.2. The RSK survey began on the fourth floor and with the exception of a number of rooms that were not accessible at the time of the survey, all of the floors above have been classified.

Note that the Damage Classification (DC) is that of the slab soffit and with respect to severity, DC0 to DC2 inclusive can be regarded as minor damage and is assumed to have negligible effect on the structural performance of the building.

The prop arrangements provided by the Tower Stability Group that Figure 4.2 is based on have been updated to reflect the additional Stage 2 propping placed since the IDV report was written.

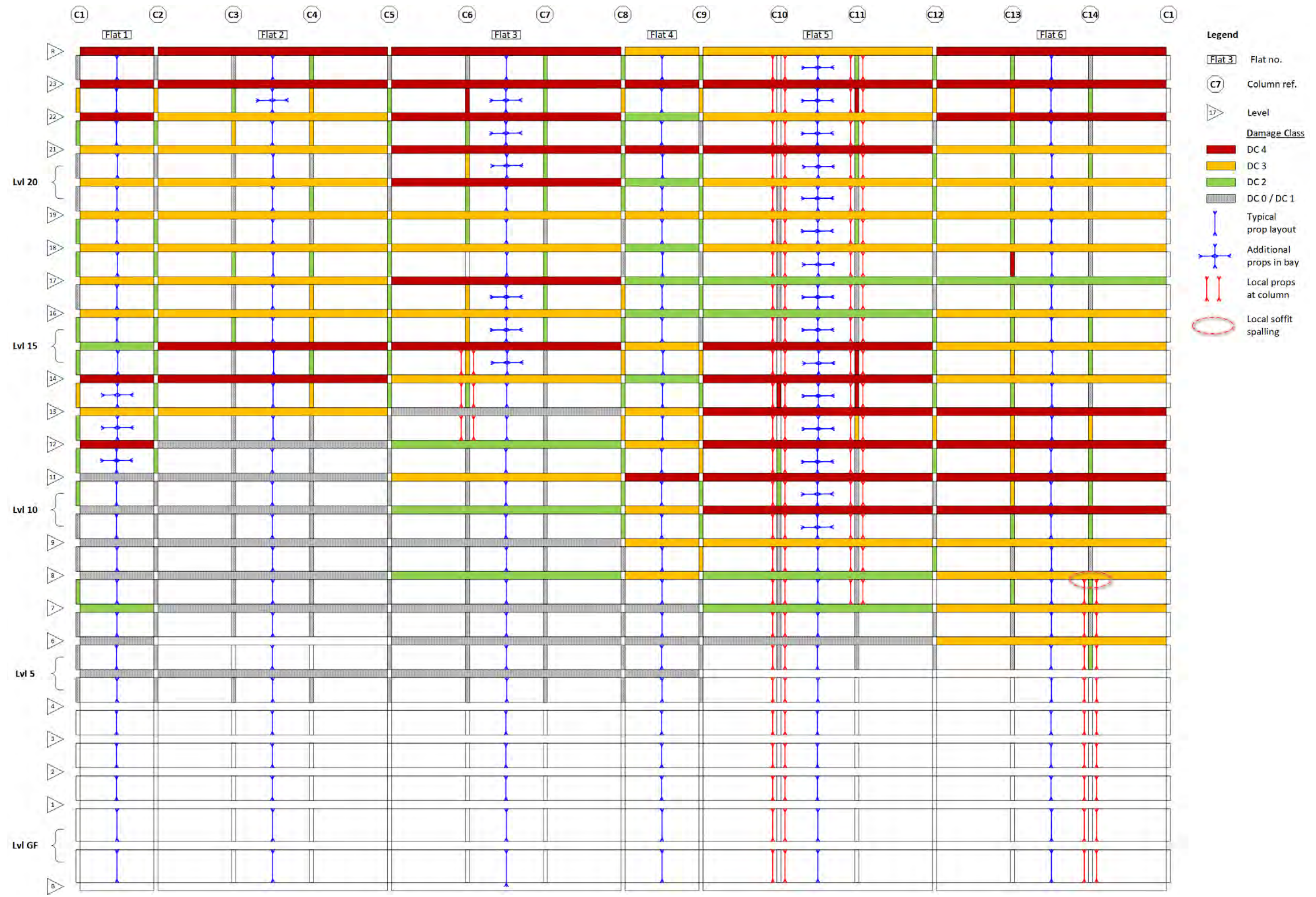


Figure 4.2 - Unwrapped section showing propping and the damage classification for slab soffits and columns as recorded by RSK

With respect to the ‘Local soffit spalling’ zone identified in Figure 4.2, this is illustrated in Figure 4.3 and photographed in Figure 4.4. The area in question is a corner portion of the suspended slab that has suffered significant damage to its soffit; a circumferential crack was also observed. In addition to the reduction in effective section thickness due to the level of spalling, the reinforcing bars have debonded. Additional Stage 2 propping was added to this region although it is understood that it will be replaced as part of the Stage 3 prop installation.

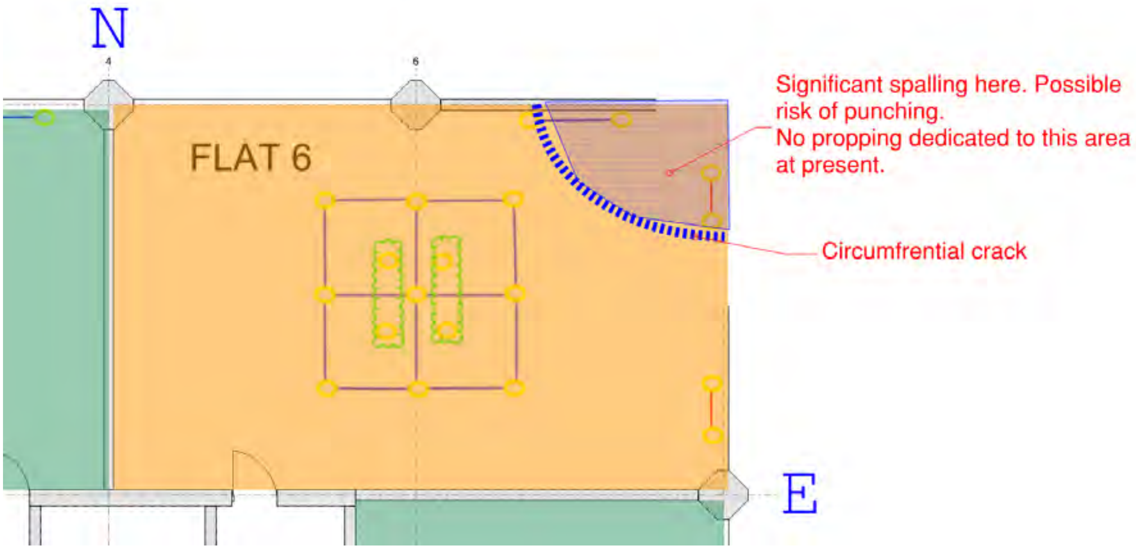
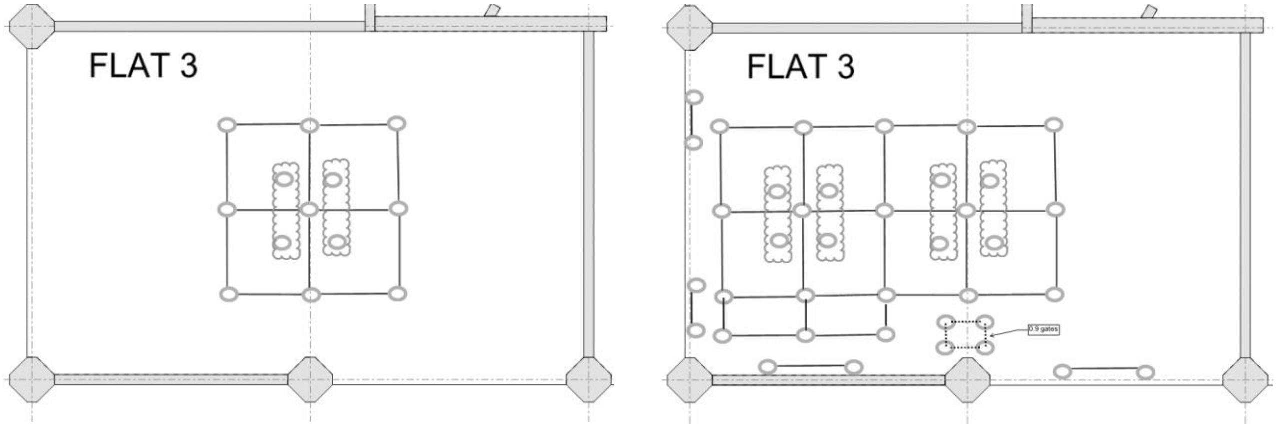


Figure 4.3 - Flat 6 – propping to soffit of eight floor and location of soffit damage (see Figure 4.2)

Figure 4.4 - Flat 6 - soffit of eighth floor slab in North east corner (photographed 27 March 2019)

With respect to the reference to a 'Typical prop layout' and 'Additional props in bay' in the legend of Figure 4.2, indicative examples of these typical Stage 2 prop layouts are shown in Figure 4.5(a) and (b) and pictured in Figure 4.5. However, this is for reference only in that whilst this Stage 2 propping is currently in place, it is to be replaced as part of the TWD's solution for the Stage 3 propping scheme.



(a) Typical prop layout

(b) Additional props in bay

Figure 4.5 - Typical and additional prop layouts

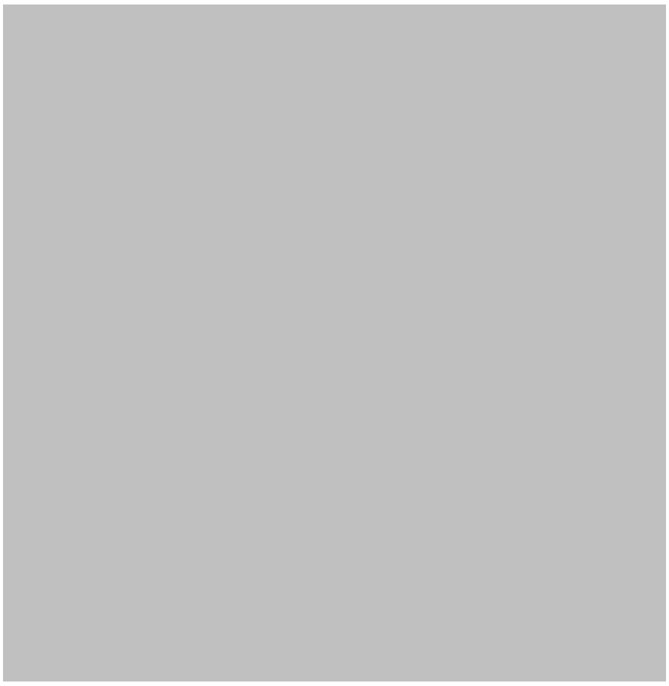


Figure 4.6 – Indicative example of typical Stage 2 propping arrangement (reproduced from RSK investigation report)

4.2. Atkins structural damage survey

Atkins carried out a structural damage survey on the 18th and 20th February 2020.The purpose of this survey was to inform the analysis as whilst the RSK survey gives damage category for a given floor, say, it does not break the assessment down into specific areas.

Thus, in order to capture the effect of damage on the rigidity of the floorplate, and hence load path, Atkins carried out a visual structural survey in order to identify areas of damage within each flat, make a qualitative assessment of the severity, and to then use this in determining suitable section properties for use in the analysis.

The visual survey results are included in Appendix A and an example page is shown in Figure 4.7. Note that each survey page indicates the floor level that the observations were made from, i.e. observations made on Level 17 are of the underside of the Level 18 slab unless noted otherwise.

As can be seen from the figure, various levels of damage are identified as are construction joints where they have become exposed. In all instances the damage zones are shown in the correct position with their size being approximately to scale. The numbers in blue circles relate to the RSK damage classification for a given slab soffit being observed and are for reference only.

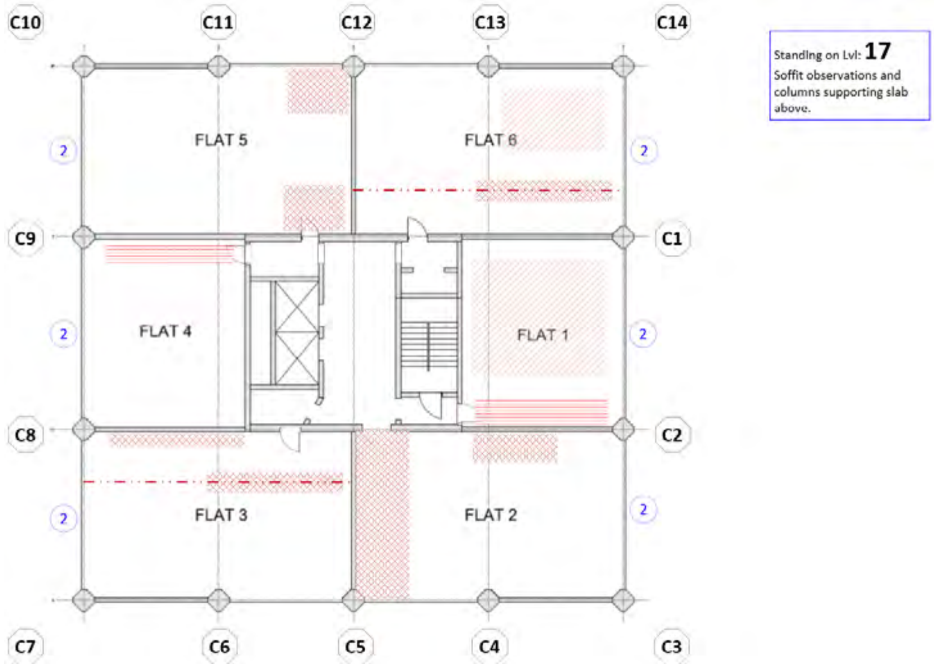


Figure 4.7 – Atkins visual structural survey report example

5. Analysis and assessment

The structural analysis and associated reporting are split between global issues such as the changing load path through the structure due to the fire damage to the structure and local issues such as the behaviour of a given floor.

In order to address these two aspects of the structural behaviour a chassis model of the entire structure and a cassette model for each floor is created.

5.1. Chassis and cassette analysis models

A global chassis model and local cassette models for every floor have been used in the analysis as shown in Figure 5.1. Note that the chassis and cassette models are different analysis files with the combined image in the figure purely being to illustrate the relationship. The cassette models themselves are automatically extracted from the chassis model by the analysis software ensuring consistency in geometry, material properties, and loading.

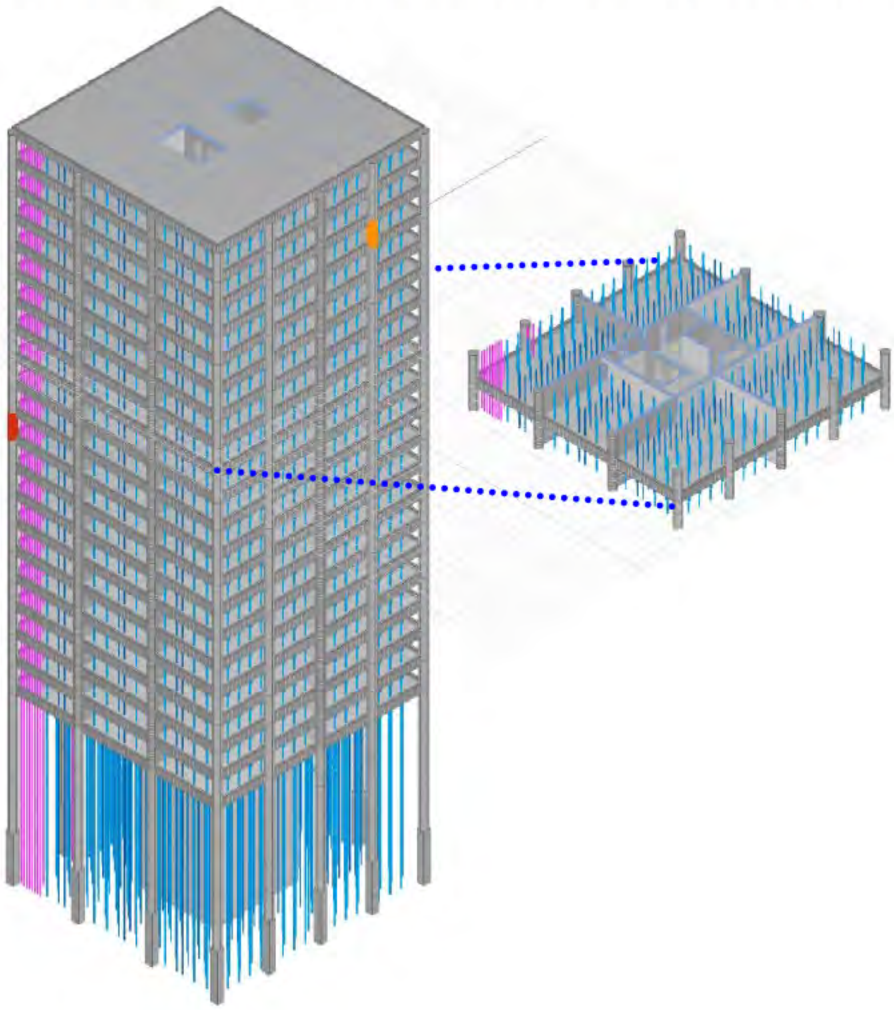


Figure 5.1 – Chassis and cassette model; illustrative only

Note that only the floors from Level 04 up have been explicitly modelled with the lower floors being represented by rigid diaphragm constraints in the chassis model.

Viewing a typical cassette model in more detail, Figure 5.2, the component parts of the analysis model are:

- 2D finite elements are used to model the floorplate and the walls whilst 1D finite elements are used to model the columns and the props
- Stage 3 props are the blue elements whilst the propping to remain from the previous stages, is in magenta
- Door and services penetrations are modelled in the walls

- Perimeter beam is modelled to capture its self-weight.

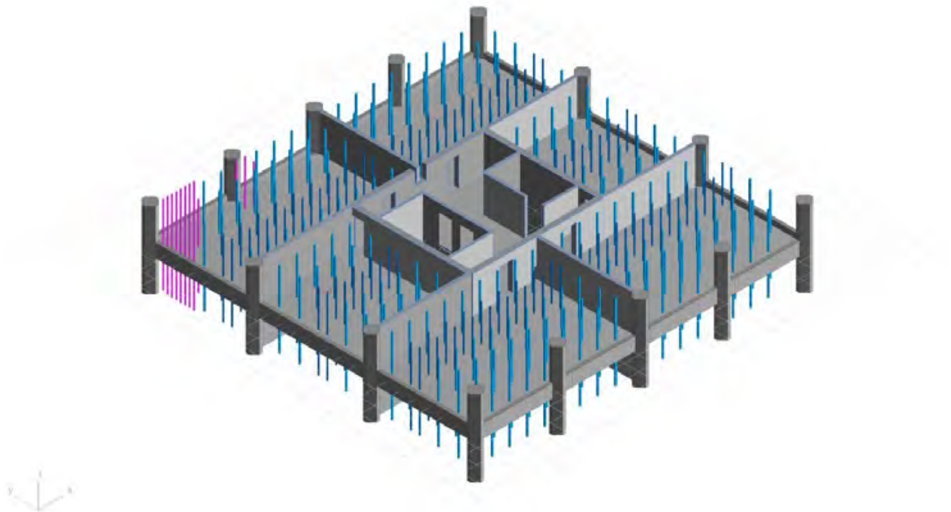


Figure 5.2 – Cassette model

The finite element mesh for the typical floorplate is shown in Figure 5.3 with the typical element size being in the order of 300 mm x 300 mm. The black dots in the figure indicate the currently proposed positions of the Stage 3 propping.

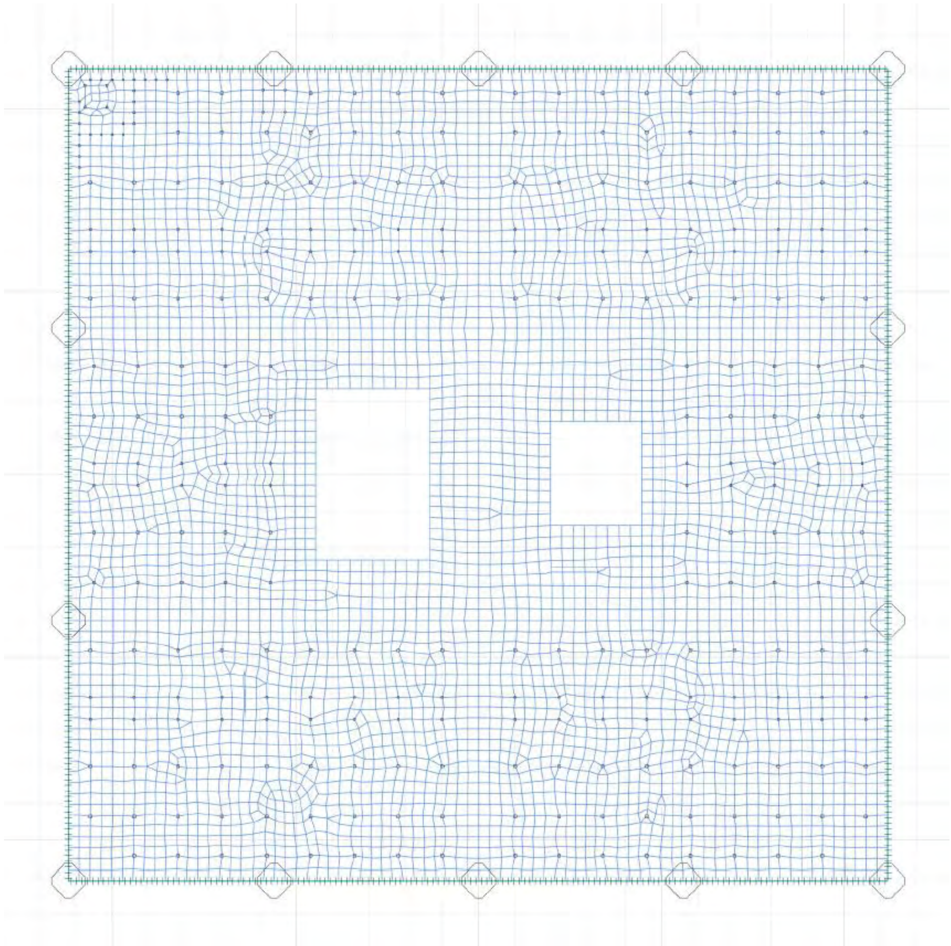


Figure 5.3 – Floorplate finite element mesh

5.1.1. Damage modelling

The level of damage to the slabs and columns varies throughout the building with the assessment of damage for the purpose of analysis having been described in Section 4.2.

With respect to how the damage is accounted for in the analysis model, having identified a particular zone of a slab, say, that has experienced damage, for example Figure 5.4, the section rigidity, EI, in the each reinforcement direction can be assessed. Having established this, an orthotropic material property is assigned to the damaged zone in question. This has the effect of influencing the load path of the structure due to the change of relative rigidity over a given slab. In the approach adopted, the absolute value of rigidity is less important than a consistent treatment of the relative rigidity between different damage areas in terms of understanding the stress in the structure.

Associated with each orthotopic property is the resistance that can be achieved for a particular section and this is used in conjunction with the analysis output in order to understand which parts of the slab are likely to be overstressed.

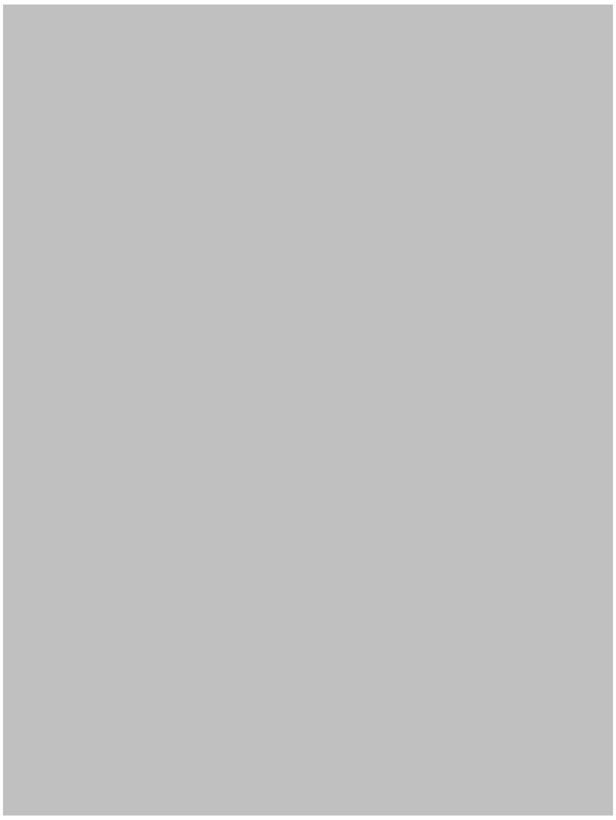


Figure 5.4 – Level 20, Flat 4 slab soffit damage

5.1.2. Staged analysis

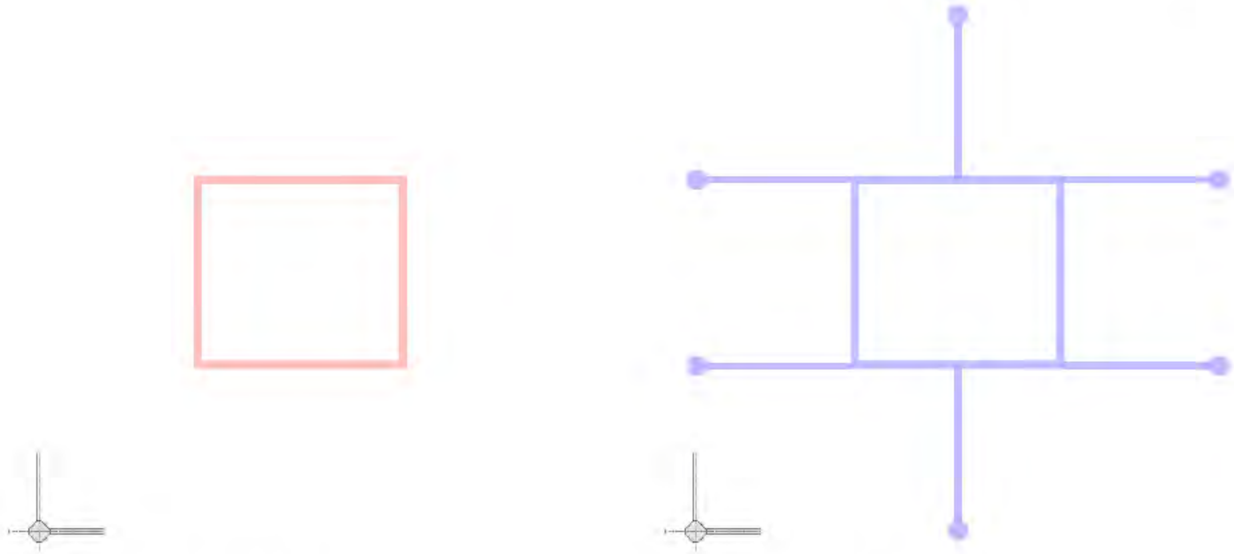
A staged analysis is used to determine the stresses in the structure. In the staging process the structure is first analysed with no props in place, the propping is then introduced and additional loading applied. In this manner the load share between primary structure and propping is captured in assessing the impact of additional loading on the structure after the installation of the Stage 3 propping.

5.2. Global stability assessment

The global stability of the structure is considered in this section.

5.2.1. Resistance provided by the stability core to lateral load

In the IDV the core alone was assumed to resist the lateral forces, i.e. any benefit from the fire walls tying the core to the perimeter columns is neglected. In the FD the interaction, and benefit, of all walls is accounted for by virtue of the nature of the analysis model where a greater level of detail is captured. The difference in the extent of the walls contributing to the lateral stability of the building between IDV and FDV is highlighted in Figure 5.5(a-b).



(a) IDV assumed stability system

(b) FDV assumed stability system

Figure 5.5 – Stability core walls considered in IDV (a) and FDV (b)

5.2.1.1. Load path from scaffold cladding to the stability system

Based on information received from Wates on 5th May 2020, the scaffolding designer Mattison is proposing to modify the scaffolding such that it would connect to the primary structure by means of 'scaffold screws' as shown in Figure 5.6.

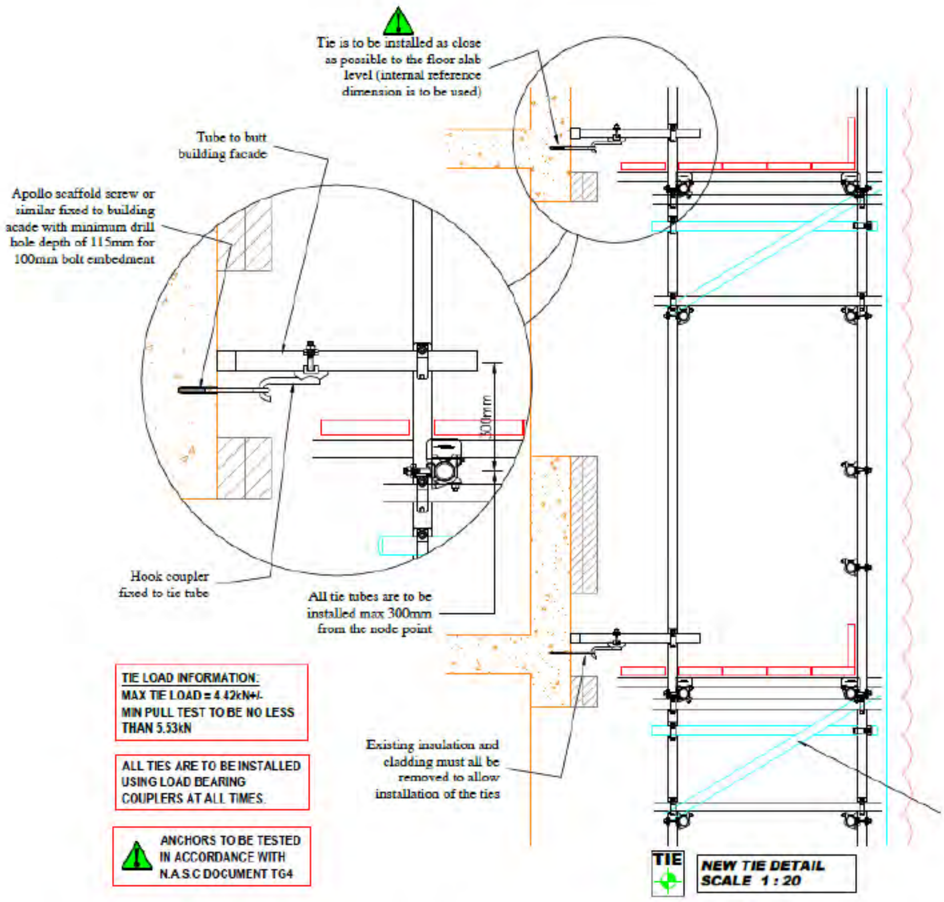


Figure 5.6 – Proposed scaffold connection from Mattison drawing A/MS 6250-63 dated 03/05/2020

The proposed detail appears to show the fixing being to the precast concrete spandrel beam with the scaffolding butting up against this beam – it is assumed the fixing is intended to resist tension whilst the tube acts in compression; elsewhere box ties are shown around the columns.

5.2.2. Findings

The findings of the stability assessment are presented in this section.

5.2.2.1. Resistance provided by the stability core to lateral load

By inspection the significant increase in the length of the stability walls can only improve the resistance to lateral load and given that the IDV findings had shown that the structure was within codified limits, lateral stability is deemed to be satisfied by inspection.

5.2.2.2. Load path from scaffold cladding to the stability system

Whilst the buildings stability system can resist the applied loads, how the load is transferred into the structure is not clear. The Mattison drawings also states that the customer should “Ensure structure is capable of withstanding all loads imposed from the scaffold” – it is not known whether this check has been carried out by the TWD.

The Mattison drawing includes a typical plan for Ground to Level 11 and it is noted that box ties are placed around Column C10. This column has failed on the upper levels and it is unclear how the scaffold transmits load to the primary structure in this area on the upper floors.

5.3. Load path assessment

The corner column, C10, in Flat 5 between Levels 13 and 14 suffered significant damage during the fire as shown in Figure 5.14. It is assumed that prior to installation of the Stage 1 propping around this column, the dead load would have redistributed to other parts of the structure.

In order to investigate the likely effect of this load distribution, analysis results for the floors and columns above Level 12 at Flat 5 have been examined in more detail; this zone is shown in Figure 5.7.

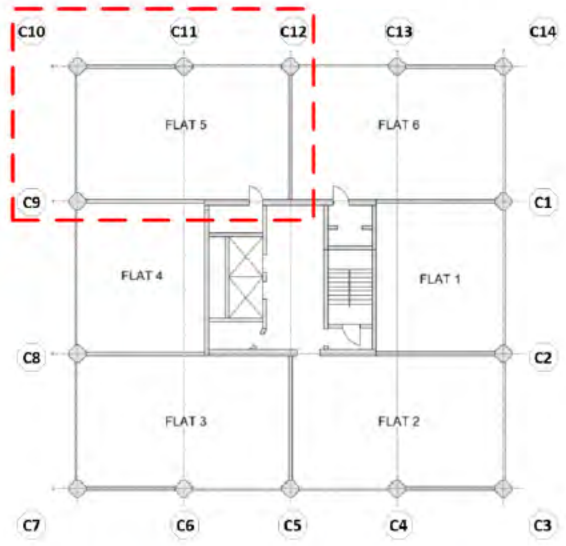
In the figure, the section of column C10 highlighted in red is section of column that has suffered significant damage whilst those column sections shown in orange have suffered some damage.

With respect to C10, several scenarios were considered under dead load where the effective area of the column was reduced and the load shed to the surrounding columns, C9, C11, and C12, was examined.

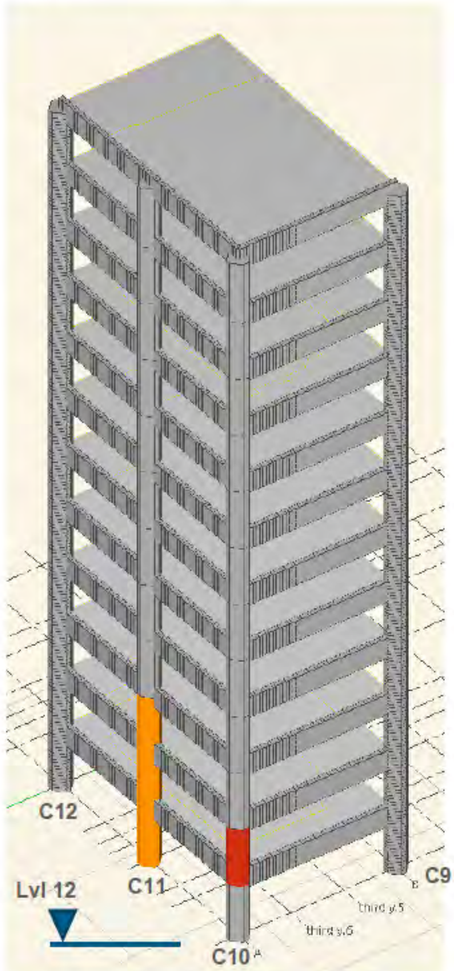
The column properties were set at 10%,1%, 0.1%, and 0.01% of the original cross-sectional area (c.s.a) and the load in the surrounding columns examined. The results of this study are shown in Figure 5.8 for each of the columns in question.

Columns C11 is subject to the largest distribution of the load redistribution followed by Column C9. Column C12 experiences no appreciable change in loading indicating that the load redistribution is focused on the adjacent columns.

One other point of interest is that for C10 the transition from 0.1% to 0.01% c.s.a puts the top stories of the column into tension. This is interpreted as the complete removal of the C10 column (in effect the 0.01% c.s.a case) requiring that section to act as a hanger. However, it is apparent from the deflections in the Level 14 slab that the column is still supporting some residual load and as such the 0.01% c.s.a case is judged to be unrealistic with the 0.1% c.s.a case being considered for evaluating column resistance under a redistributed load.



(a) Key plan



(b) Key plan

Figure 5.7 – Load path examination

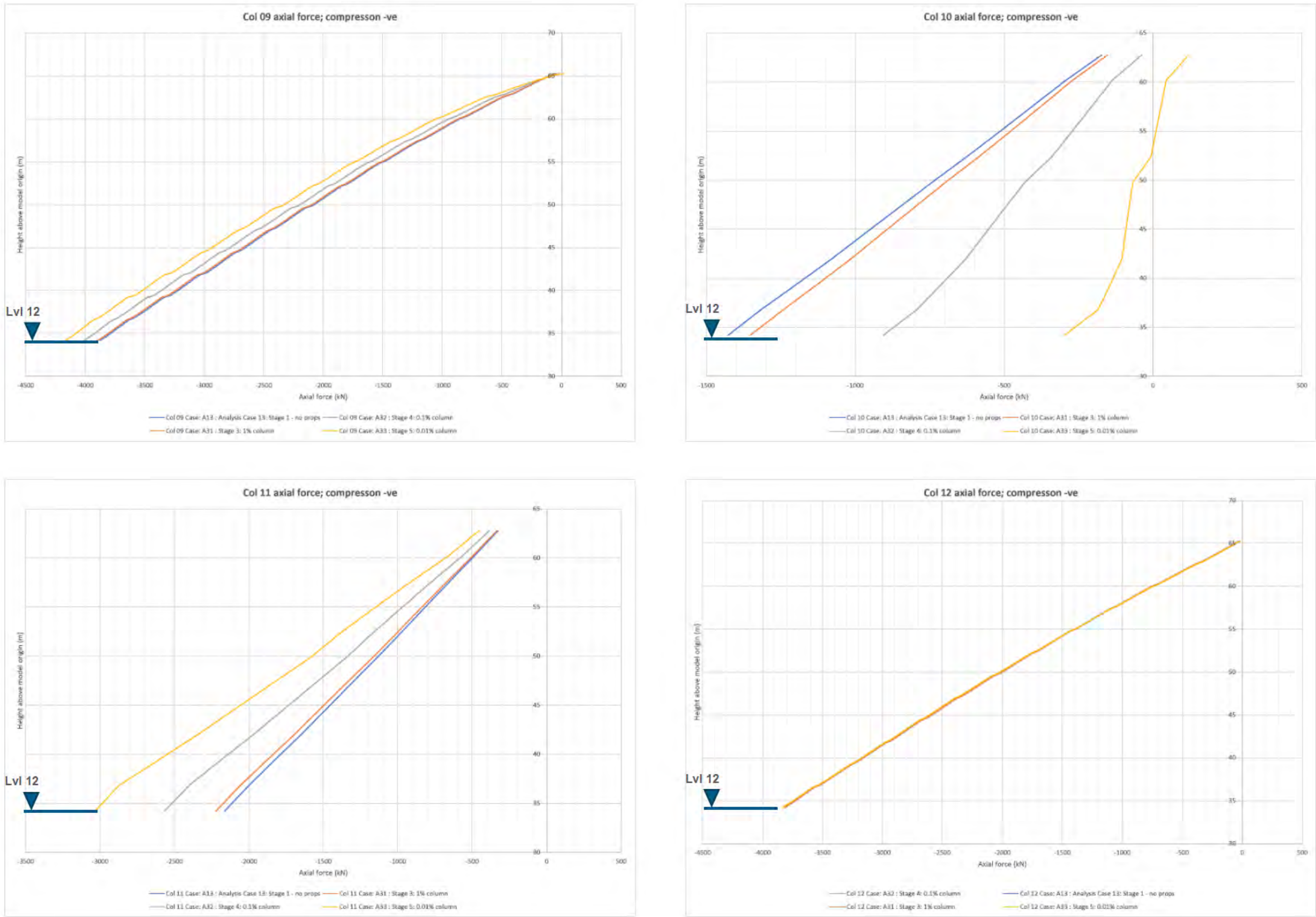


Figure 5.8 – Axial load comparison

5.4. Column assessment (gravity loading)

Based on the revised load path due to the structural damage of columns and slabs as described in Section 5.3, the loads in the columns were determined and the critical sections checked in a number of locations; this is reported in this section.

5.4.1. Column models

The analytical models for edge and corner columns are shown in Figure 5.9 and Figure 5.10 respectively.

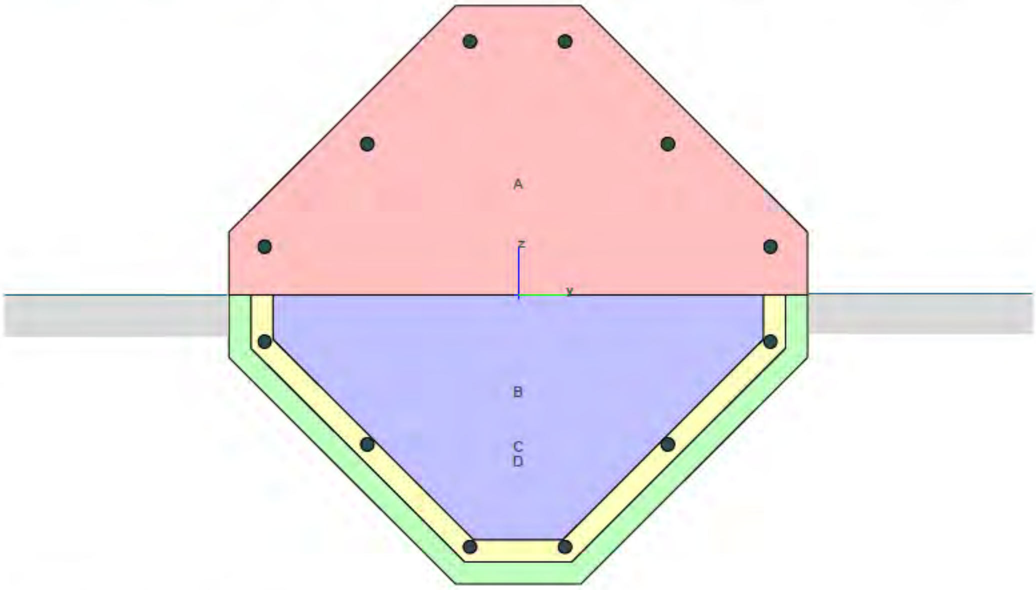


Figure 5.9 - Edge column model

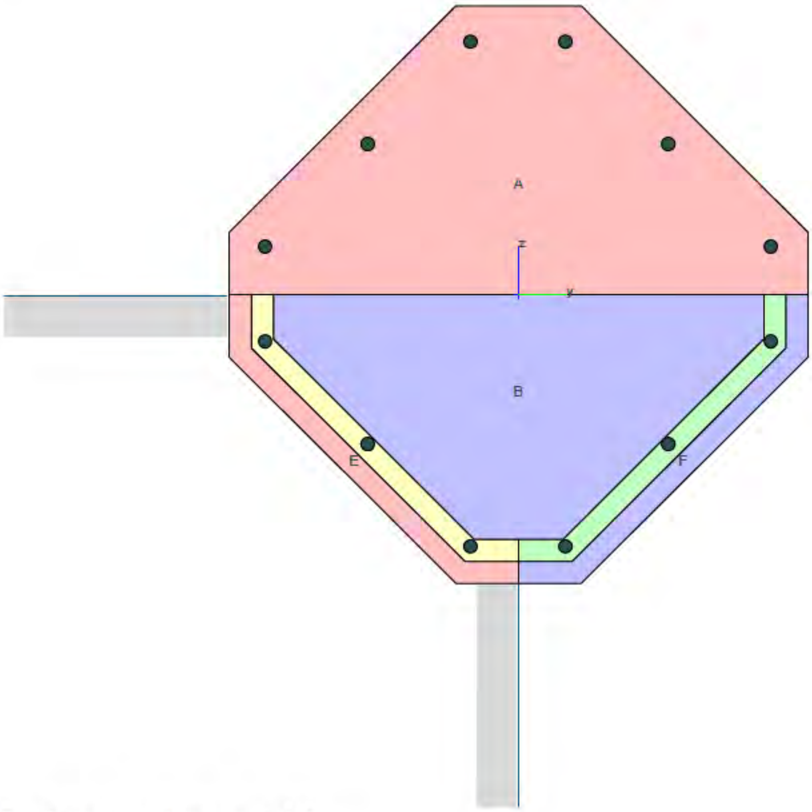


Figure 5.10 - Corner column model

The different lettered zones in the models represent the component parts of the compound section that may be assigned their own unique properties. Note that in Figure 5.10, whilst zones A and E have the same colour, this is simply a function of the software used but each has its own set of unique properties.

The approach taken in the section analysis was to alter the properties of the various zones to reflect the changing material strengths and the loss of concrete through spalling. Similarly, the reinforcing bars in the section have unique definitions, again allowing the effect of temperature to be accounted for and in the case of buckled bars for them to be discounted completely.

5.4.2. Column reinforcement

No reinforcement drawings for the structure have been made available. In the case of constant column size over the height of Grenfell Tower, and accounting for the size of the columns, it would have been expected that the density of reinforcement would have reduced with height due to less load being in the columns.

However, in the absence of reinforcement details, a conservative approach has been taken where the columns are assumed to have the minimum amount of reinforcement permitted at the time. On the assumption that the design code was CP114 (1969), see Table 3.1, the minimum reinforcement that the engineer was required to provide was 0.8% of the columns cross-sectional area.

5.4.3. Findings

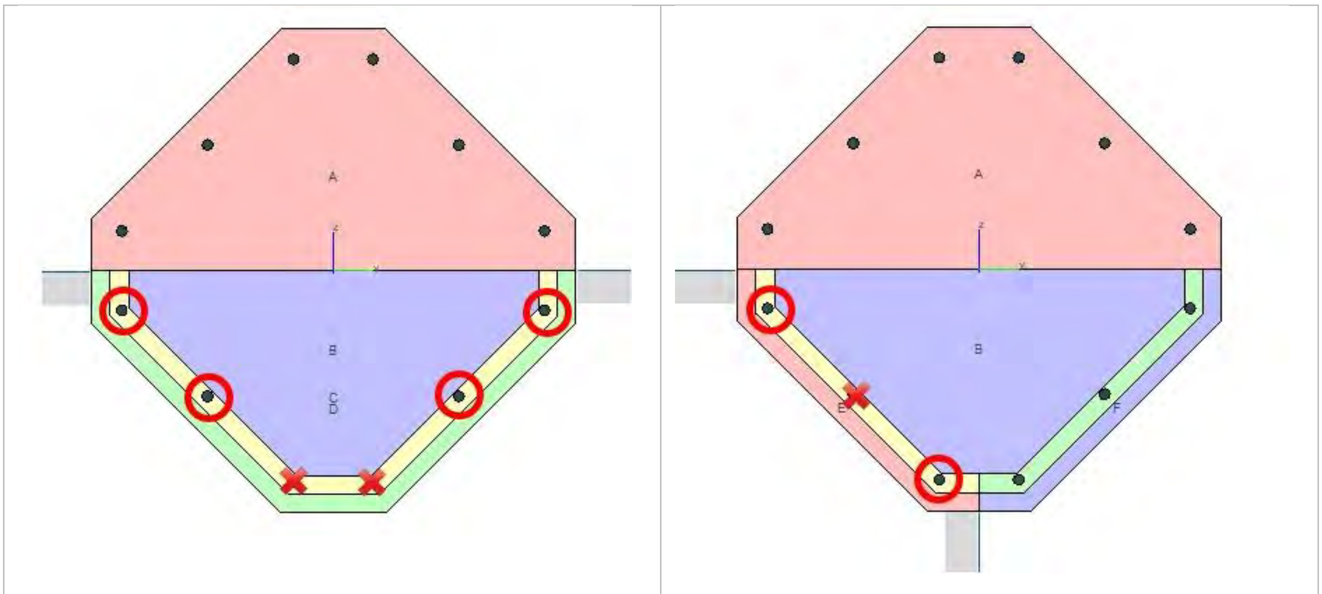
For the purposes of the column assessment, typical column damage is considered as is atypical column damage.

For most of the building the columns appear to have performed well in the fire condition – the typical column damage case – whilst severely damage columns, the atypical case, relates to Columns C10 and C11 in Flat 5 on the 13th Level.

5.4.3.1. Typical column damage

Using the models outlined in Section 5.4.1, section resistances were determined for the reduced sections, i.e. the outer layers of the concrete column were considered to be ineffective. With respect to the reinforcement, and with reference to the photographs of spalling, the reinforcing bars shown in Figure 5.11 had their properties modified.

The circled bars had their strengths factored by 0.6 whilst the bars struck through with an **x** were discounted entirely. The reason for this reduction is that whilst material testing of the reinforcement post-fire has accounted for the temperature experienced, where concrete has spalled, it is likely the reinforcing bars locally would have experienced a higher temperature. The reduction in strength, post cooling is illustrated in Figure 5.12 and the 0.6 factor is considered to be a conservative assumption for the purposes of the FDV.



(a) Edge column | (b) Corner column

Figure 5.11 - Reinforcement with modified properties

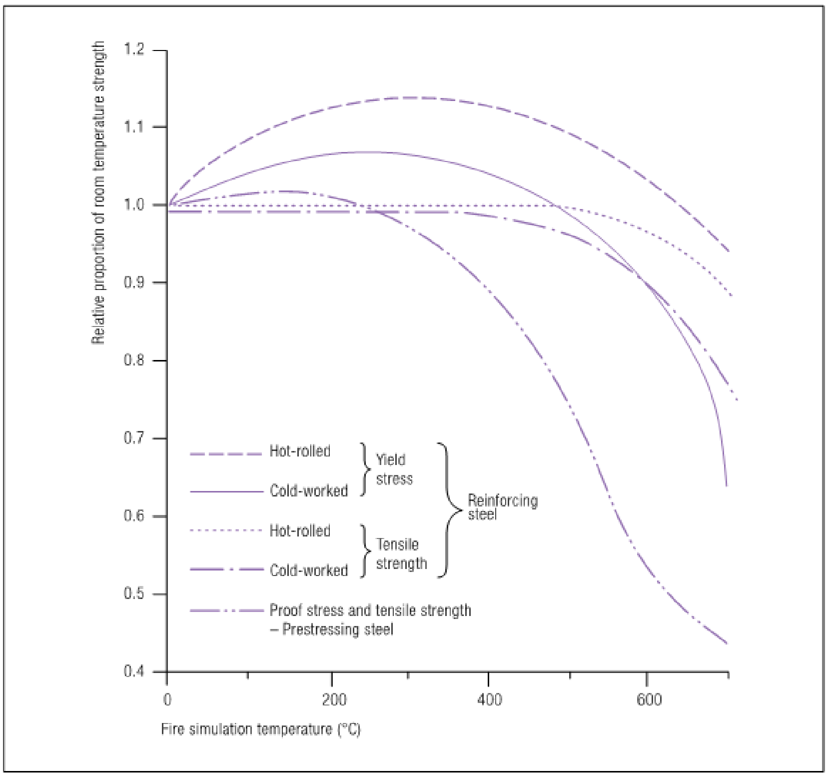


Figure A6.1 Residual strength properties upon cooling of reinforcing bars and prestressing tendons following fire-simulation requirements

Figure 5.12 - Residual strength of reinforcement (reproduced from the IStructE guidance[1])

The findings are consistent with those of the IDV, namely that at lower levels for the highest loaded of the columns it cannot be shown that the full section, i.e. undamaged by fire, can resist the applied loads. However, this is based on minimum reinforcement and it is likely that the reinforcement amount would have increased at lower levels. Further, it is also noted that the highest loaded columns are also those that support the fire walls and as such it is likely that they would have been designed with an increased level of reinforcement.

Further, by inspection, the columns at the lower levels were not affected by the fire and considering that in-service before the fire they would have had to resist a greater total factored load than at present. As such, the adequacy of the lower level columns can be justified by comparison with their previous in-service resistance to applied load.

5.4.3.2. Atypical column damage

Two columns, C10 and C11, on the 13th Level within Flat 5 are considered for the purposes of atypical levels of damage.

5.4.3.2.1. Column C10

Column C10 is considered as an atypical case due to the level of damage identified in the RSK assessment and pictured in Figure 4.2. This is also reflected in the Stage 1 propping arrangement in this flat, Figure 5.13; it is understood that this propping is to be retained as part of the Stage 3 propping scheme.

[1] Institution of Structural Engineers. *Appraisal of existing structures*, 3rd Ed., Institution of Structural Engineers, London, 2010

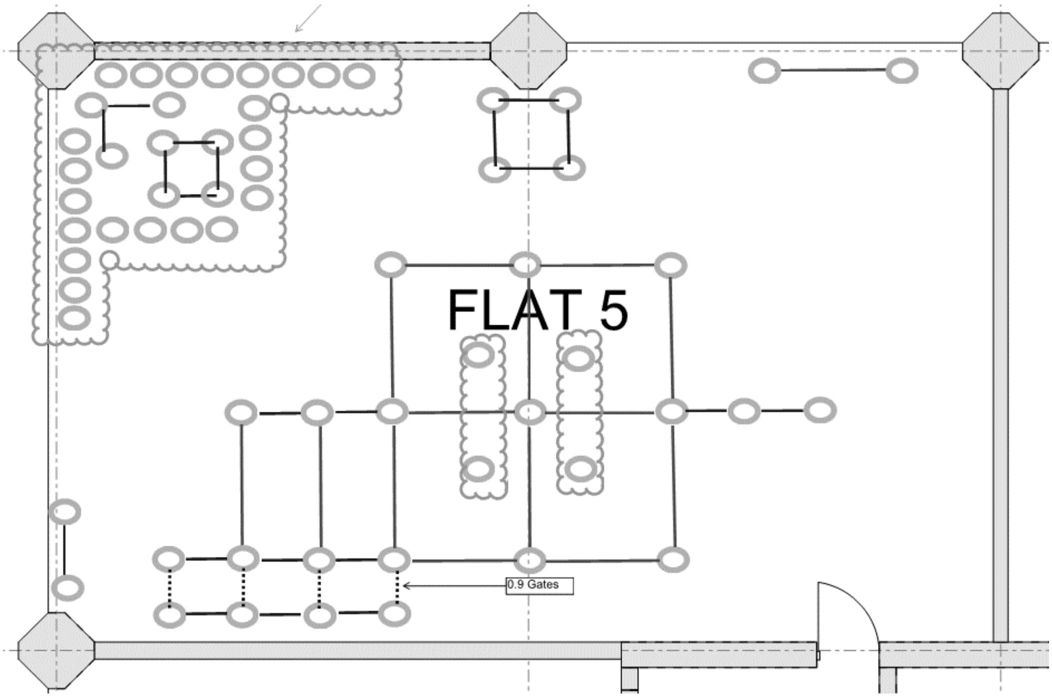


Figure 5.13 - 13th Floor Flat 5 – prop arrangement

The column damage is shown in Figure 5.14 which is taken from Arup's Summary Report. However, at the time of RSKs site survey, and the later site visit by Atkins, the column was obscured and inaccessible due to the propping that had been installed, Figure 5.15.

Figure 5.14 - Spalling on Column C10 at 13th Floor (reproduced from Arup Summary Report)

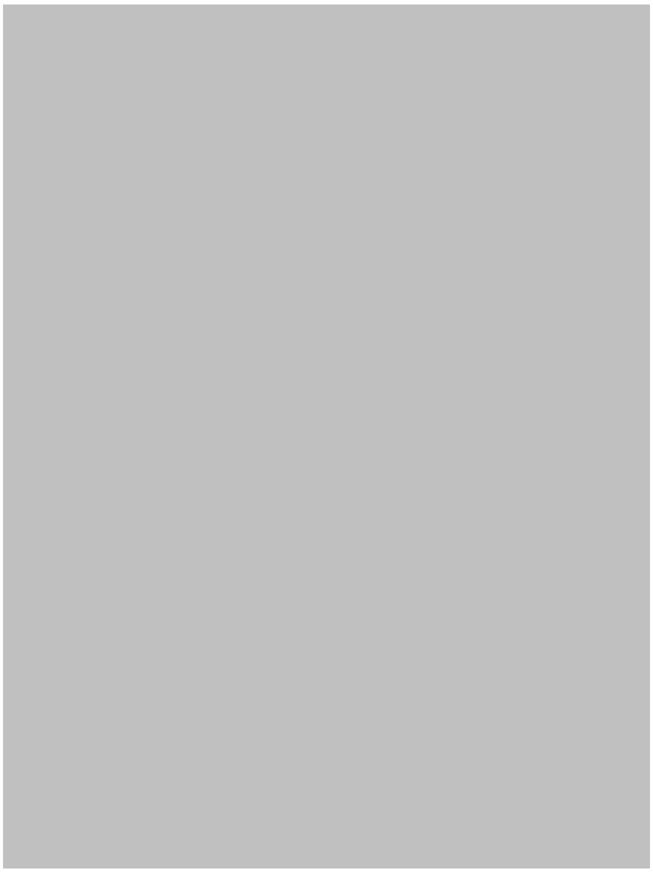


Figure 5.15 - 13th Floor Flat 5 – propping at Column C10 (reproduced from RSK investigation report)

Based on the photographic evidence, primarily Figure 5.14, the column appears to have failed. Whilst some residual capacity may be retained in the outer portion of the concrete section, based on the information currently available it is not possible to assess the state of the column.

On the assumption that the column is only carrying a negligible load, due to the spalling, subsequent bar buckling, and part loss of the concrete core, occurred during or immediately after the fire, i.e. prior to prop installation, the load from the upper floors onto C10 will have redistributed within the structure to other columns and walls. This was investigated in Section 5.3 to determine the load shed relative to an assumed level of damage. Note that this alternate load path implies that the propping is not carrying a significant amount of load.

5.4.3.2.2. Column C11

In the same flat at the same level, i.e. 13th Level – Flat 5, the adjacent column, Column 11, has also undergone significant spalling as shown in Figure 5.16. Whilst this is similar to the analysis case shown in Figure 5.11(a), it is thought likely that depending on when the spalling occurred the HAZ of concrete would be greater. As such a further analysis was carried out where the core strength of the concrete was reduced by 50%.

The analysis was carried out based on the force in C11 resulting from the redistributed load path and shows that the section has adequate resistance under the assumed axial load and a nominal moment.

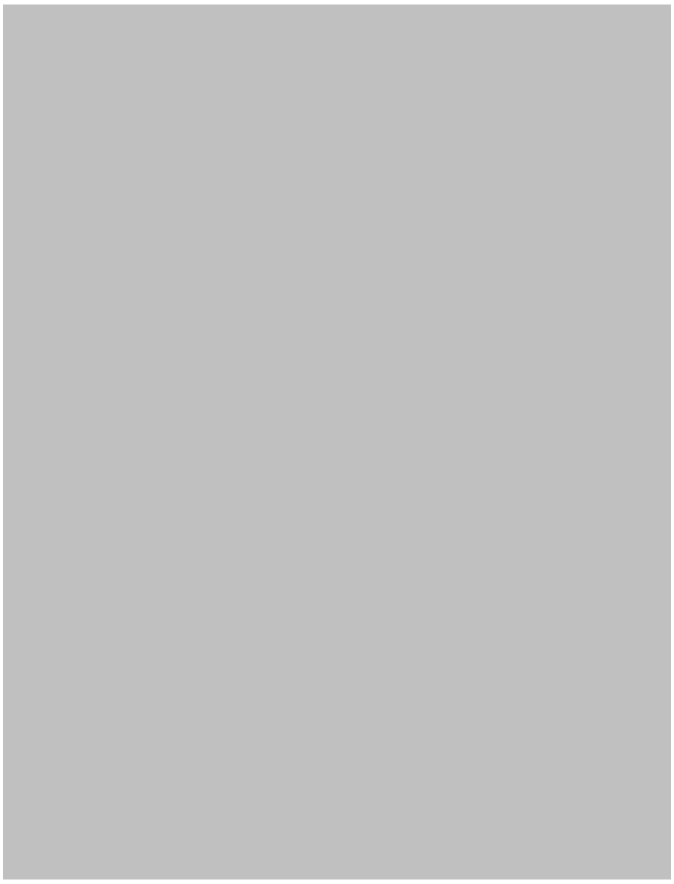


Figure 5.16 - 13th Floor Flat 5 – spalling at Column C11 (reproduced from RSK investigation report)

5.5. Slab assessment (gravity loading)

The analysis output for each floor is given in Appendix B for flexure and shear. Based on these results the slabs are assessed with the findings being presented in graphical form in Appendix C for all affected floors. In this section, the report for a typical floor is examined and the annotations used explained.

5.5.1. Section resistance - flexural

The assessment of strength is based on the damage classification assigned to a given floor and analysis has been carried out to consider various levels of loss of concrete cover and bond to reinforcement. Analysis models similar to that shown in Figure 5.17 have been created for a range of sections.

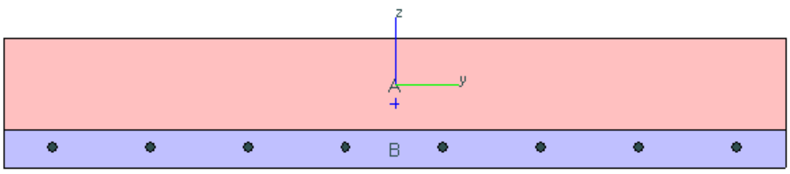


Figure 5.17 - Slab section analysis model

The blue layer, labelled B, is considered to be either significantly spalled, or to be the HAZ and thus contributes nothing to the section. The number of reinforcing bars has also been varied in different analysis models to examine the cases where bars have debonded from the section and as such are ineffective with respect to a flexural resistance.

Where tension is likely to have been developed at the top of the slabs, e.g. at supports and hogging regions, it has not been possible to assess the resistance to such stresses due to a lack of information on the top reinforcement in the slabs.

Given the 50 mm floor screed is likely to have provided a level of insulation against the temperature effects it is likely that the damage to the top surface of the slab, and temperature effects on the reinforcement are likely to be less than on the soffit. As such there is likely to have been less loss of resistance in these regions.

5.5.2. Section resistance - shear

The shear resistance of the sections is calculated in accordance with Eurocode 2. In all instances it has been assumed that the cover layer to the B1 layer is lost in determining the overall section depth.

With respect to areas of the slab where tension is on the bottom face, the shear resistance is assessed against the residual concrete shear strength alone whilst for cases where tension is at the top face of the slab, a conservative contribution is taken from an assumed top reinforcement quantity.

Knowing the various resistance values, these are used as the contour values in the through thickness shear plots in order to visually assess the slabs.

5.5.3. Slab assessment

The purpose of the slab assessment is to examine those areas of the slab that are overstressed in the absence of propping. In this manner the final design of the propping by the TWD can be evaluated against the expectations from the analysis.

As noted, the slab assessment is presented in sketch form for all slabs and these are included in Appendix C. A typical example of this is shown in Figure 5.18. Similar to the damage survey, the slab assessment indicates zones where:

- the slab is unable to support its own weight and propping is expected to support it (blue hatching)
- the top of the slabs is overstressed (green hatching).

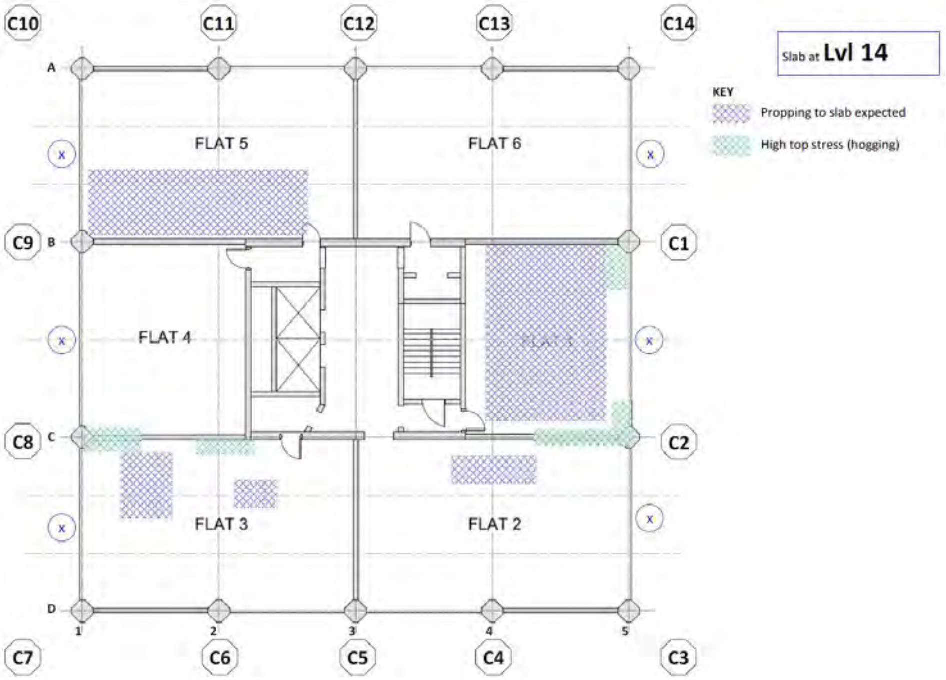


Figure 5.18 – Example of analysis findings

Whilst the analysis indicates that the slabs are overstressed in some of the hogging regions, the green hatched areas, this is less of a concern than the sagging regions as a conservative assumption has been made of top reinforcement in the slabs as this is currently unknown. Also, when reviewing the stress state of a floor showing no signs of structural damage, e.g. Level 05, the same pattern of stress being reported by the analysis.

It is likely that rather than being overstressed, the slabs will have already cracked and the excess stress redistributed back into the span of the slabs.

Flat 5 above Level 12 is a special case with respect to top reinforcement stress. Given the level of damage to the corner column C10, large deflections are predicted by the analysis giving rise to higher stresses in both the hogging and sagging regions due to the redistribution of load. As such a conservative assessment has been made as to the requirements of support to the slab in this flat over the top levels of the building.

With respect to shear, there is no evidence from the analysis that the shear stress in the slabs is greater that allowable.

6. Structural degradation

In the absence of a façade, the exposure of the primary structure to the elements is increased. In the short-term, i.e. to the end of 2021, this is likely to have limited impact on the structural soundness of the building. However, the following are recommended as safeguarding measures with respect to the overall durability of the structure.

6.1. Rooftop waterproofing

It was noted during the Atkins visual structural survey that water was continually dripping from the soffit of the roof slab in all flats; note that on the days of, and preceding, the survey it was raining.

To limit the corrosion risk to the reinforcement the cause of the leaks should be found and addressed. It is suggested that the waterproofing layer be inspected and the repaired as appropriate.

6.2. Concrete repair and reinforcement exposure

Due to the extensive spalling throughout the building, a significant amount of reinforcement is exposed.

In order to protect the reinforcement and the concrete face, the reinforcement should be cleaned of rust where practicable and a protective coating applied such as those supplied by Fosroc, Sika, or FIS Products.

Further, depending on the expected additional lifespan of the damaged structure, engaging a concrete repair specialist such as FIS Products or Concrete Repairs Limited to provide a maintenance and repair plan should be considered.

The extent of such repair measures may be limited to those areas deemed to be the worst affected. However, a residual risk remains in that untreated areas may suffer further deterioration; regular inspections will partly mitigate this risk.

6.3. Perimeter protection

It is expected that the scaffolding will remain wrapped in suitable sheeting and it is expected that this has been specified such that it provides a suitable barrier to the elements.

7. Conclusions and next steps

The conclusions of the FDV and possible next steps are presented in this section.

7.1. FDV conclusions

The conclusions of the FDV are based on the installation of the Stage 3 propping systems as shown in Cantillon's work-in-progress Stage 3 propping drawings of 28 March 2020.

The global stability of the structure has been found to be within the acceptable lateral movement limits of current practice.

Typically, the column resistance, even where some fire damage has occurred, is acceptable. On the lower floors for the columns that connect to the fire walls, it has not been possible to demonstrate that their load carrying capacity is adequate. However, this assessment is based on the codified minimum reinforcement amount of the time rather than the actual reinforcement in the column which is unknown. Given that at the time of design the design load on such columns would have been higher than that currently used in the assessment, and that they exhibit no signs of distress, it is probably that the reinforcement amounts will be higher than those currently assumed.

The corner column in Flat 5, Column C10, between levels 13 and 14 has failed as evidenced from the buckling to the reinforcement and spalling into the core of the section. Given that this would have happened during and immediately after the fire before the Stage 1 propping was in place, the load that was in the column will have redistributed to adjacent vertical structure. This has been examined and the adjacent structure shown to have adequate resistance.

On the majority of floorplates where there has been significant spalling, areas of the floor slabs are typically overstressed under dead load and in the absence of propping. This indicates areas where the current propping system may be contributing the means by which the slabs are supported and where the Stage 3 propping would be expected to be designed to actively carry the slab dead load.

From the analysis the tops of the slabs by the support walls are shown to be overstressed in a number of locations. This is a local effect and is also reported for undamaged slabs. It is likely that either:

- the designers will have increased the top reinforcement over the supports from that assumed in the IDV to address the increased stress levels.
- the stress reported would have caused the slabs to crack sometime during the building's life before the fire and the residual stress redistributed to the surrounding structure.

In either of the above cases, this is not considered to be of concern.

7.2. Next steps

The following should be considered with respect to future work to be carried out.

7.2.1. Further analysis and design

The FDV is based on the Stage 3 propping being installed over the entire height of the building from Basement Level.

If the propping strategy changed such that propping started on a suspended slab level rather than at Basement Level, a high-level investigation of the consequence of this change could be carried out through modification of the analysis model used for the FDV.

7.2.2. Column C10

As has been noted, column C10 between Level 13 and 14 has failed. Beyond making this safe, it could be encased/repaired as suggested by the TWD.

It is important to recognise that this will not transfer load back to the column but should be designed to act tertiary load path should the propping fail, or need to be removed at some point. For this to be effective, and depending on the form of encasement/repair, the edge beams would need to be removed in order to bear on the columns above and below.

7.2.3. Scaffolding load path

As noted in Section 5.2.2.2, the means by which the scaffold is stabilised or how the load is transmitted from the scaffold is transmitted to the primary structure.

Clarification should be sought on this item in addition to confirmation that the TWD has checked the structural soundness of the members that the scaffold is connected to.

7.2.4. Propping load path assumption confirmation

The TWDs analysis model and associated calculations demonstrating the suspended slabs do not carry any component of dead load should be validated by the CAT3 checker, Michael Barclay Partnership, and explicitly confirmed to MHCLG.

7.2.5. Repair

Repairs should be carried out to the roof waterproof membrane, or that it be replaced, in order to prevent water ingress to the structure.

For the structure generally, it is recommended that exposed reinforcement and spalled concrete faces be painted with suitable protective compound. Whilst the extent of such repair measures may be limited to those areas deemed to be the worst affected, a residual risk remains in that untreated areas may suffer further deterioration; regular inspections will partly mitigate this risk.

7.2.6. Further investigation works

In order to better understand the resistance of the slabs and columns it is recommended that:

- Local opening up of the top of a slab at a support, e.g. fire wall, be carried out in order to understand the reinforcement size and spacing used. Alternatively, it may be possible to carry out a ferroscan to obtain this information and avoid opening up works.
- The reinforcement in the columns at the lower levels in unknown. In order to better understand how they have been reinforcement, it should be determined whether a ferroscan type survey would allow the reinforcement amounts to be established and if yes, such a scan carried out.
- The reinforcement spacing appears variable based on the zones exposed. To have a better record of both reinforcement spacing and bar sizes a ferroscan type survey, supplemented by local opening up works, would facilitate this.

Appendices

Appendix A. Atkins structural damage survey

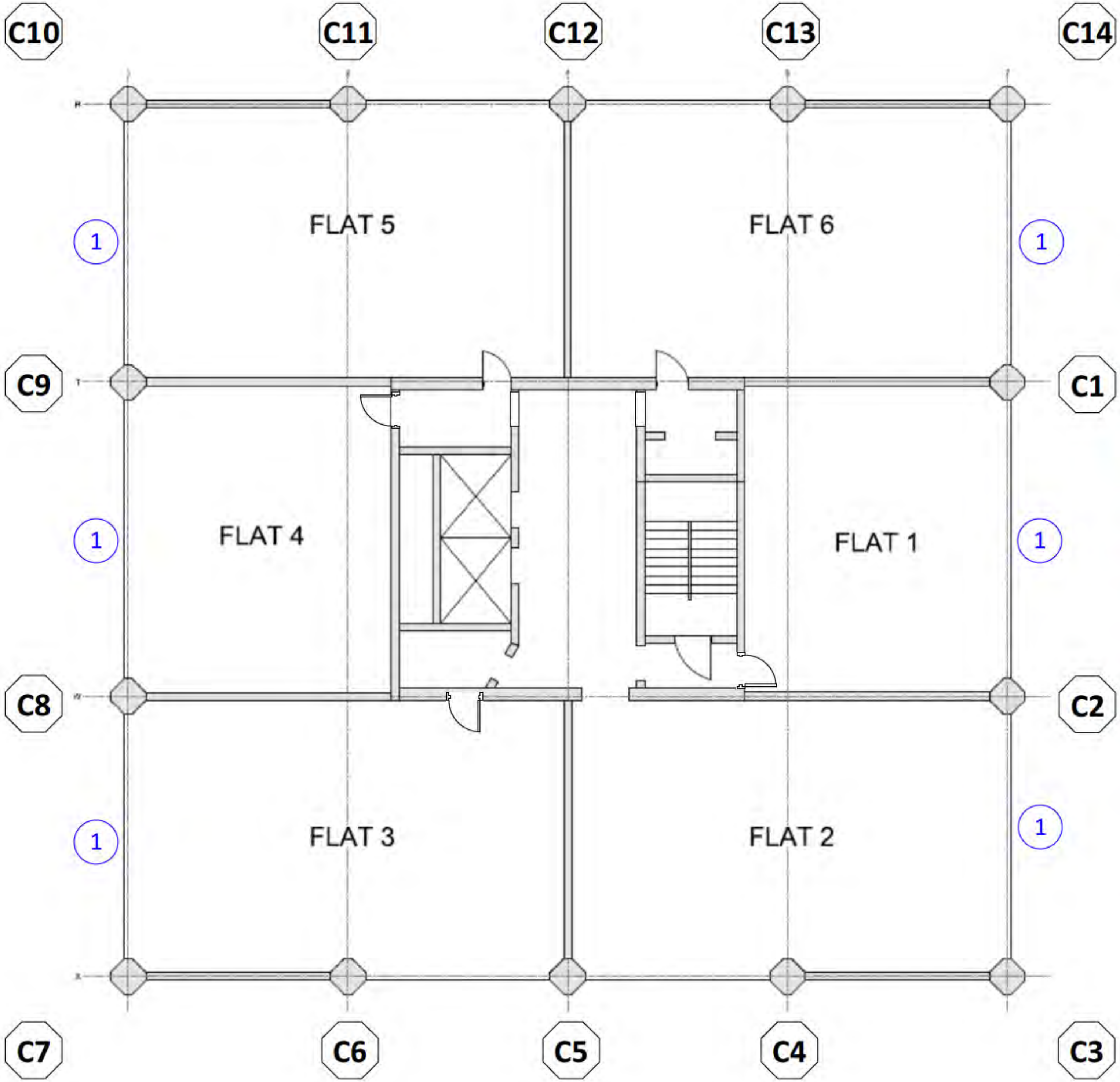
A.1. Introduction

The diagrams in this Appendix are a record of the finding of the Atkins visual structural damage survey.

Note that each survey page indicates the floor level that the observations were made from, e.g. observations made on Level 17 are of the underside of the Level 18 slab unless noted otherwise.

As can be seen on the survey record, various levels of damage are identified for each floor and in all instances the damage zones are shown in the correct position with their size being approximately to scale.

The numbers in blue circles relate to the RSK damage classification for a given slab soffit being observed and are for reference only

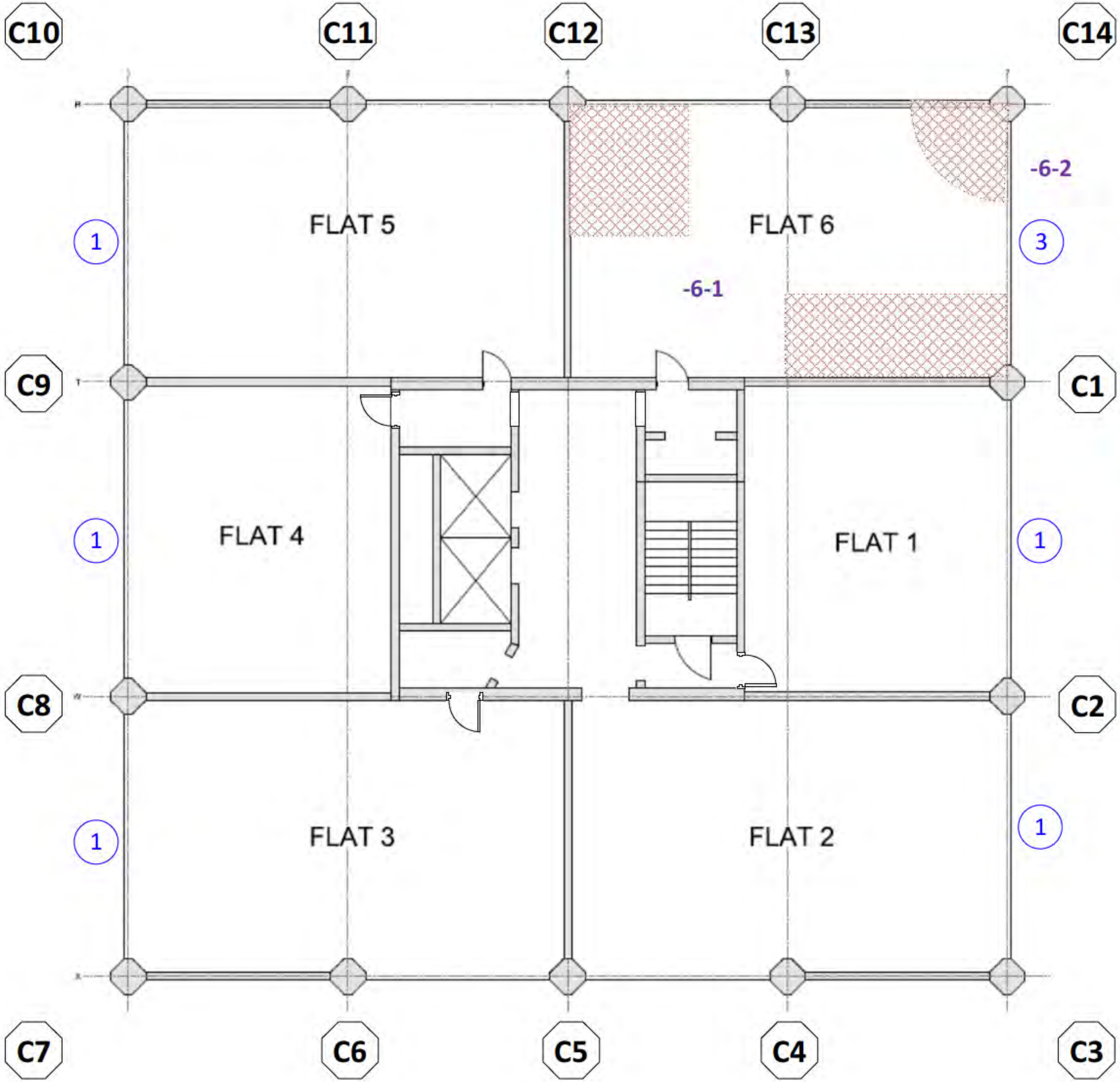


Standing on Lvl: **4**

Soffit observations and columns supporting slab above.

KEY

- Minor damage / patch spalling
- Significant damage
- Major damage
- Bars debonded in the direction of the lines
- Construction joint
- Break and clear step in slab
- 4 Damage Class from RSK survey
- -3-2 Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example



Standing on Lvl: **5**

Soffit observations and columns supporting slab above.

KEY

Minor damage / patch spalling

Significant damage

Major damage

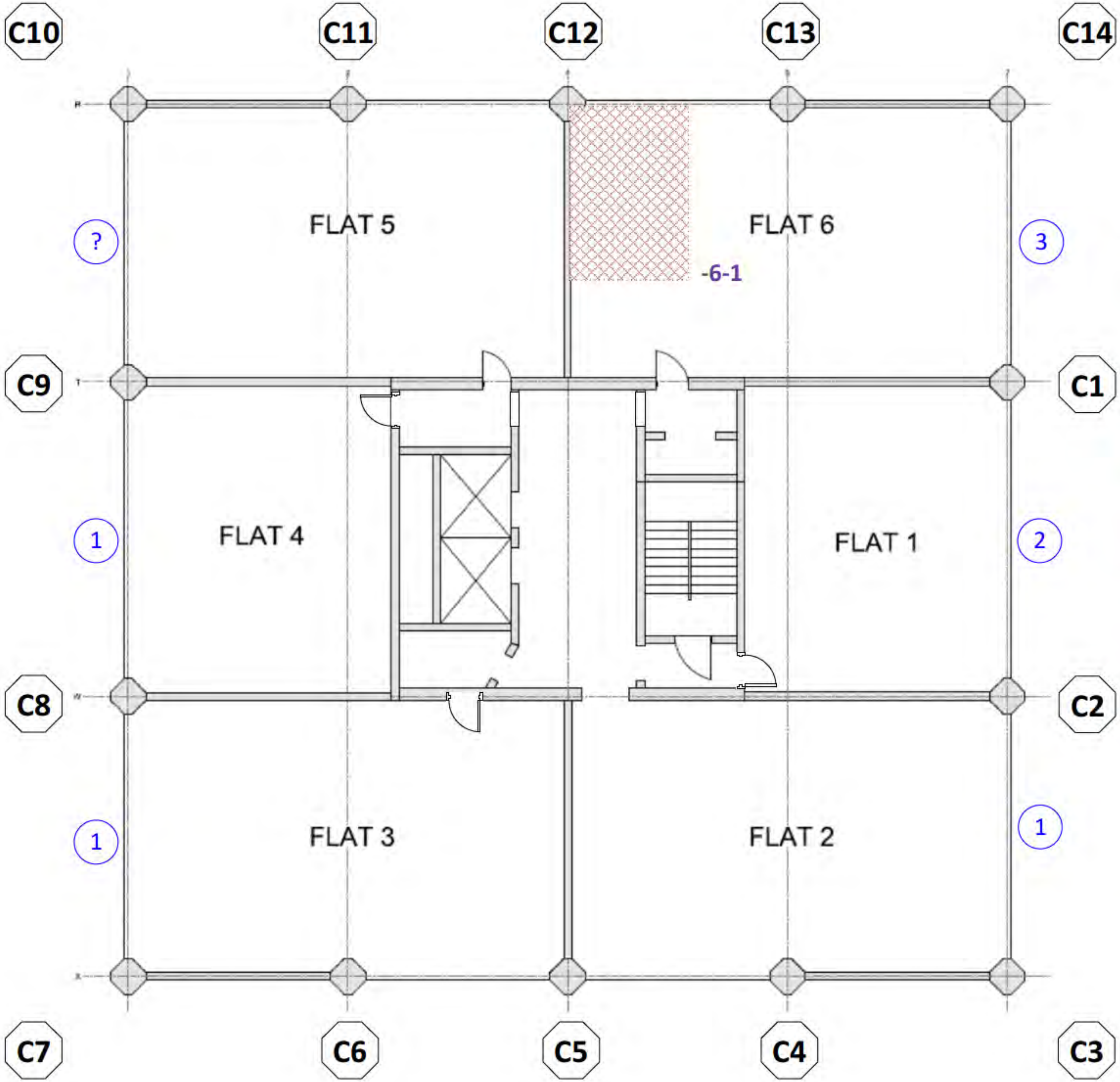
Bars debonded in the direction of the lines

Construction joint

Break and clear step in slab

4 Damage Class from RSK survey

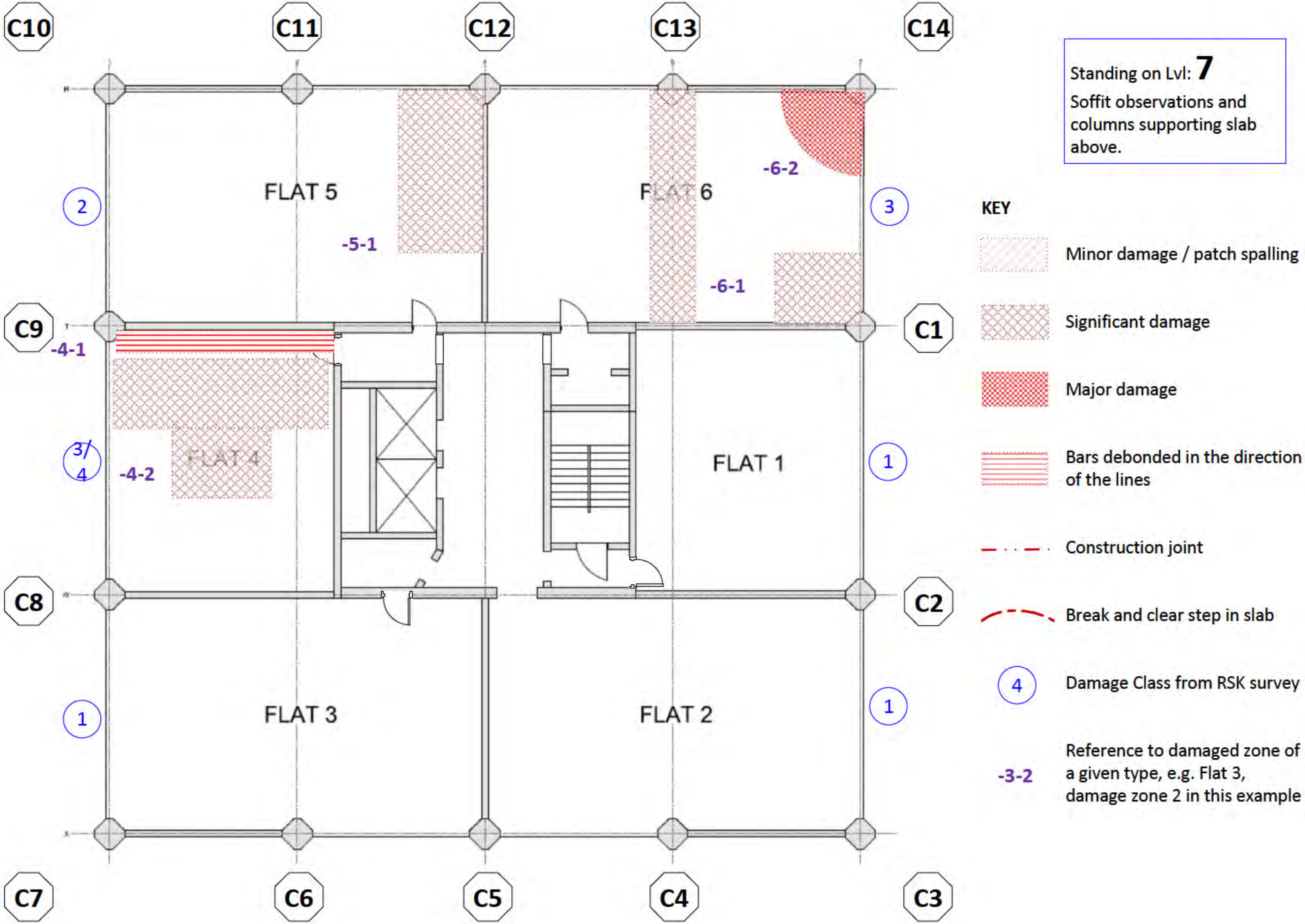
-3-2 Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example



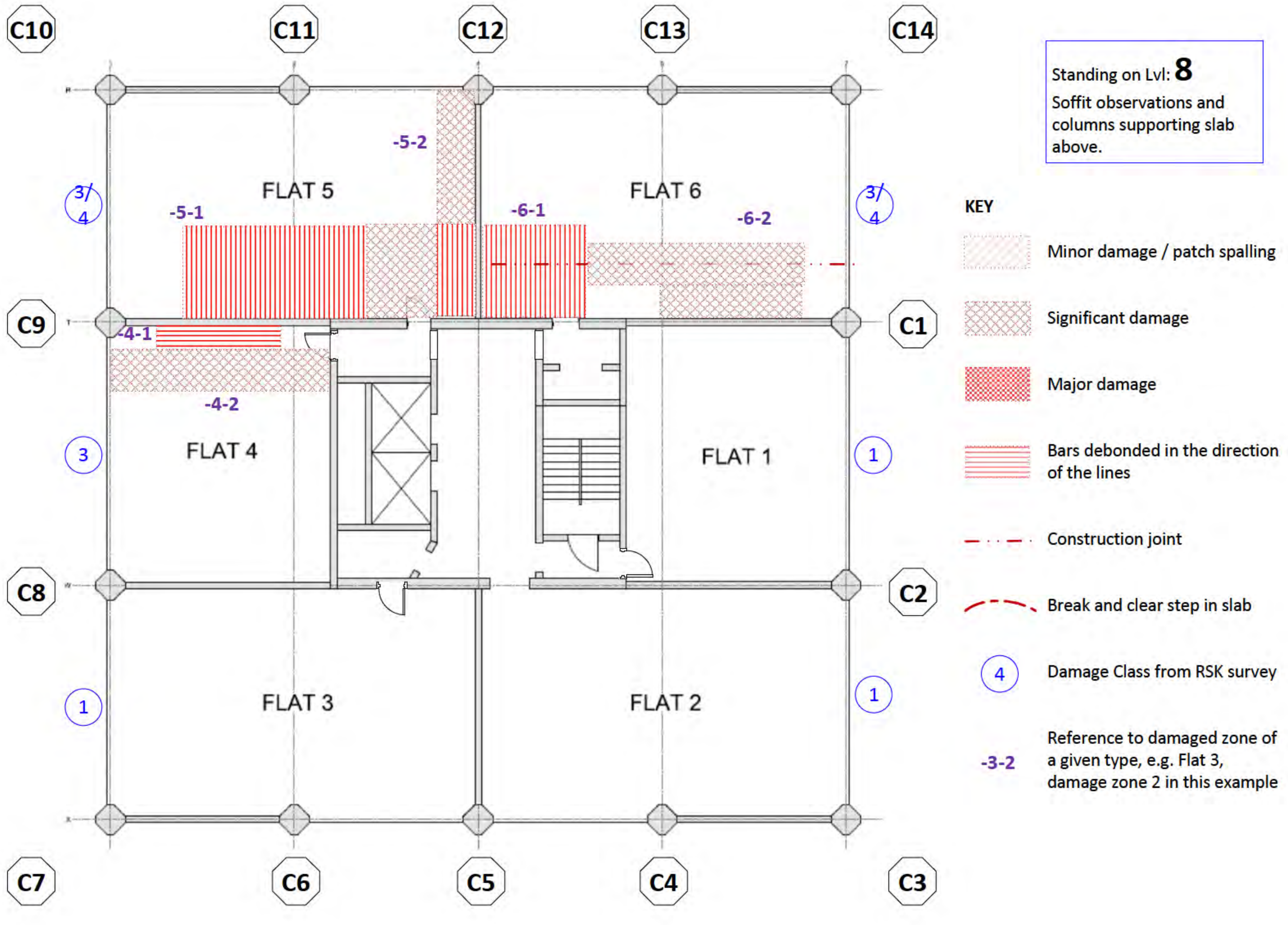
Standing on Lvl: **6**
Soffit observations and columns supporting slab above.

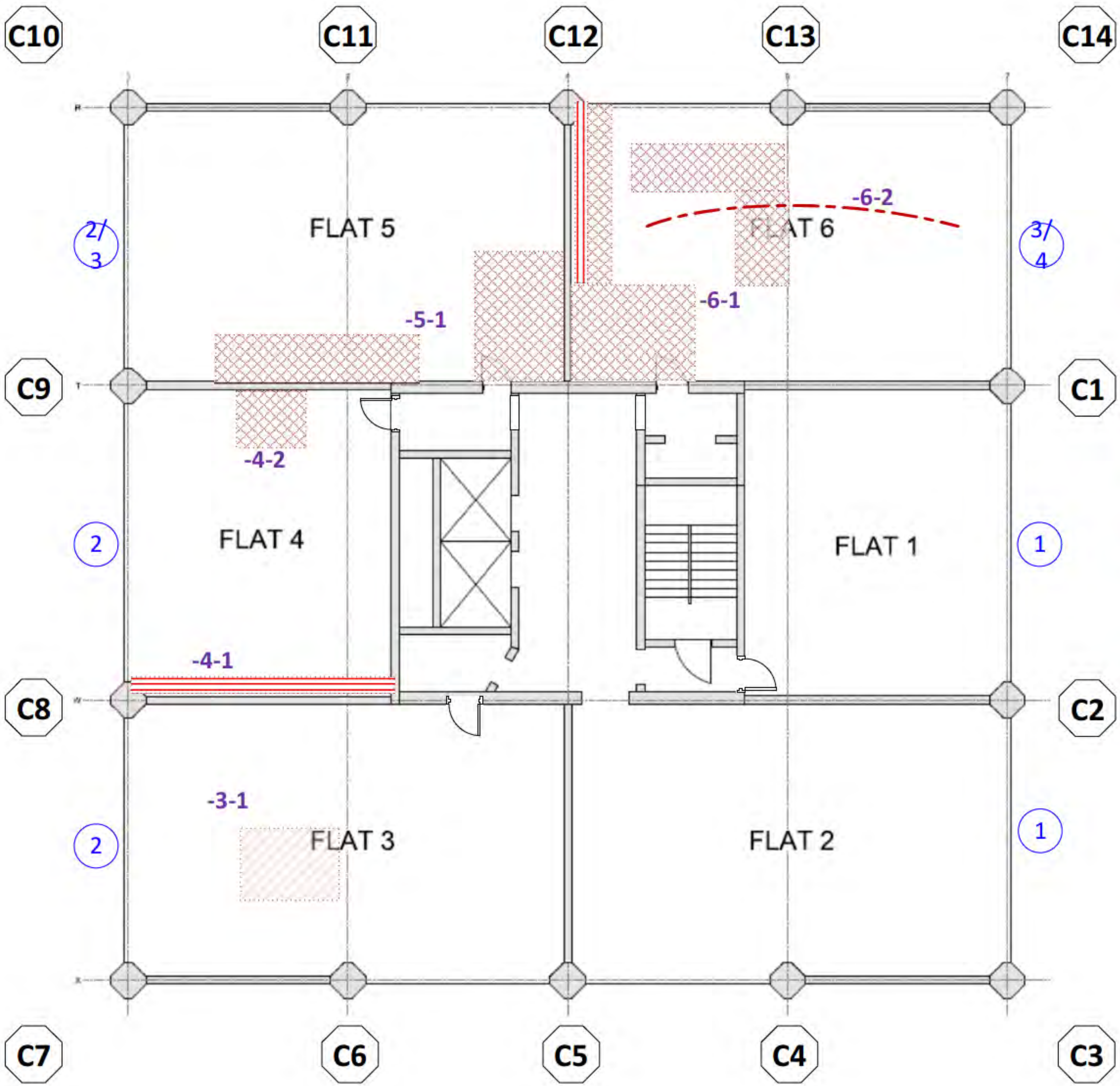
KEY

- Minor damage / patch spalling
- Significant damage
- Major damage
- Bars debonded in the direction of the lines
- Construction joint
- Break and clear step in slab
- 4 — Damage Class from RSK survey
- -3-2 — Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example



C10
C11
C12
C13
C14
Standing on Lvl: 7
Soffit observations and columns supporting slab above.
FLAT 5
FLAT 6
-6-2
-5-1
-6-1
2
3
KEY
Minor damage / patch spalling
Significant damage
Major damage
Bars debonded in the direction of the lines
Construction joint
Break and clear step in slab
Damage Class from RSK survey
Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example
-3-2
4
C9
C1
-4-1
3/4
-4-2
FLAT 4
FLAT 1
1
C8
C2
FLAT 3
FLAT 2
1
1
C7
C6
C5
C4
C3


C10
C11
C12
C13
C14
Standing on Lvl: 8
Soffit observations and columns supporting slab above.
FLAT 5
FLAT 6
-5-2
-5-1
-6-1
-6-2
3/4
3/4
C9
C1
-4-1
-4-2
FLAT 4
FLAT 1
3
1
C8
C2
FLAT 3
FLAT 2
1
1
C7
C6
C5
C4
C3
KEY
Minor damage / patch spalling
Significant damage
Major damage
Bars debonded in the direction of the lines
Construction joint
Break and clear step in slab
4
Damage Class from RSK survey
-3-2
Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example



Standing on Lvl: **9**
Soffit observations and columns supporting slab above.

KEY

Minor damage / patch spalling

Significant damage

Major damage

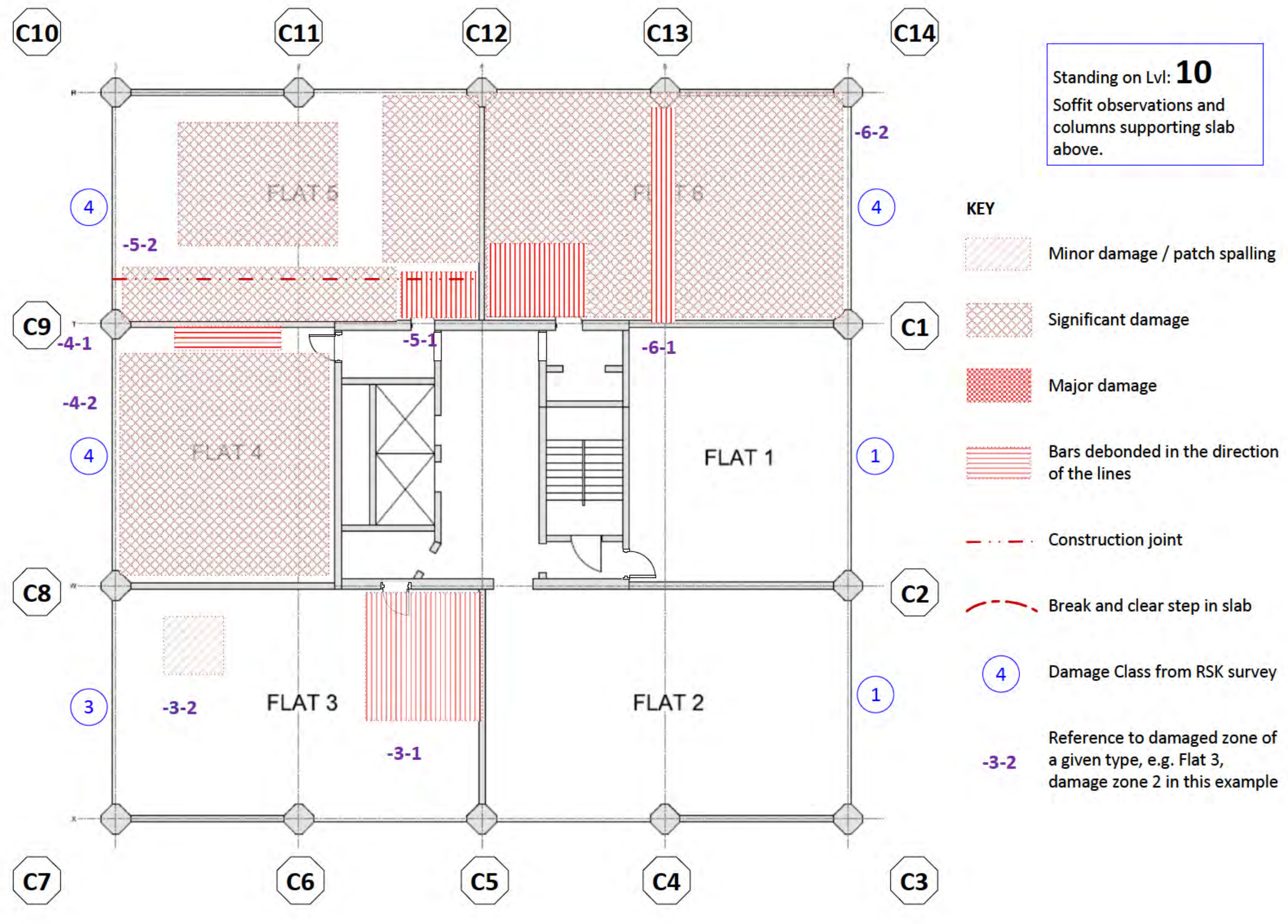
Bars debonded in the direction of the lines

Construction joint

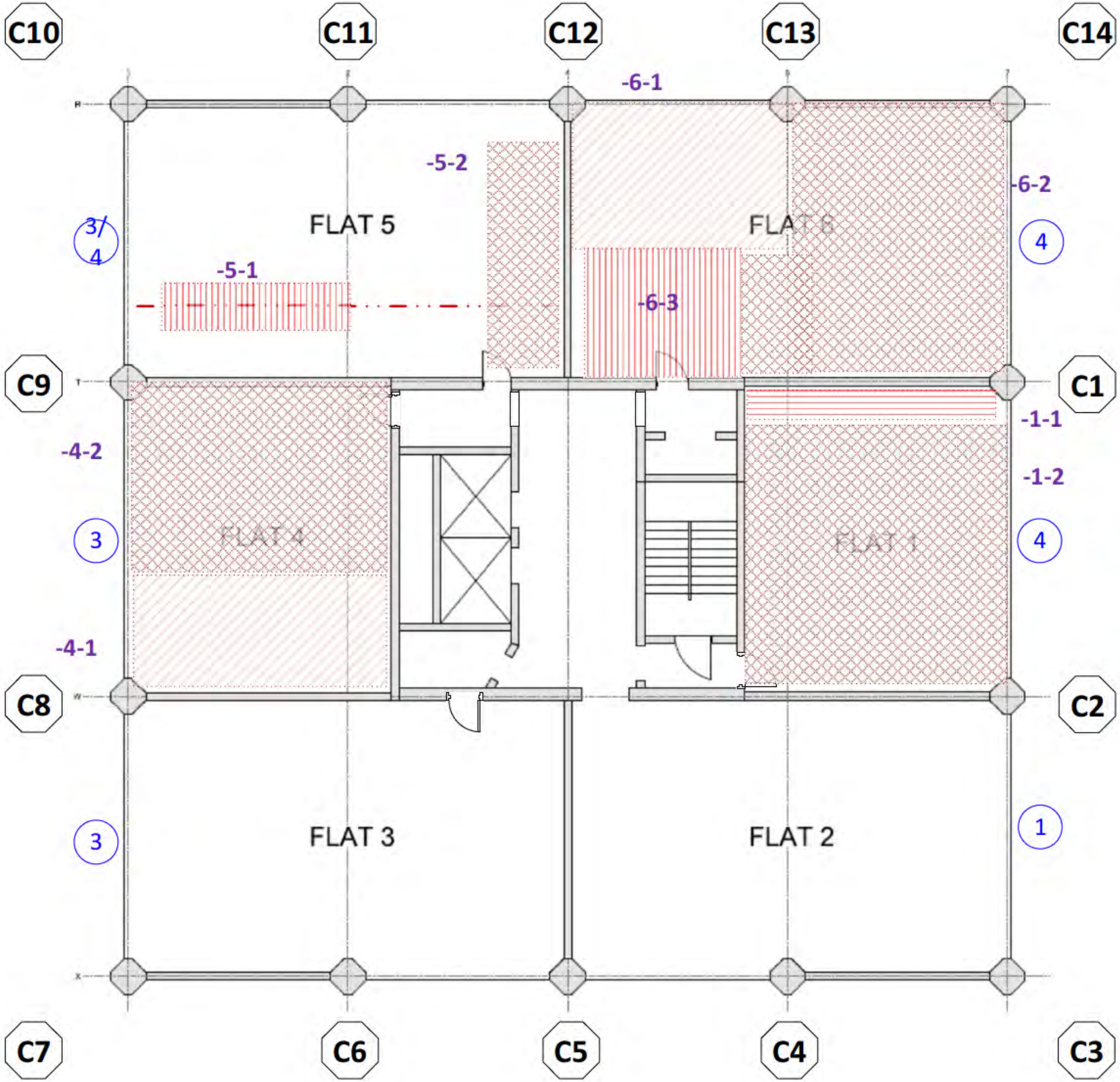
Break and clear step in slab

4 Damage Class from RSK survey

-3-2 Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example



C10
C11
C12
C13
C14
C9
C1
C8
C2
C7
C6
C5
C4
C3
Standing on Lvl: 10
Soffit observations and columns supporting slab above.
FLAT 5
FLAT 6
FLAT 4
FLAT 1
FLAT 3
FLAT 2
-6-2
-5-2
-4-1
-5-1
-6-1
-4-2
-3-2
-3-1
4
4
4
1
3
1
KEY
Minor damage / patch spalling
Significant damage
Major damage
Bars debonded in the direction of the lines
Construction joint
Break and clear step in slab
4
Damage Class from RSK survey
-3-2
Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example



Standing on Lvl: **11**

Soffit observations and columns supporting slab above.

KEY

Minor damage / patch spalling

Significant damage

Major damage

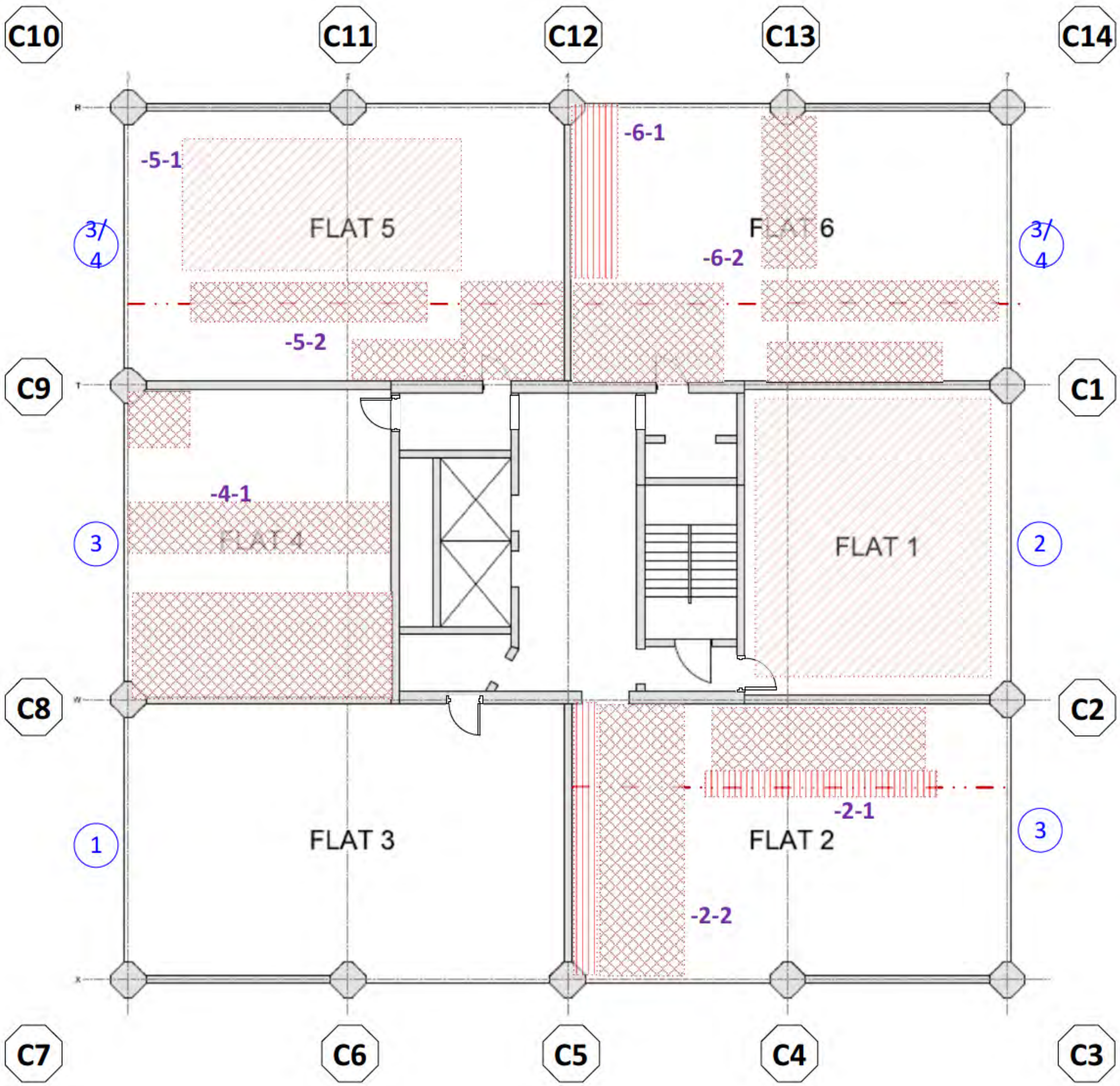
Bars debonded in the direction of the lines

Construction joint

Break and clear step in slab

4 Damage Class from RSK survey

-3-2 Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example



Standing on Lvl: **12**

Soffit observations and columns supporting slab above.

KEY

Minor damage / patch spalling

Significant damage

Major damage

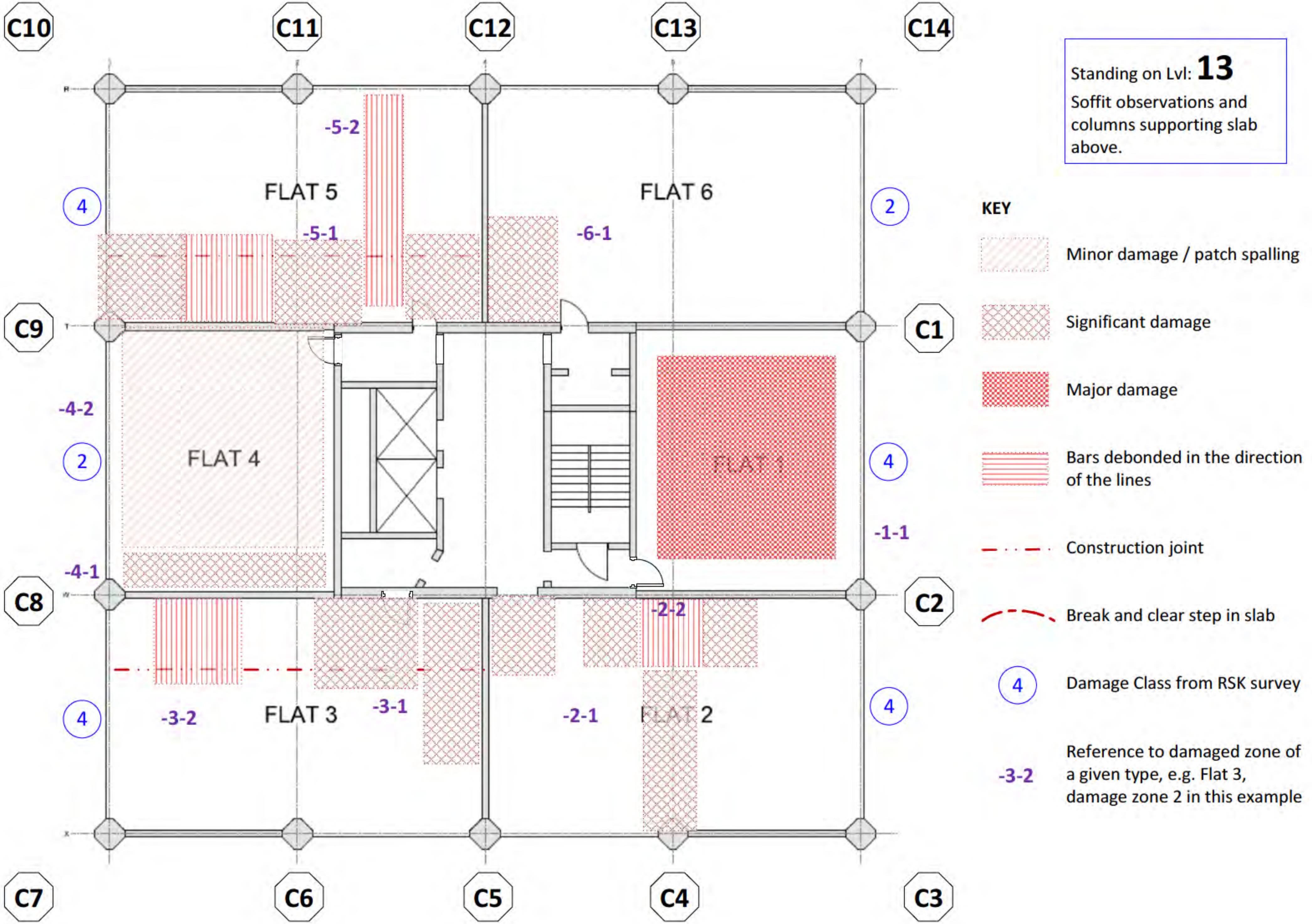
Bars debonded in the direction of the lines

Construction joint

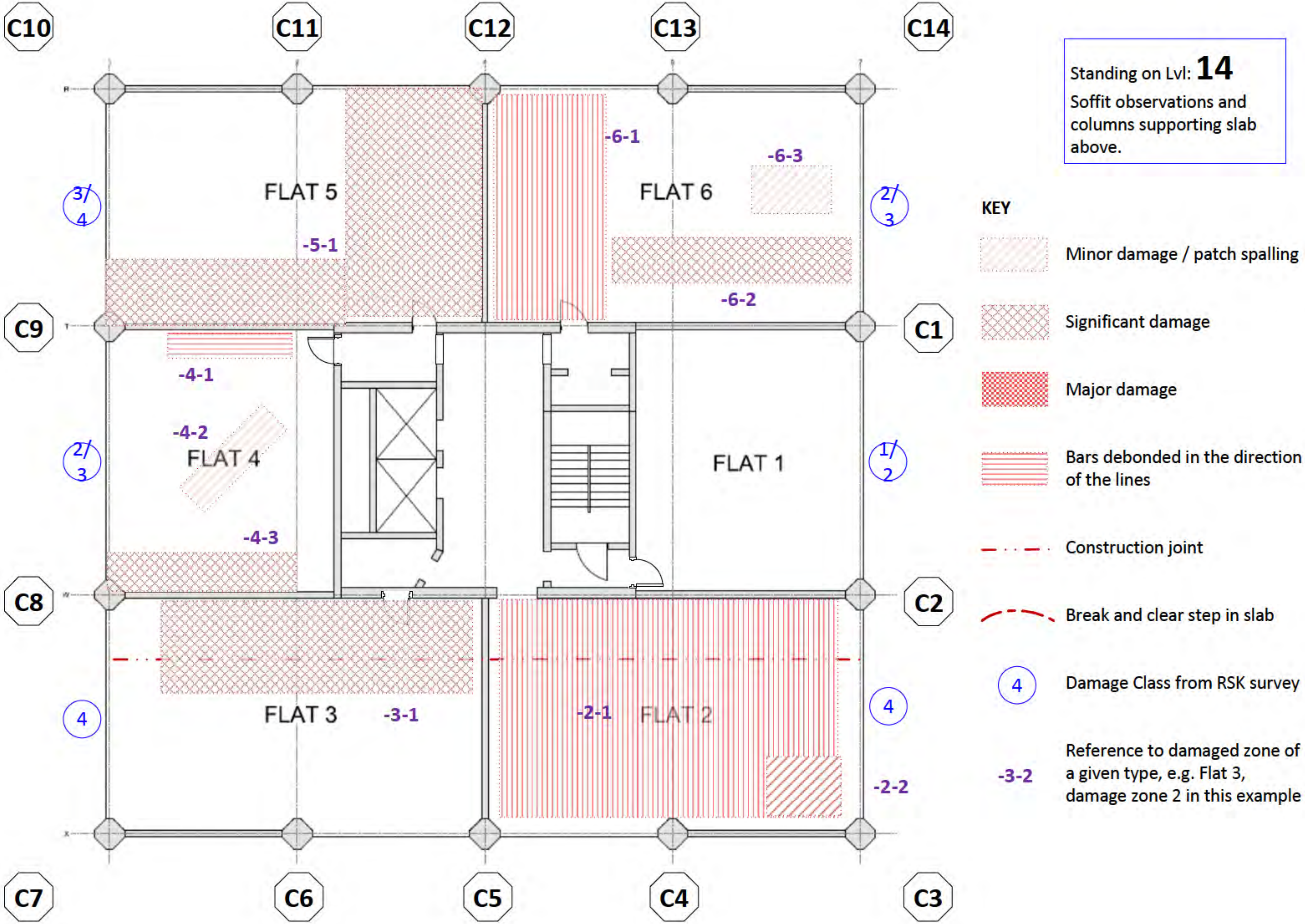
Break and clear step in slab

4 Damage Class from RSK survey

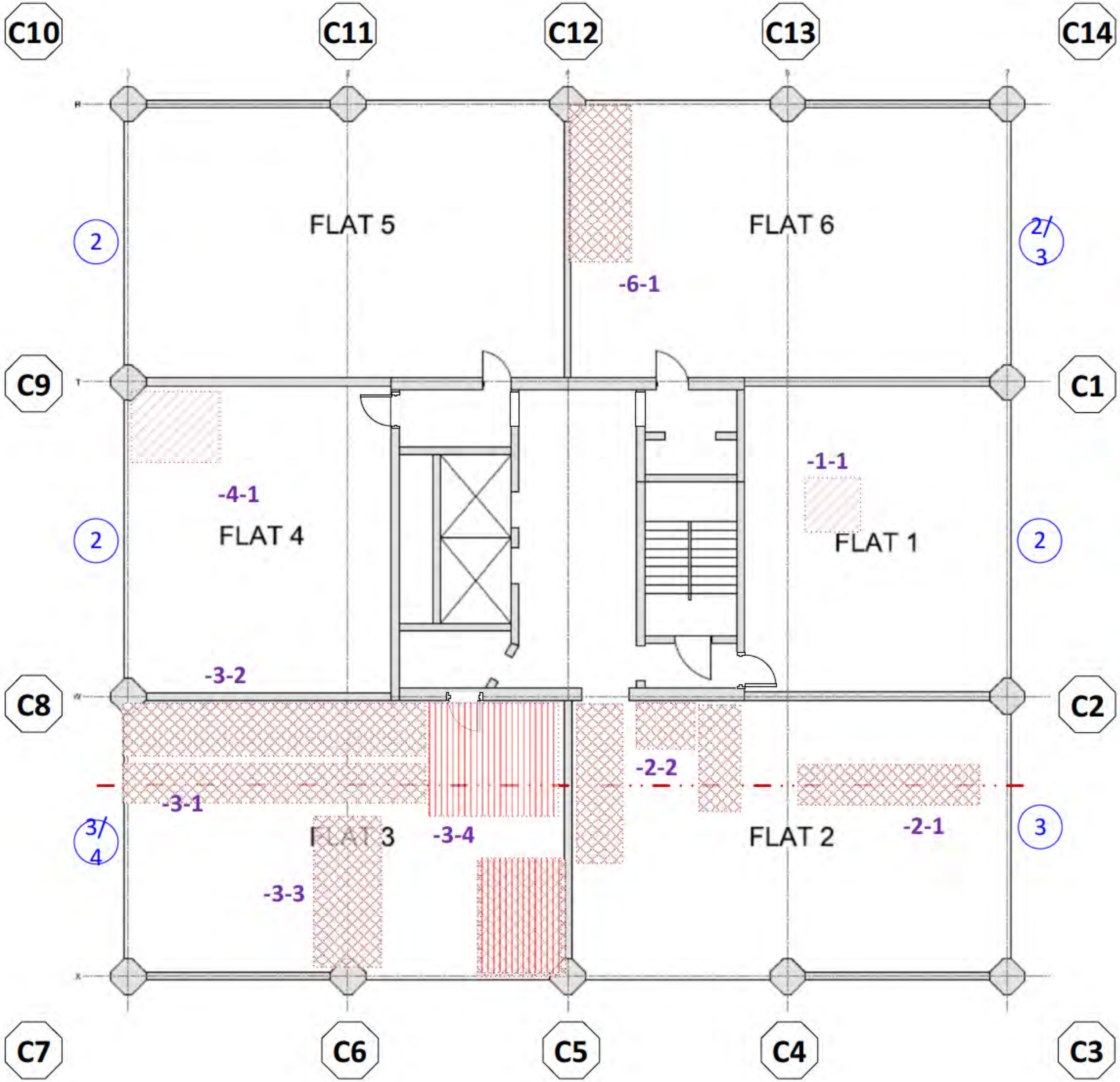
-3-2 Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example



C10
C11
C12
C13
C14
Standing on Lvl: 13
Soffit observations and columns supporting slab above.
FLAT 5
FLAT 6
-5-2
-5-1
-6-1
4
2
KEY
Minor damage / patch spalling
Significant damage
Major damage
Bars debonded in the direction of the lines
Construction joint
Break and clear step in slab
4
Damage Class from RSK survey
-3-2
Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example
C9
C1
-4-2
2
FLAT 4
FLAT 1
4
-1-1
-4-1
C8
C2
-2-2
4
-3-2
FLAT 3
-3-1
-2-1
FLAT 2
4
C7
C6
C5
C4
C3



C10
C11
C12
C13
C14
C9
C1
C8
C2
C7
C6
C5
C4
C3
FLAT 5
FLAT 6
FLAT 4
FLAT 1
FLAT 3
FLAT 2
-5-1
-6-1
-6-2
-6-3
-4-1
-4-2
-4-3
-3-1
-2-1
-2-2
3/4
2/3
2/3
1/2
4
4
Standing on Lvl: 14
Soffit observations and columns supporting slab above.
KEY
Minor damage / patch spalling
Significant damage
Major damage
Bars debonded in the direction of the lines
Construction joint
Break and clear step in slab
4 Damage Class from RSK survey
-3-2 Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example



Standing on Lvl: **15**
Soffit observations and columns supporting slab above.

KEY

Minor damage / patch spalling

Significant damage

Major damage

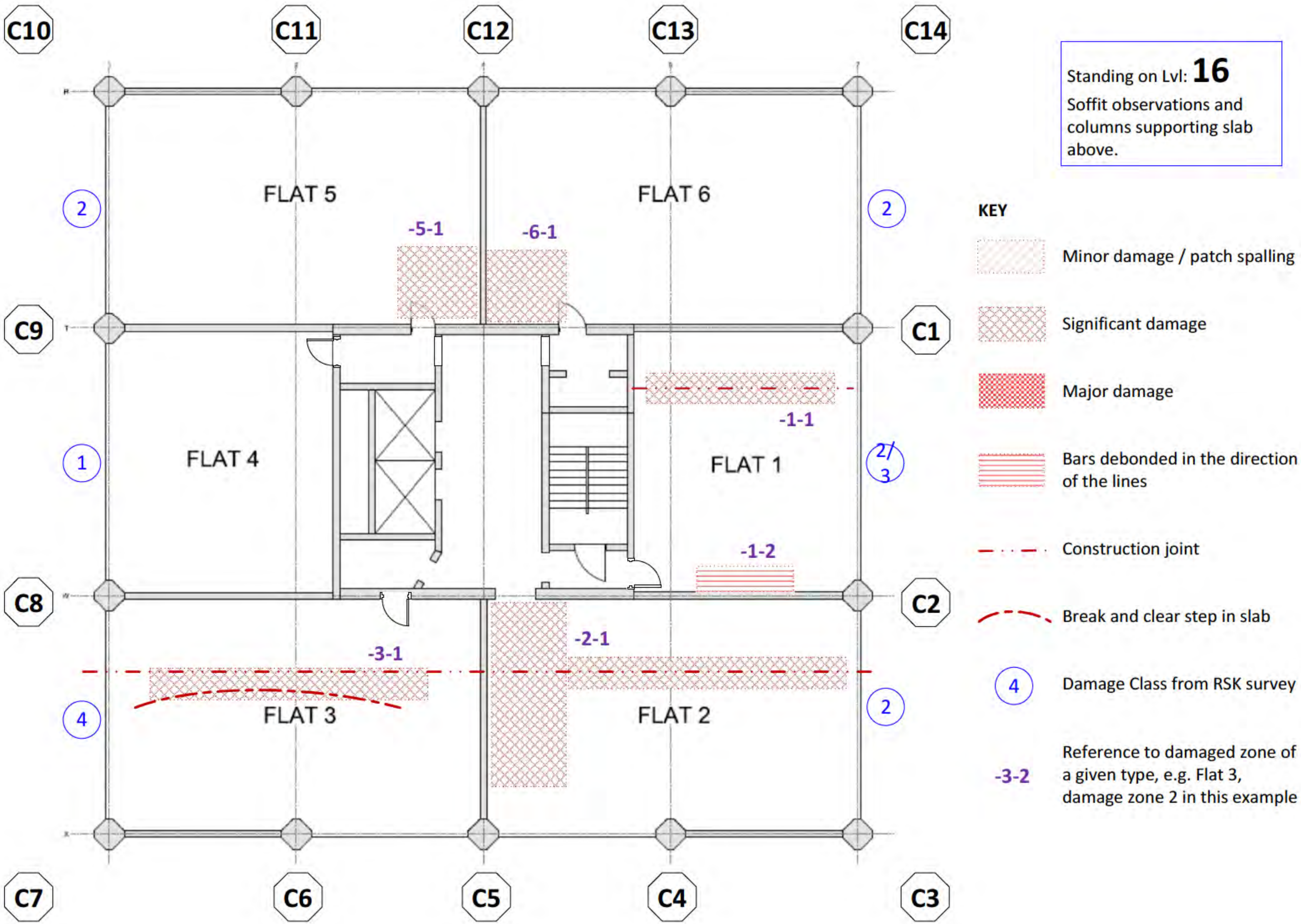
Bars debonded in the direction of the lines

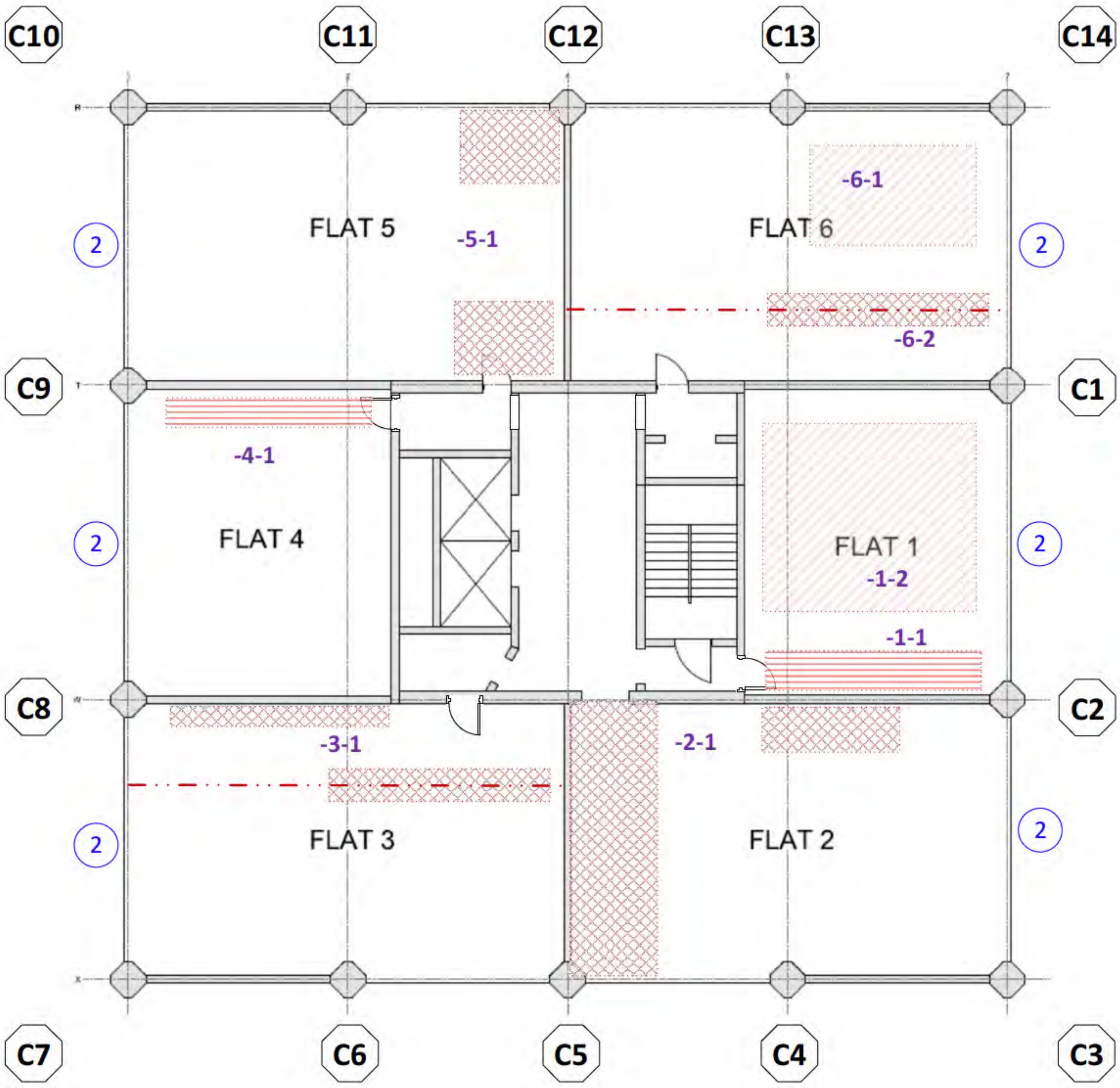
Construction joint

Break and clear step in slab

4 Damage Class from RSK survey

-3-2 Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example

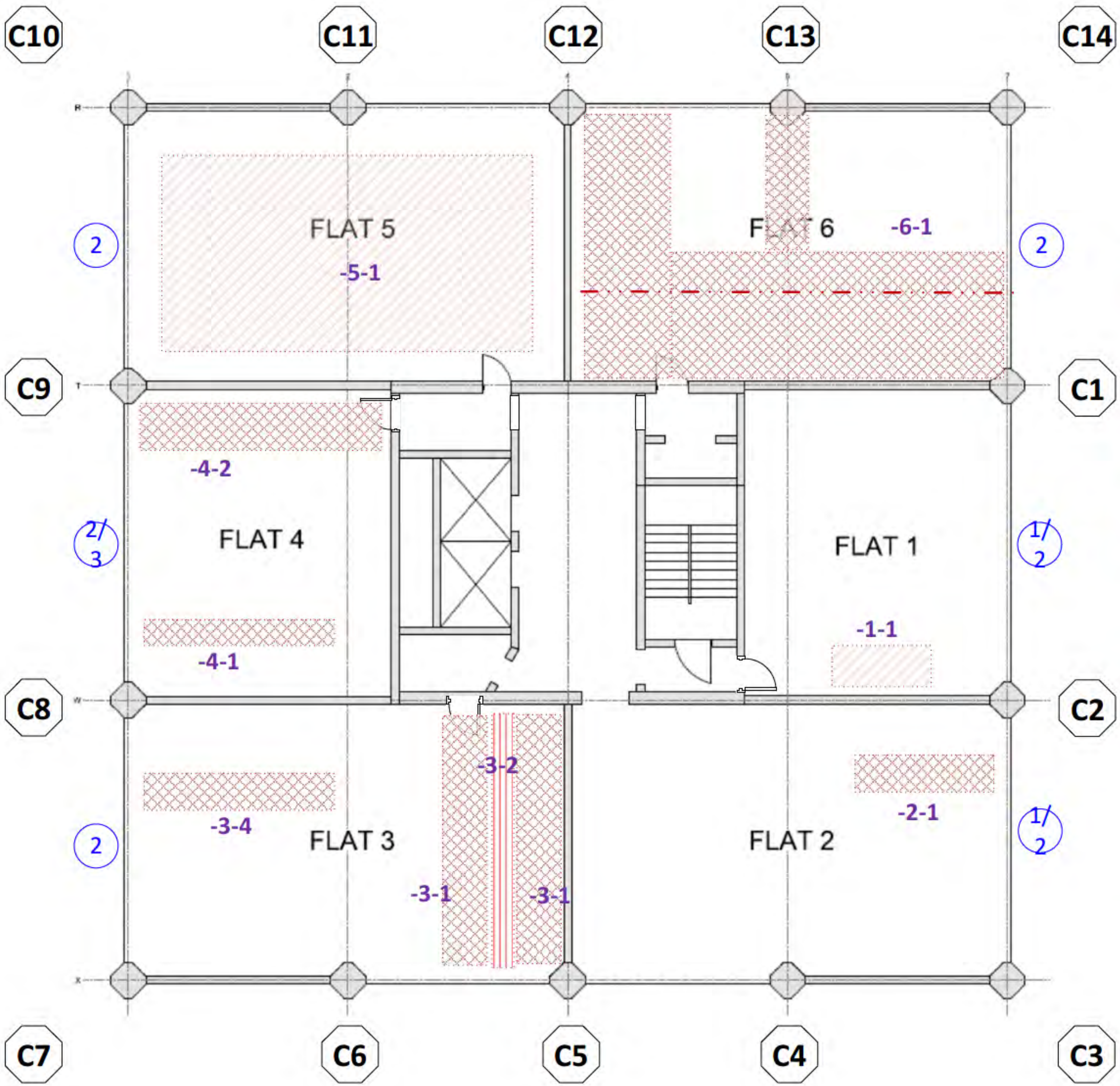

C10
C11
C12
C13
C14
Standing on Lvl: 16
Soffit observations and columns supporting slab above.
FLAT 5
FLAT 6
2
2
-5-1
-6-1
KEY
Minor damage / patch spalling
Significant damage
Major damage
Bars debonded in the direction of the lines
Construction joint
Break and clear step in slab
4 Damage Class from RSK survey
-3-2 Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example
C9
C1
-1-1
FLAT 4
1
FLAT 1
2/3
-1-2
C8
C2
-2-1
-3-1
4
FLAT 3
FLAT 2
2
C7
C6
C5
C4
C3



Standing on Lvl: **17**
Soffit observations and columns supporting slab above.

KEY

- Minor damage / patch spalling
- Significant damage
- Major damage
- Bars debonded in the direction of the lines
- Construction joint
- Break and clear step in slab
- 4 Damage Class from RSK survey
- -3-2 Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example



Standing on Lvl: **18**

Soffit observations and columns supporting slab above.

KEY

Minor damage / patch spalling

Significant damage

Major damage

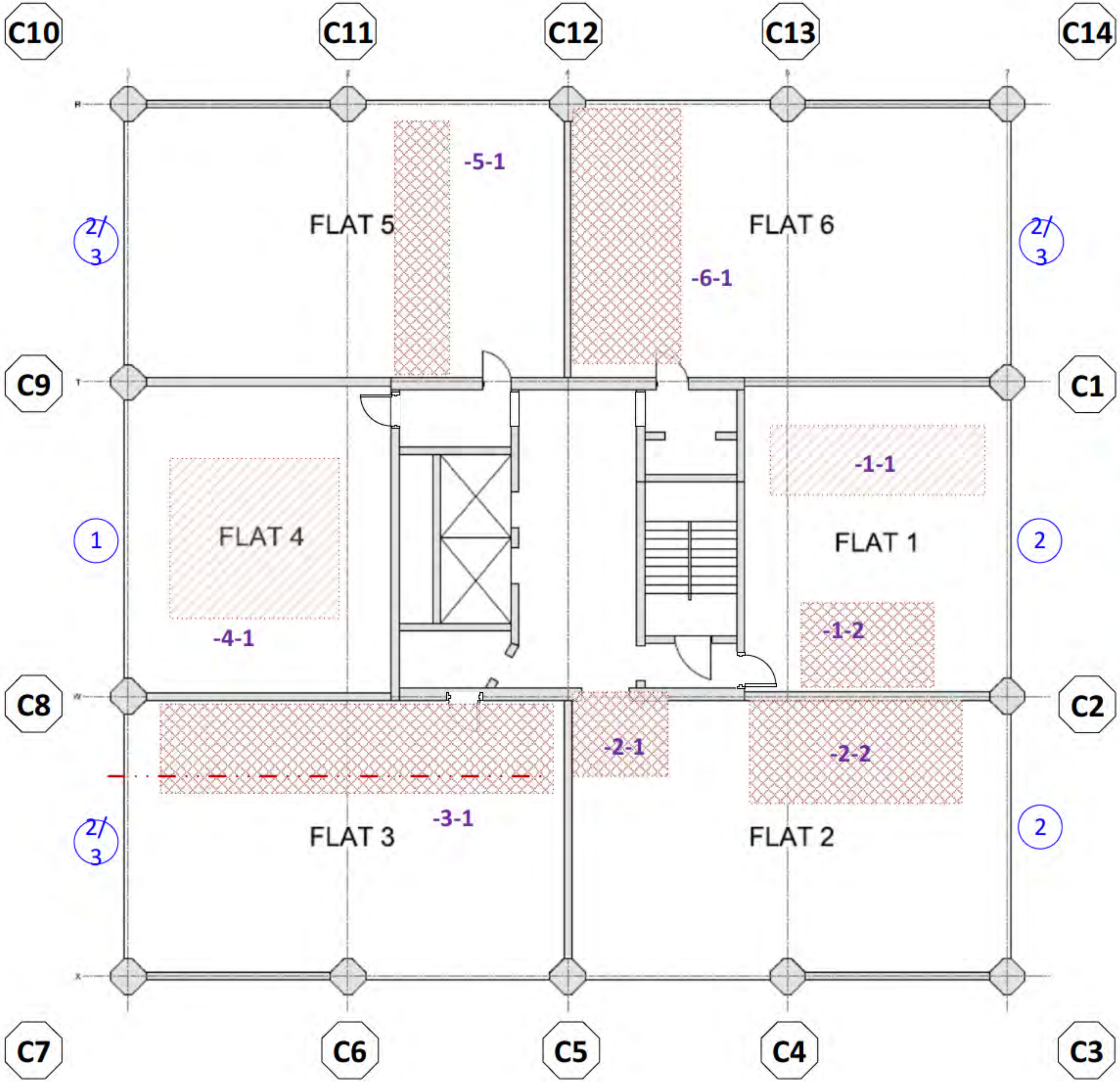
Bars debonded in the direction of the lines

Construction joint

Break and clear step in slab

4 Damage Class from RSK survey

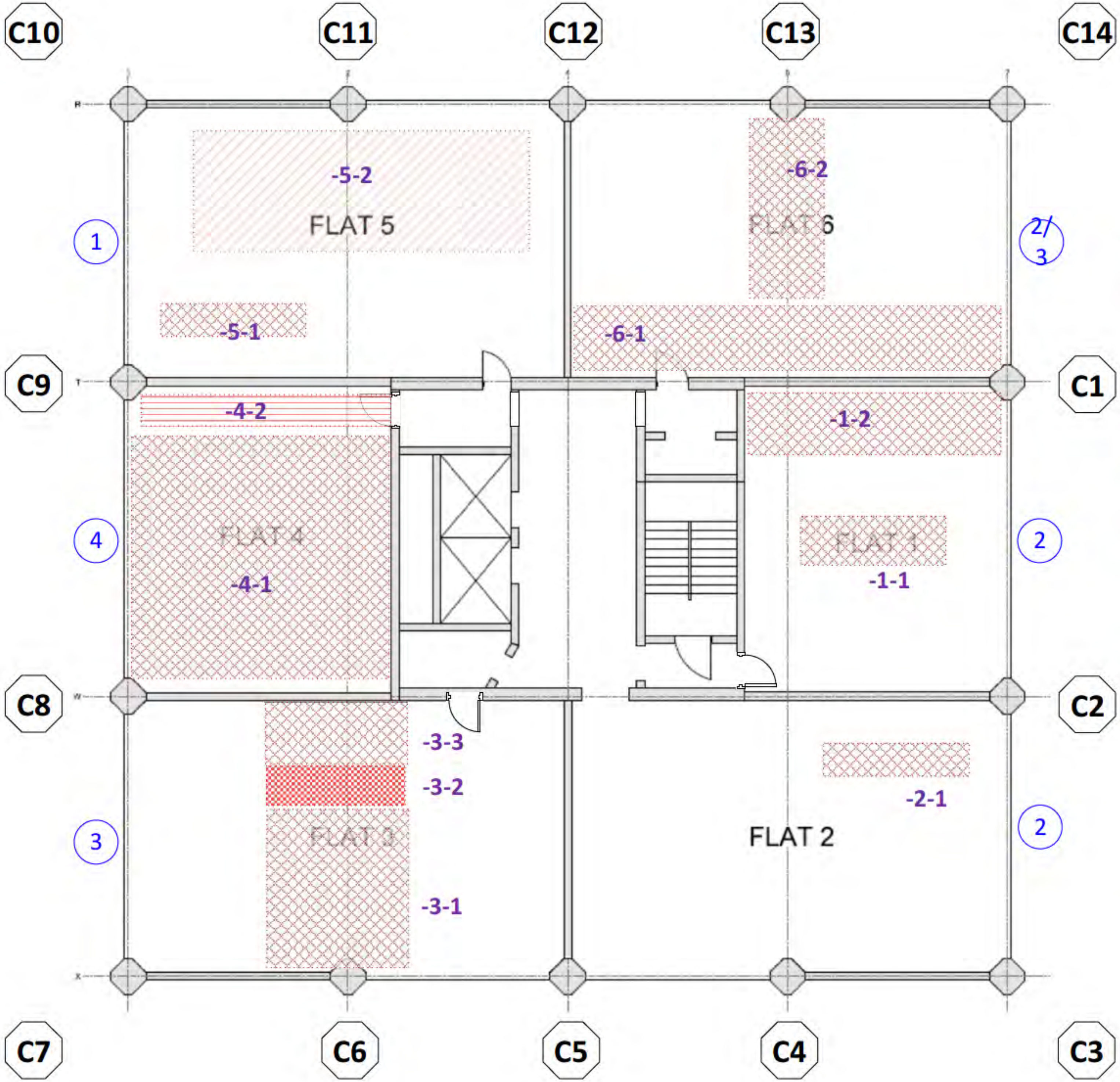
-3-2 Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example



Standing on Lvl: **19**
Soffit observations and columns supporting slab above.

KEY

- Minor damage / patch spalling
- Significant damage
- Major damage
- Bars debonded in the direction of the lines
- Construction joint
- Break and clear step in slab
- 4 — Damage Class from RSK survey
- -3-2 — Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example



Standing on Lvl: **20**

Soffit observations and columns supporting slab above.

KEY

Minor damage / patch spalling

Significant damage

Major damage

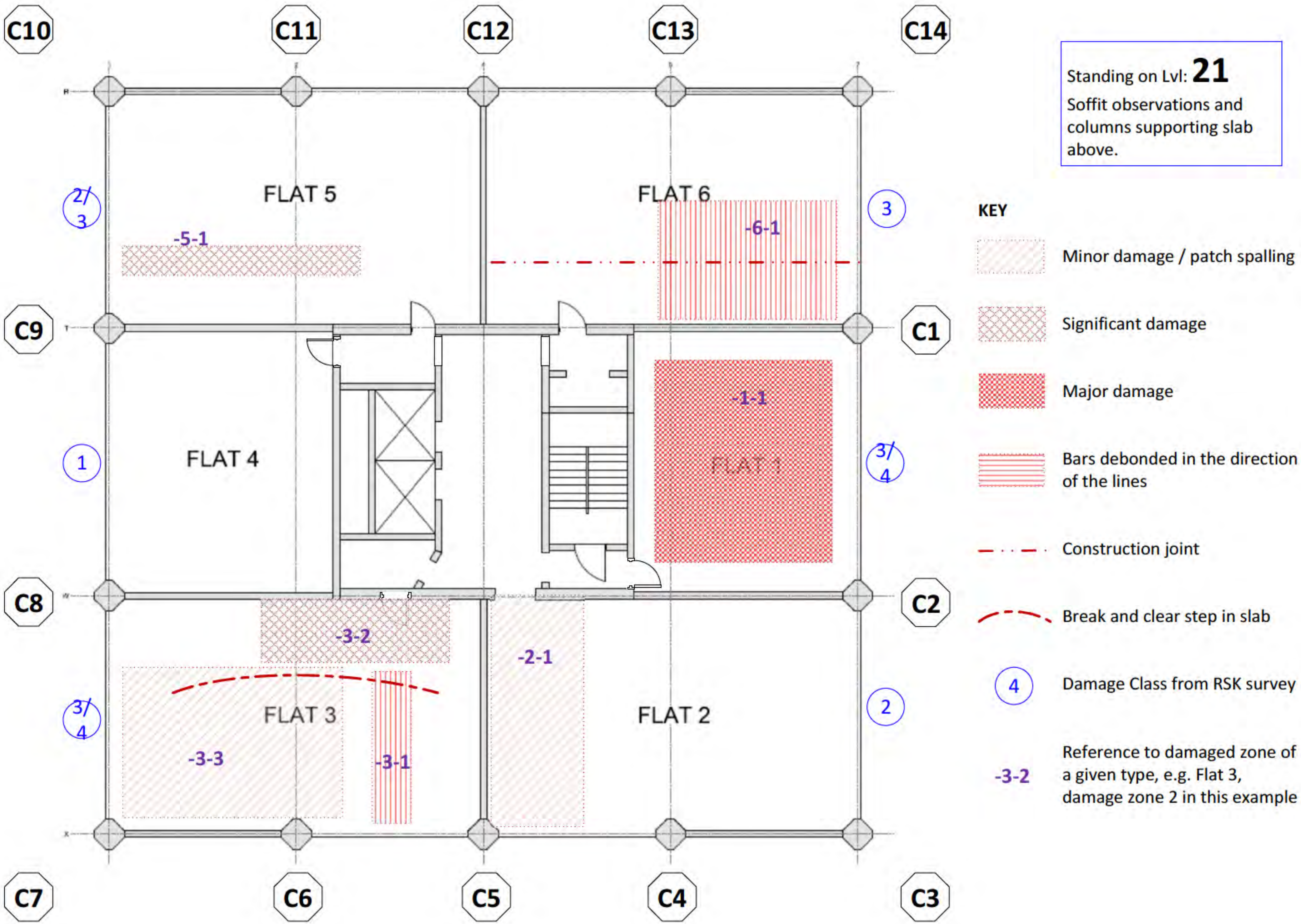
Bars debonded in the direction of the lines

Construction joint

Break and clear step in slab

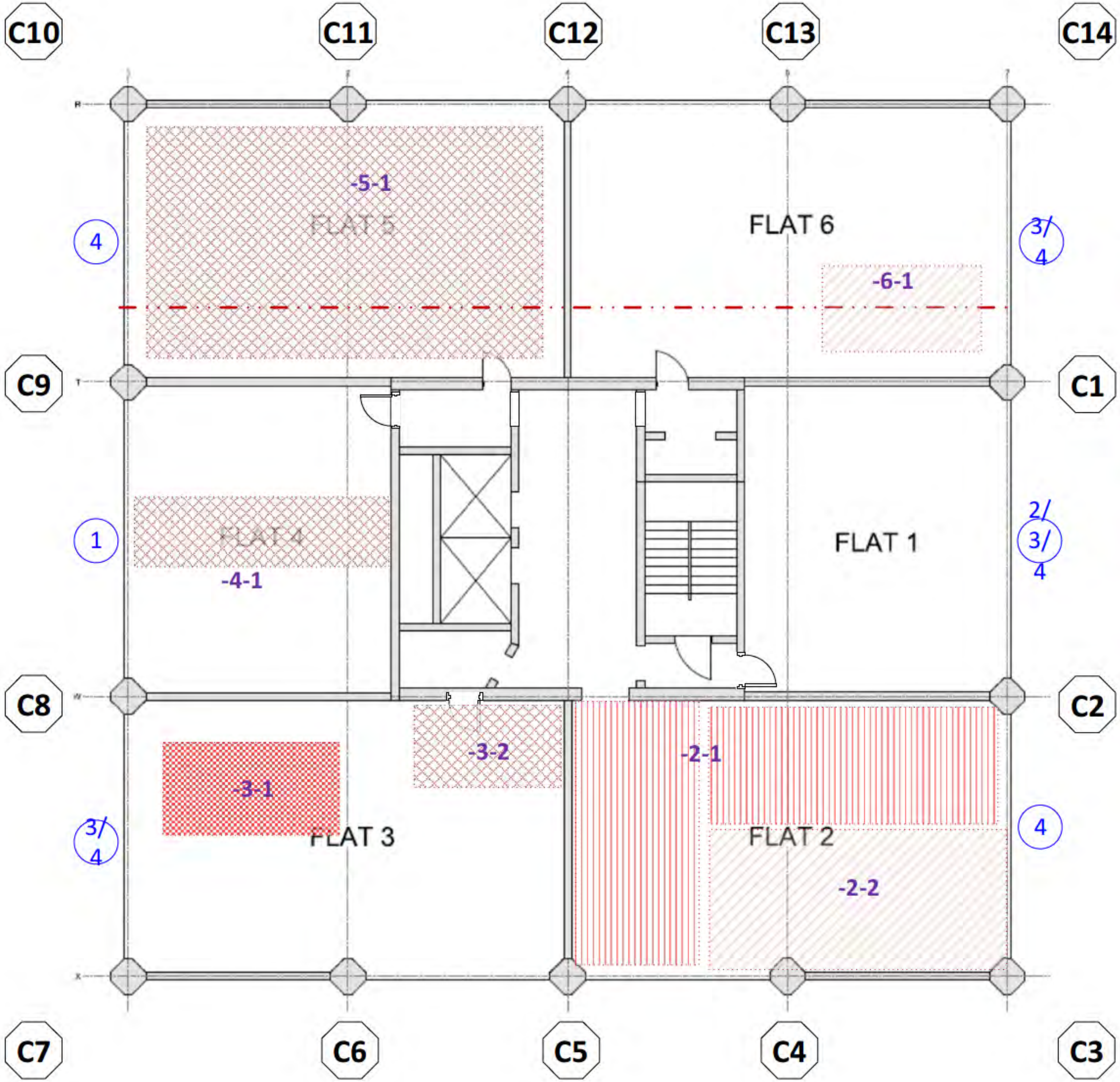
4 Damage Class from RSK survey

-3-2 Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example


C10
C11
C12
C13
C14
Standing on Lvl: 21
Soffit observations and columns supporting slab above.
FLAT 5
FLAT 6
2/3
-5-1
-6-1
3
KEY
Minor damage / patch spalling
Significant damage
Major damage
Bars debonded in the direction of the lines
Construction joint
Break and clear step in slab
Damage Class from RSK survey
Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example
4
-3-2
C9
C1
-1-1
FLAT 4
FLAT 1
1
3/4
C8
C2
-3-2
-2-1
3/4
FLAT 3
FLAT 2
2
-3-3
-3-1
C7
C6
C5
C4
C3

Standing on Lvl: **22**

Soffit observations and columns supporting slab above.



KEY

Minor damage / patch spalling

Significant damage

Major damage

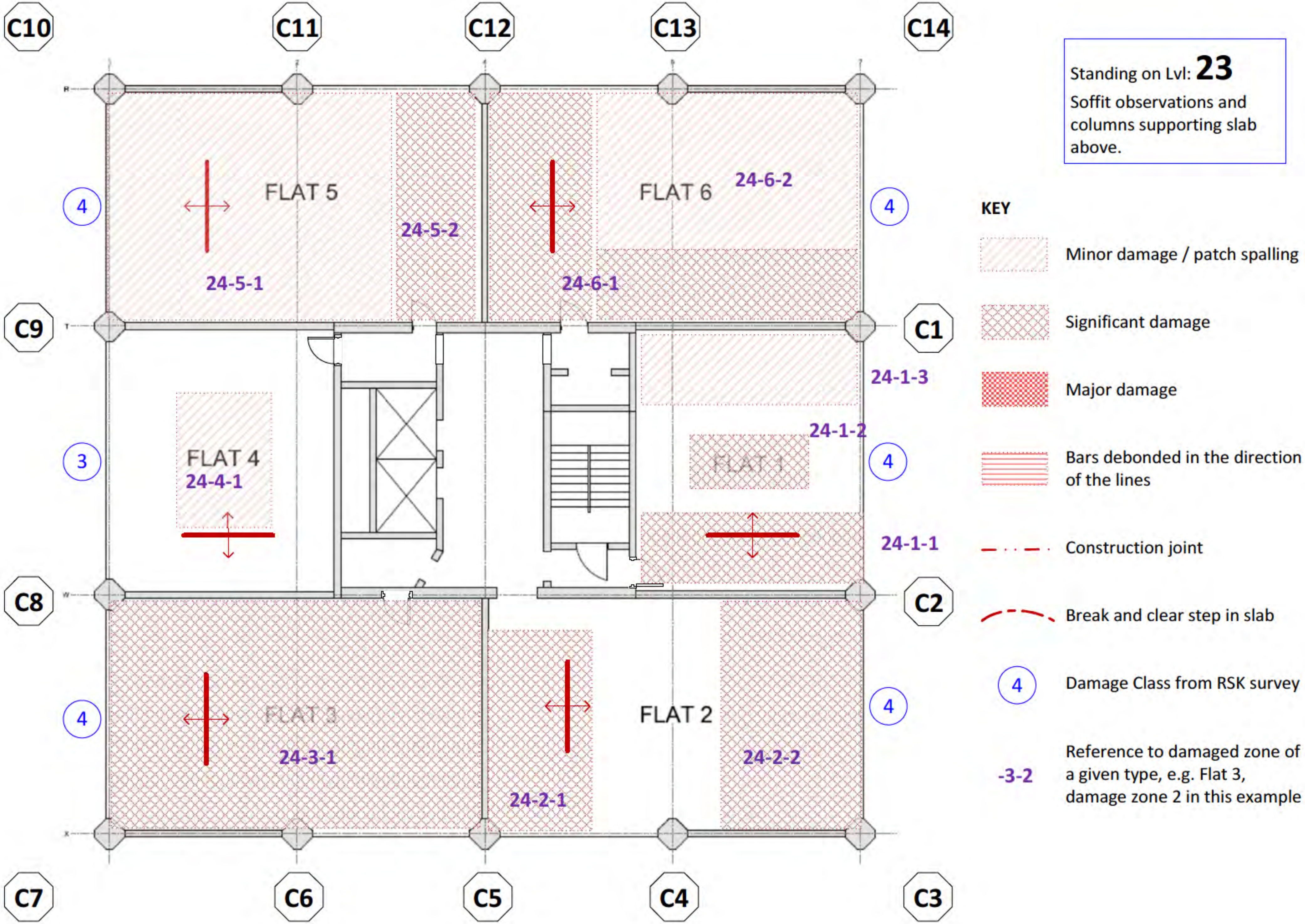
Bars debonded in the direction of the lines

Construction joint

Break and clear step in slab

4 Damage Class from RSK survey

-3-2 Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example


Standing on Lvl: 23
Soffit observations and columns supporting slab above.
C10
C11
C12
C13
C14
C9
C1
C8
C2
C7
C6
C5
C4
C3
FLAT 5
24-5-1
24-5-2
FLAT 6
24-6-1
24-6-2
FLAT 4
24-4-1
FLAT 1
24-1-1
24-1-2
24-1-3
FLAT 3
24-3-1
FLAT 2
24-2-1
24-2-2
4
4
3
4
4
4
KEY
Minor damage / patch spalling
Significant damage
Major damage
Bars debonded in the direction of the lines
Construction joint
Break and clear step in slab
4
Damage Class from RSK survey
-3-2
Reference to damaged zone of a given type, e.g. Flat 3, damage zone 2 in this example

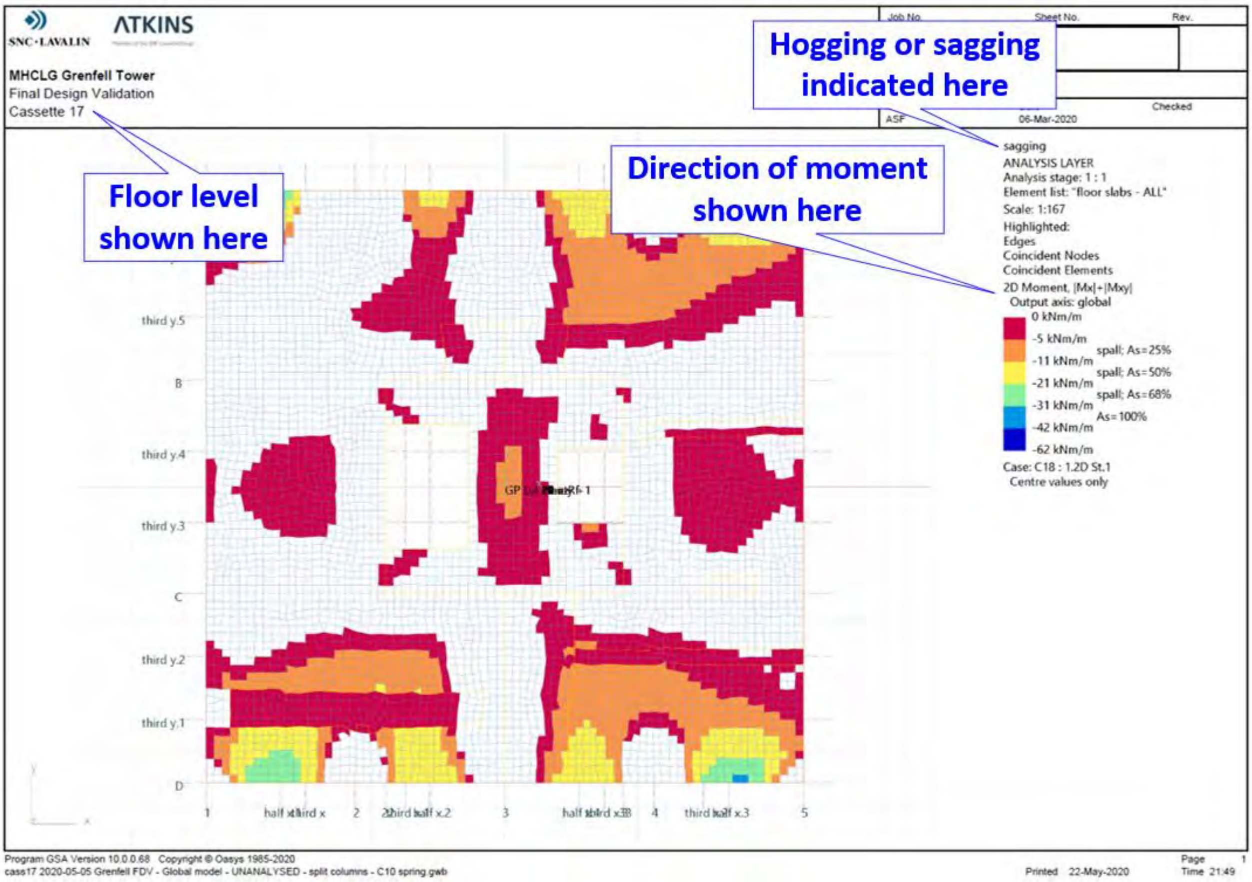
Appendix B. Structural analysis output

B.1. Introduction

The diagrams in this Appendix are the bending moment and through thickness shear outputs for the slabs that have been used in arriving at the assessment of a given floors resistance as documented in Appendix C.

The example below indicates where the key pieces of information are on the plot with respect to identifying what it shows.

With respect to terminology, hogging relates to an area of the slab where the top face is in tension, whilst sagging relates to an area of the slab where the bottom face is in tension. For ease of interpretation, plots show either sagging or hogging but not both. With respect to sign convention, a moment M_n is defined as being in the n-direction



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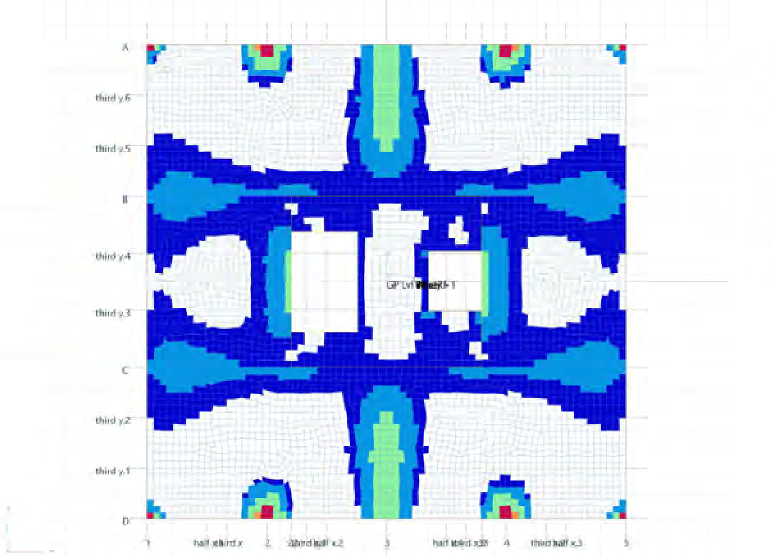

hogging
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Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
63 kNm/m
42 kNm/m — As=100%; no spall
36 kNm/m — As=100%; T1; spall
32 kNm/m — As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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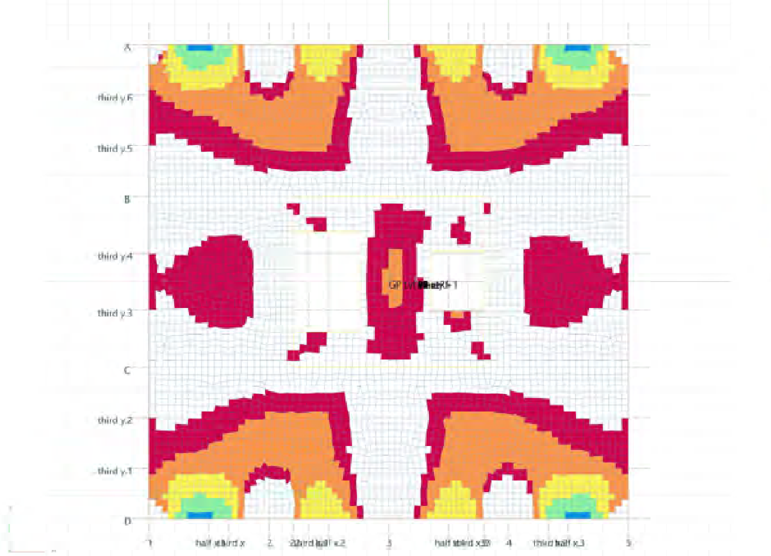

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Highlighted:
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Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m — spall; As=25%
-11 kNm/m — spall; As=50%
-21 kNm/m — spall; As=68%
-31 kNm/m — As=100%
-42 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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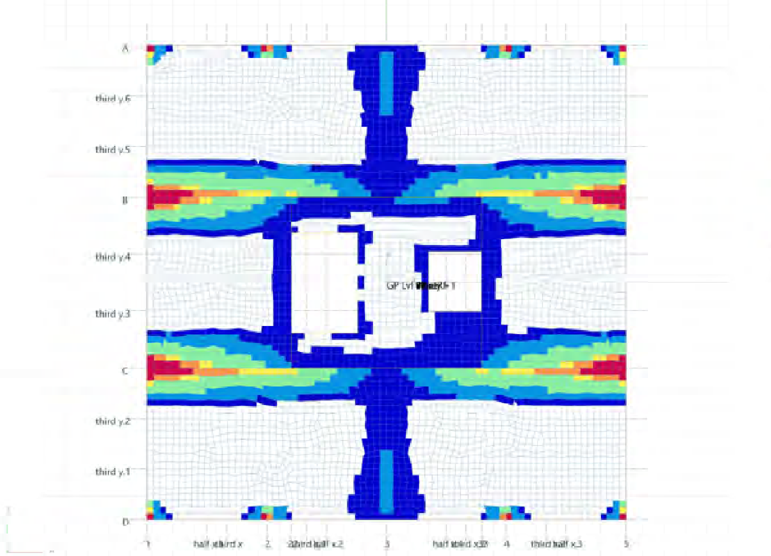

hogging
ANALYSIS LAYER
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Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
56 kNm/m
42 kNm/m — As=100%; no spall
36 kNm/m — As=100%; T1; spall
32 kNm/m — As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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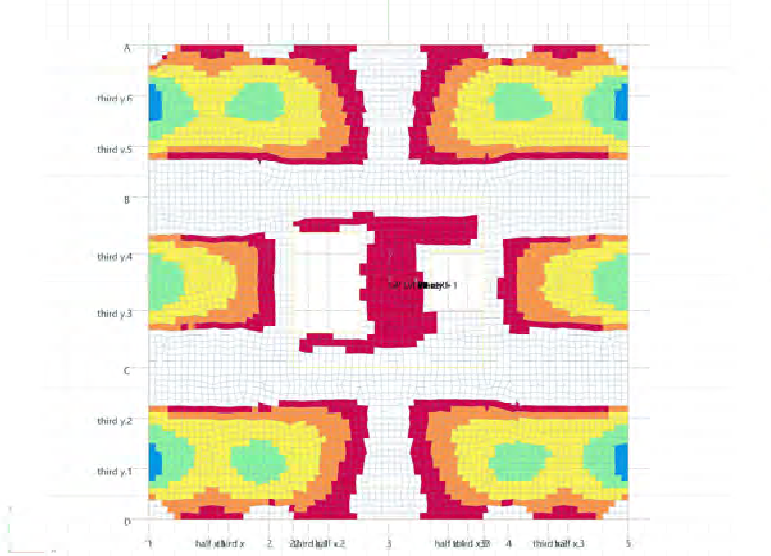

sagging
ANALYSIS LAYER
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Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0 kNm/m
-5 kNm/m — spall; As=25%
-11 kNm/m — spall; As=50%
-21 kNm/m — spall; As=68%
-31 kNm/m — As=100%
-42 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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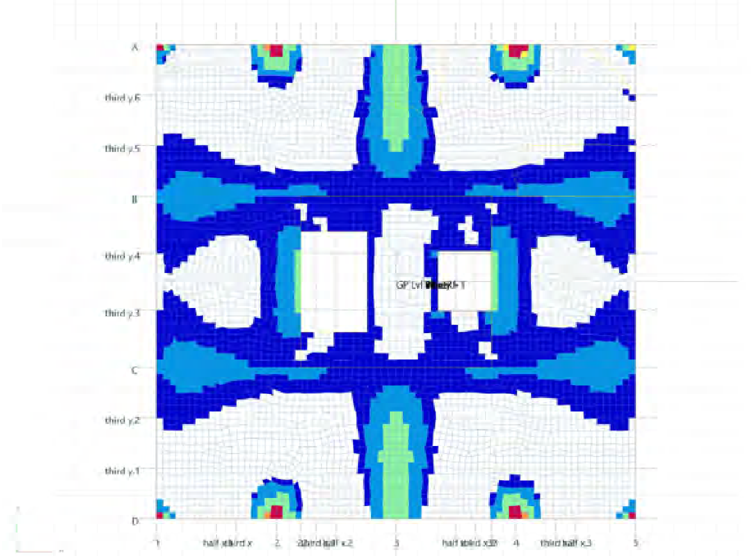

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Coincident Elements
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36 kNm/m As=100%; T1; spall
32 kNm/m As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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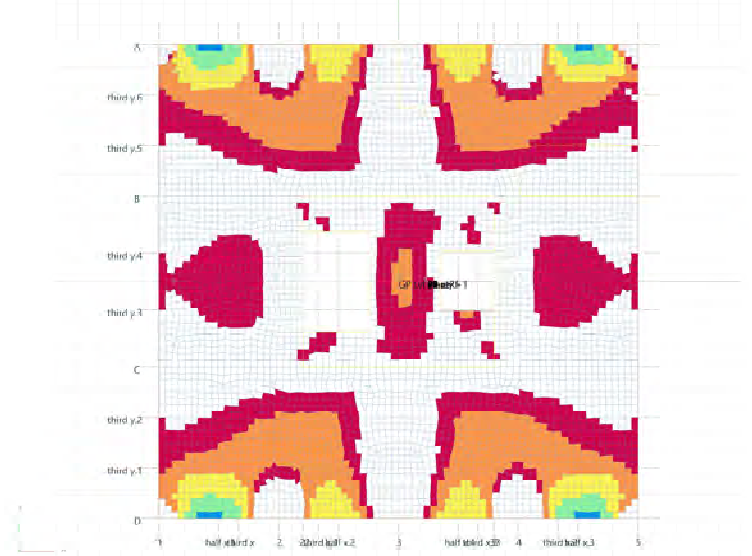

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Edges
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Output axis: global
0 kNm/m
-5 kNm/m
spall; As=25%
-11 kNm/m
spall; As=50%
-21 kNm/m
spall; As=68%
-31 kNm/m
As=100%
-42 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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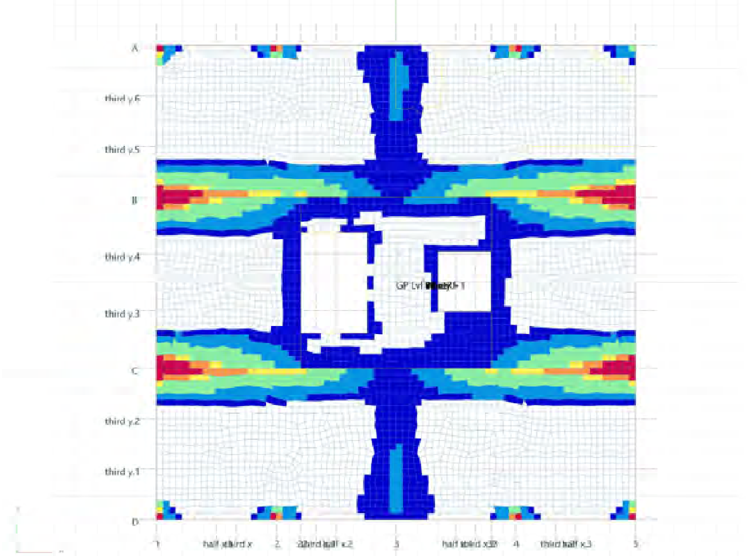

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Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
59 kNm/m
42 kNm/m As=100%; no spall
36 kNm/m As=100%; T1; spall
32 kNm/m As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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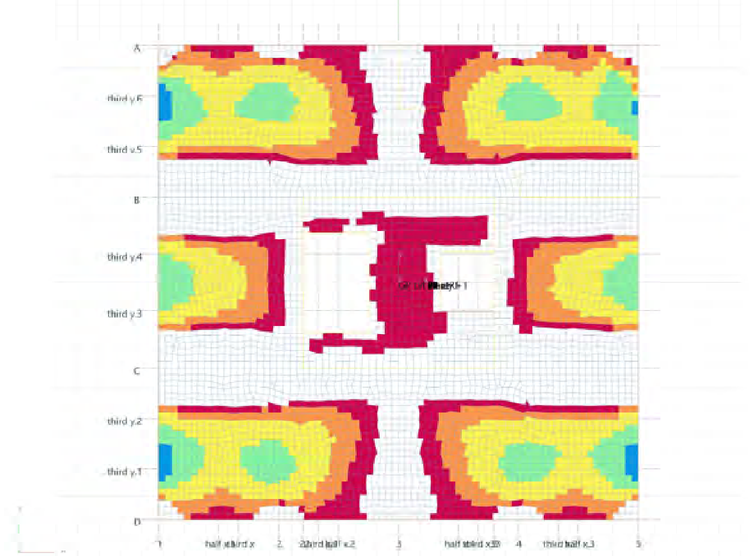

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2D Moment, |My|+|Myx|
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spall; As=25%
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spall; As=50%
-21 kNm/m
spall; As=68%
-31 kNm/m
As=100%
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Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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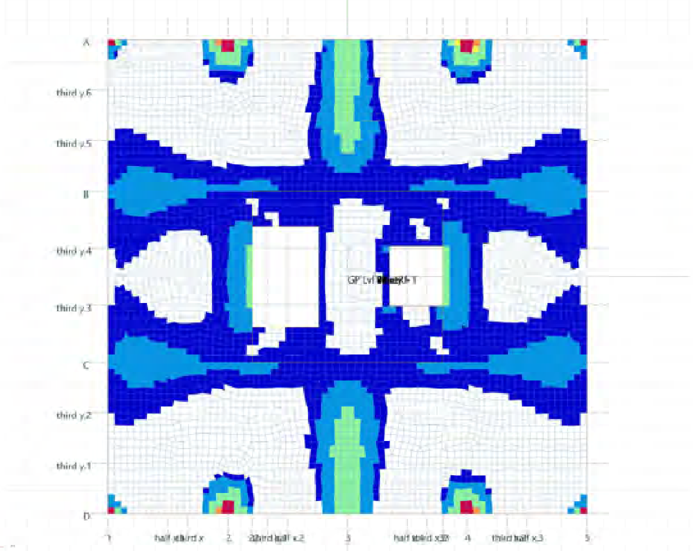

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Coincident Elements
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15 kNm/m
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Centre values only
(Results stage and display stage differ.)

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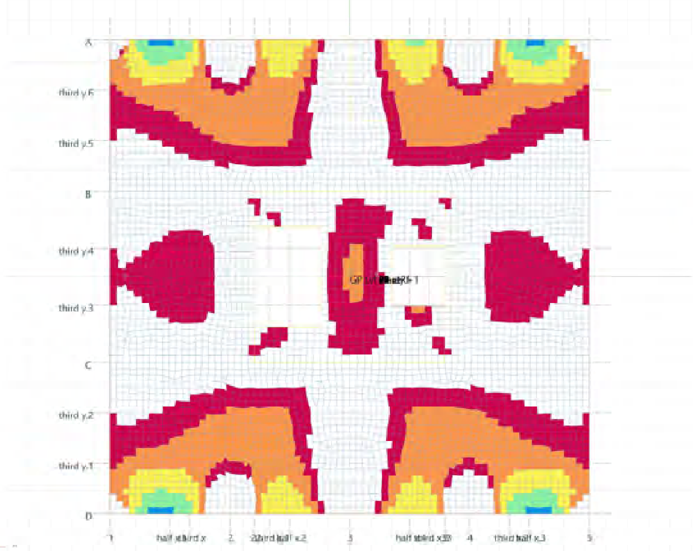

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-42 kNm/m
Case: C18 : 1.2D St.1
Centre values only
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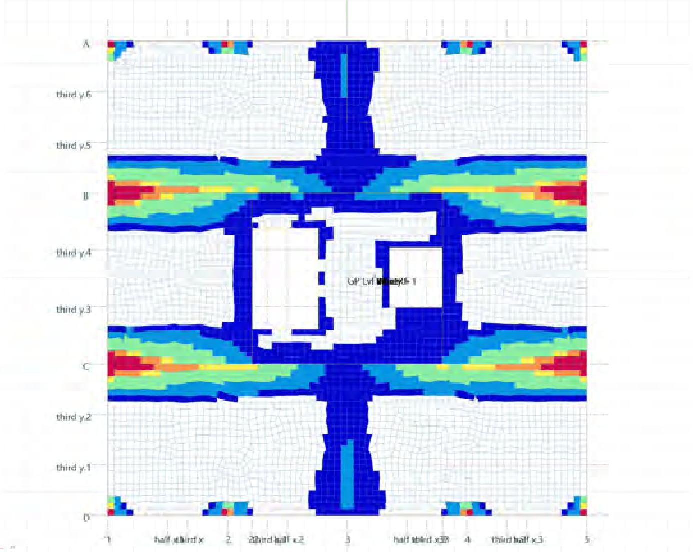

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Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
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42 kNm/m — As=100%; no spall
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32 kNm/m — As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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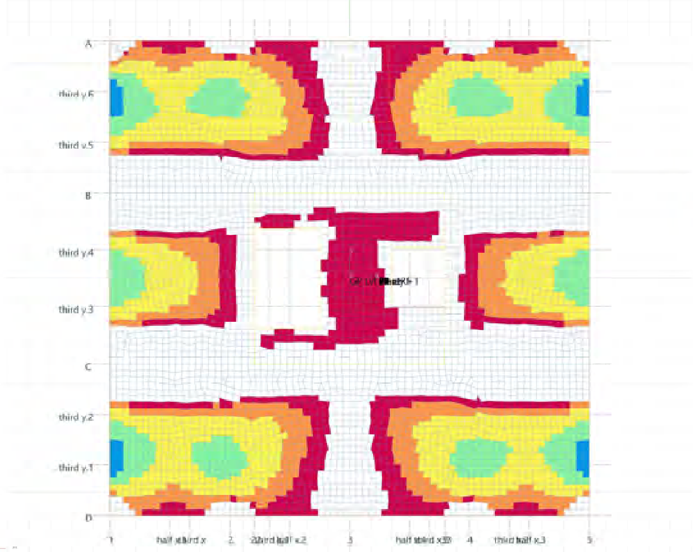

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-21 kNm/m — spall; As=68%
-31 kNm/m — As=100%
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Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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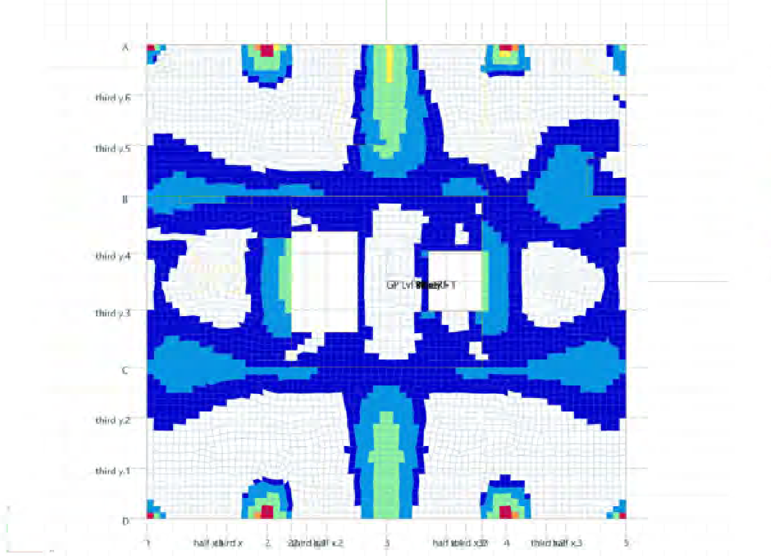

hogging
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Highlighted:
Edges
Coincident Nodes
Coincident Elements
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Output axis: global
64 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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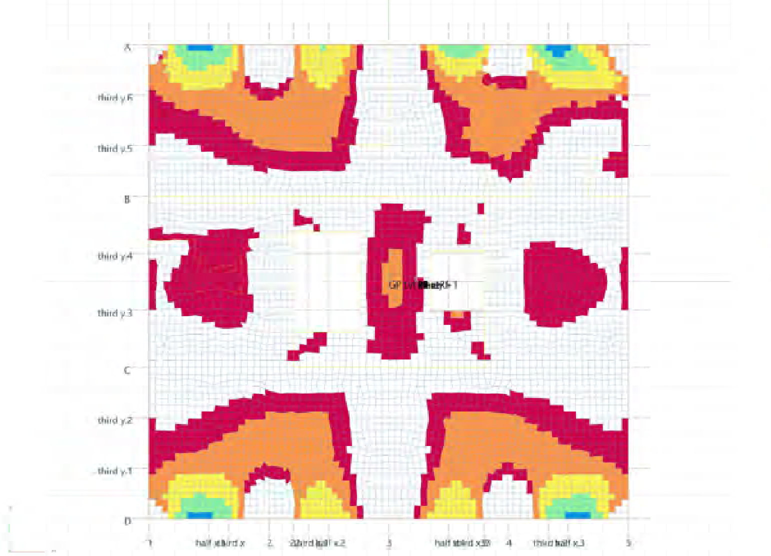

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Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
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-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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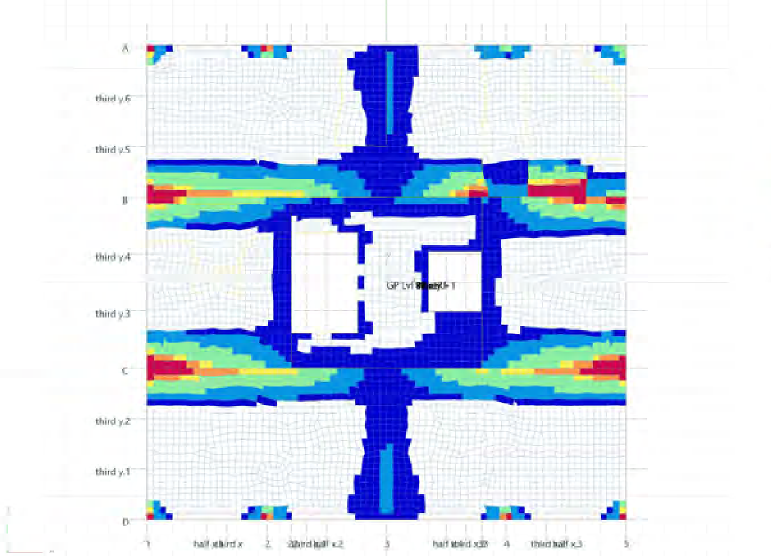

hogging
ANALYSIS LAYER
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Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
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42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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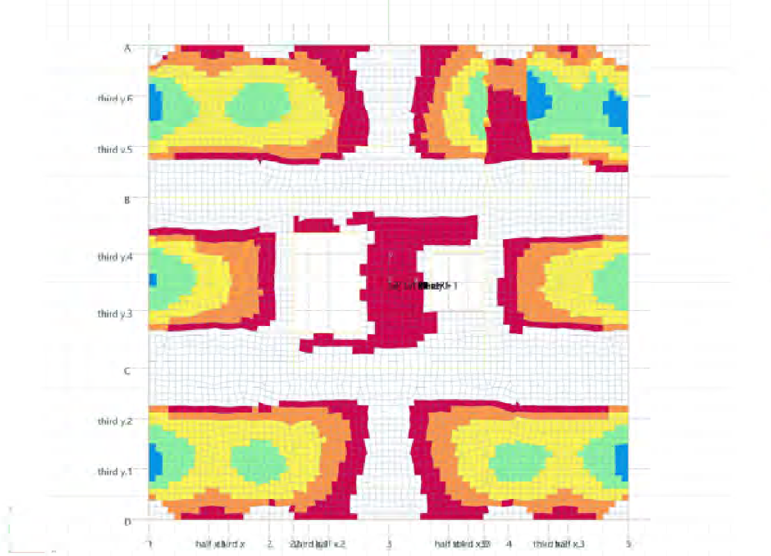

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Edges
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Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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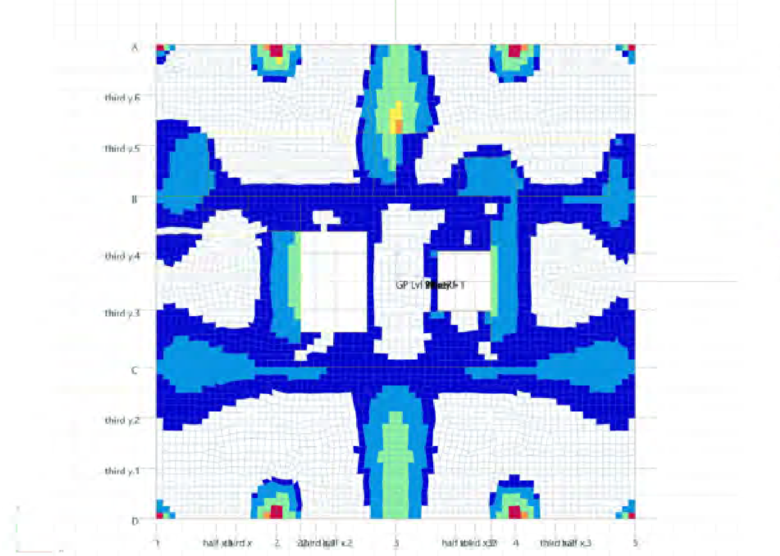

hogging
ANALYSIS LAYER
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Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
66 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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ASF	06-Mar-2020	

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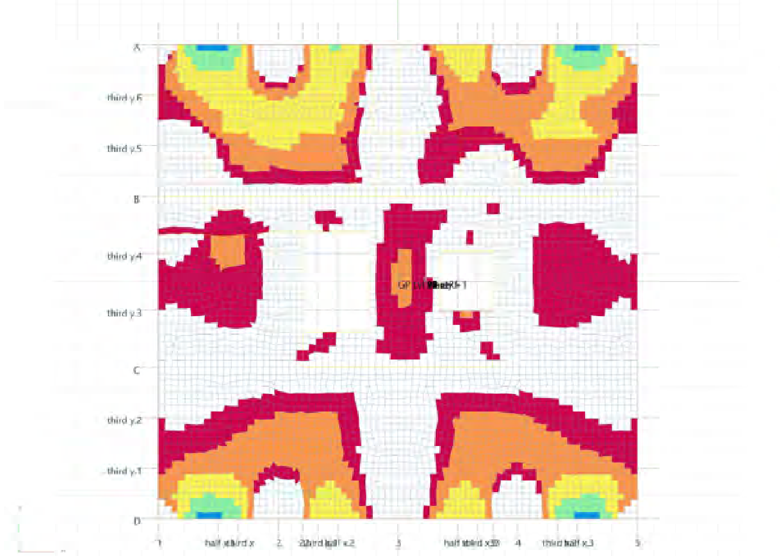

sagging
ANALYSIS LAYER
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Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Printed 13-May-2020
Page 1
Time 14:38

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ASF	06-Mar-2020	

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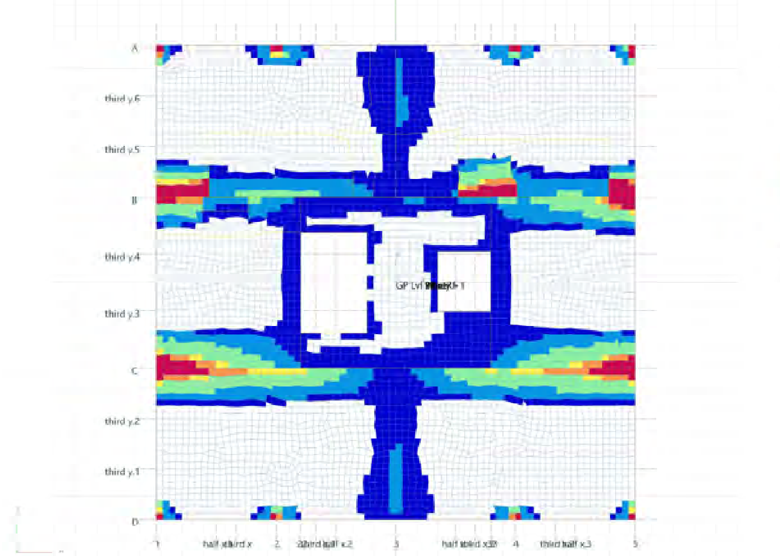
Cassette 9



hogging
ANALYSIS LAYER
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Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
84 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Printed 13-May-2020
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Time 14:38

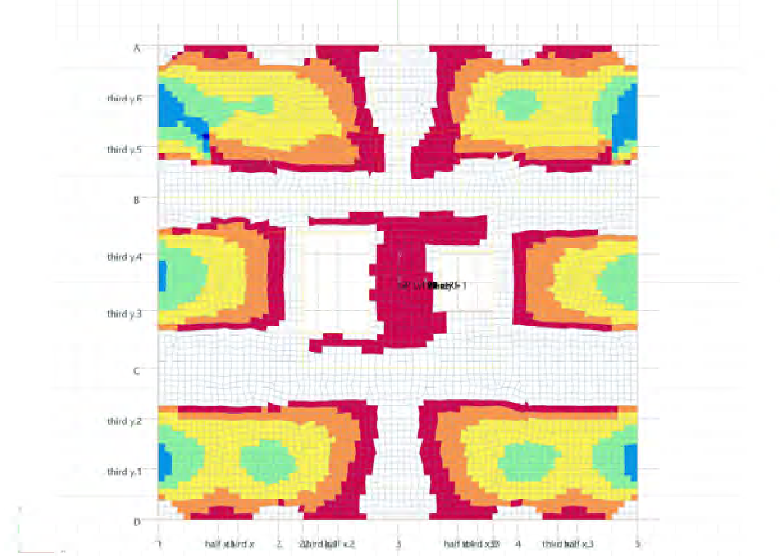
ATKINS
SNC·LAVALIN

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	

MHCLG Grenfell Tower
Final Design Validation
Cassette 9



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
-42 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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D:...\cass09 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns.gwb
Printed 13-May-2020
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Time 14:38

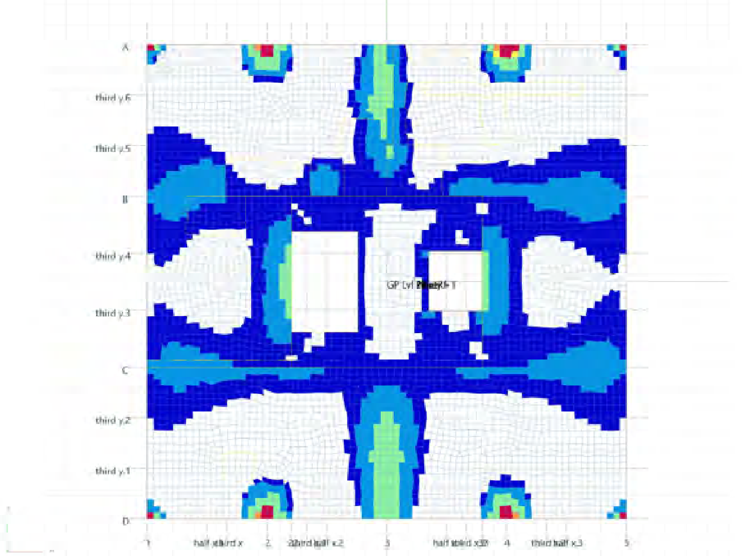
ATKINS
SNC·LAVALIN

MHCLG Grenfell Tower
Final Design Validation
Cassette 10

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
70 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

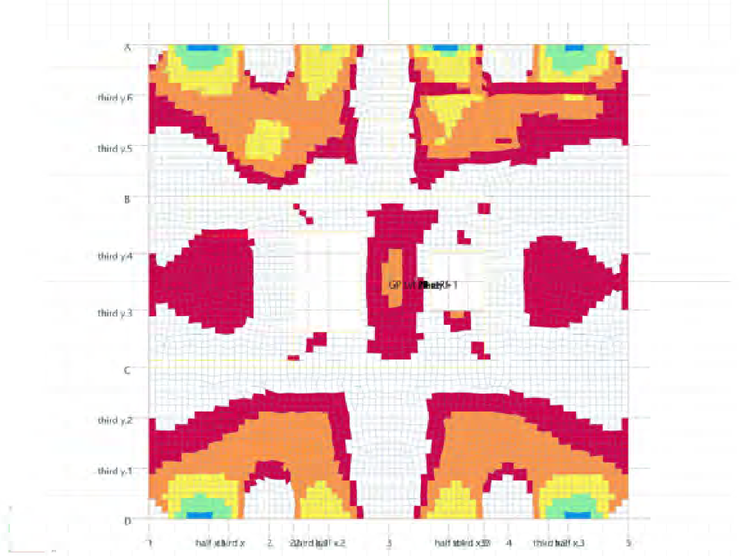
ATKINS
SNC·LAVALIN

MHCLG Grenfell Tower
Final Design Validation
Cassette 10

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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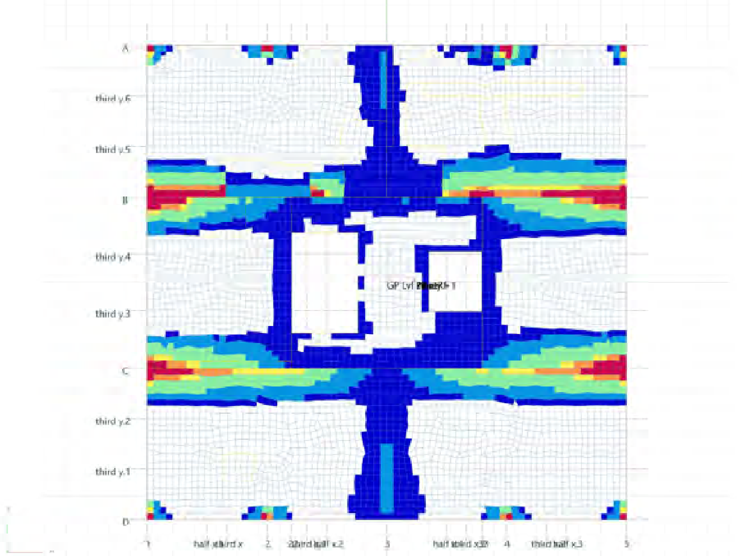
MHCLG Grenfell Tower
Final Design Validation
Cassette 10

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
76 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

ATKINS
SNC·LAVALIN

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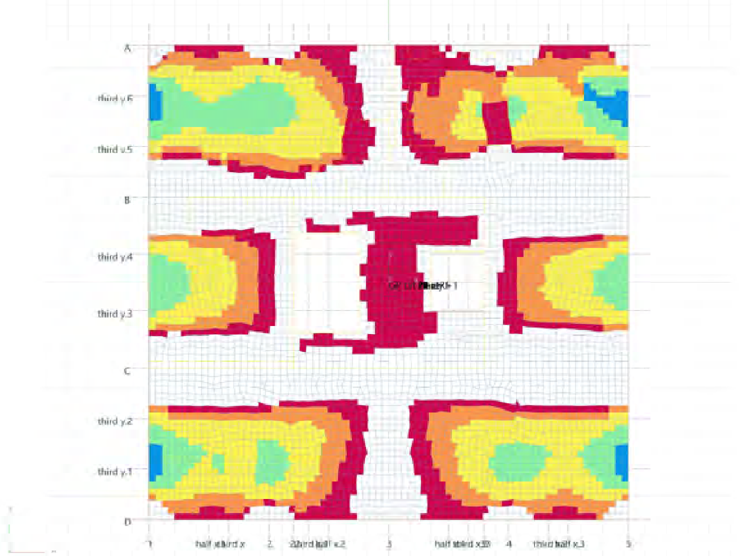
Final Design Validation
Cassette 10

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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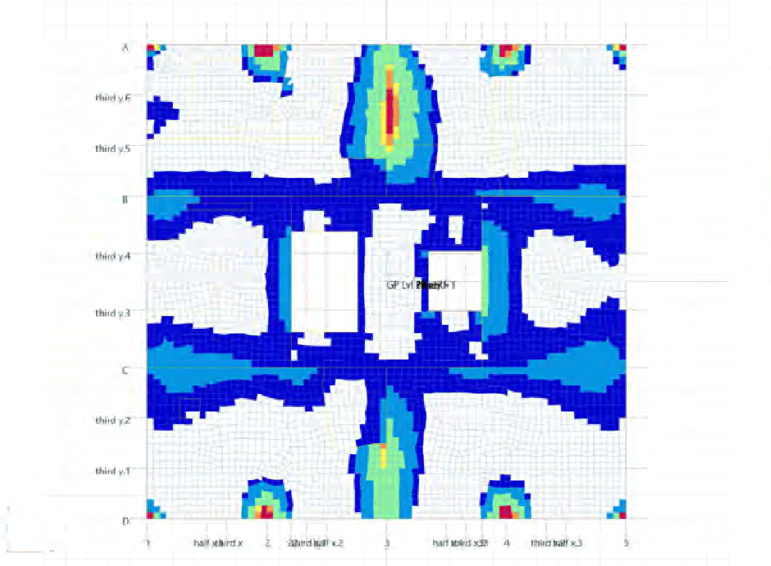
Final Design Validation
Cassette 11

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
74 kNm/m
42 kNm/m — As=100%; no spall
36 kNm/m — As=100%; T1; spall
32 kNm/m — As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

SNC·LAVALIN ATKINS

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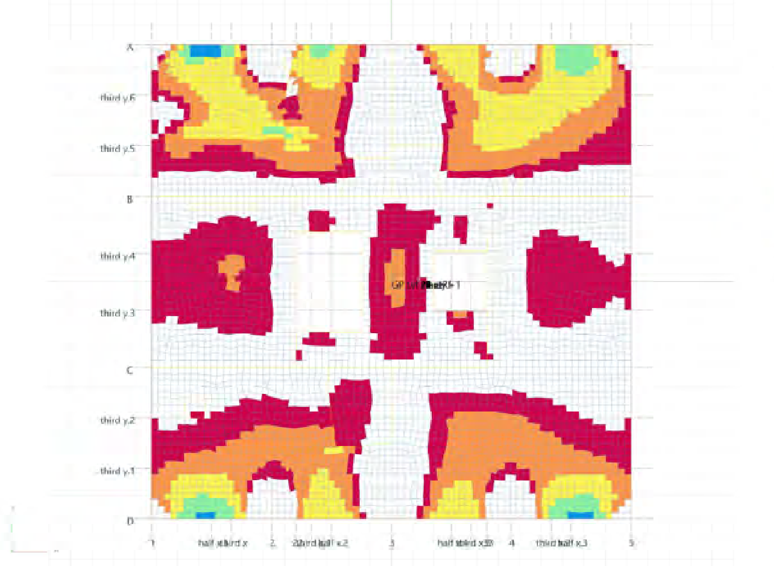
Final Design Validation
Cassette 11

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m
spall; As=25%
-11 kNm/m
spall; As=50%
-21 kNm/m
spall; As=68%
-31 kNm/m
As=100%
-42 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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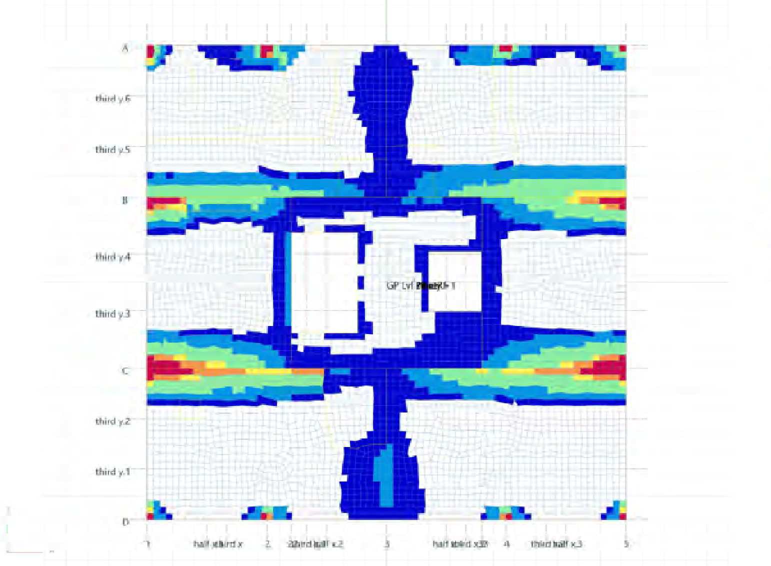
Final Design Validation
Cassette 11

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
88 kNm/m
42 kNm/m — As=100%; no spall
36 kNm/m — As=100%; T1; spall
32 kNm/m — As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Final Design Validation
Cassette 11

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
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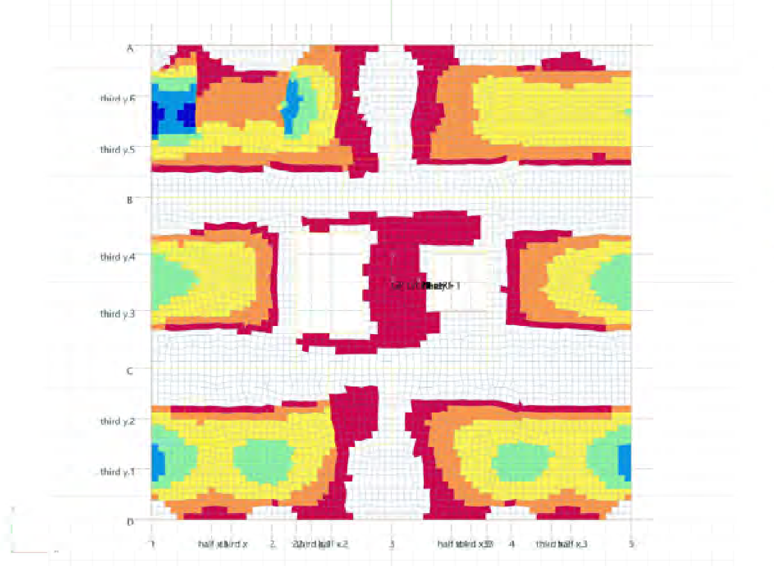

sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0 kNm/m
-5 kNm/m
spall; As=25%
-11 kNm/m
spall; As=50%
-21 kNm/m
spall; As=68%
-31 kNm/m
As=100%
-42 kNm/m
-51 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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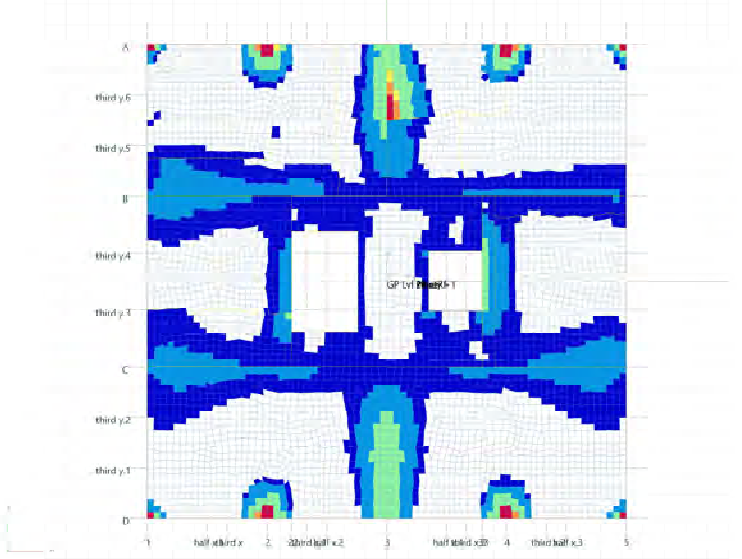
Final Design Validation
Cassette 12

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
63 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Cassette 12

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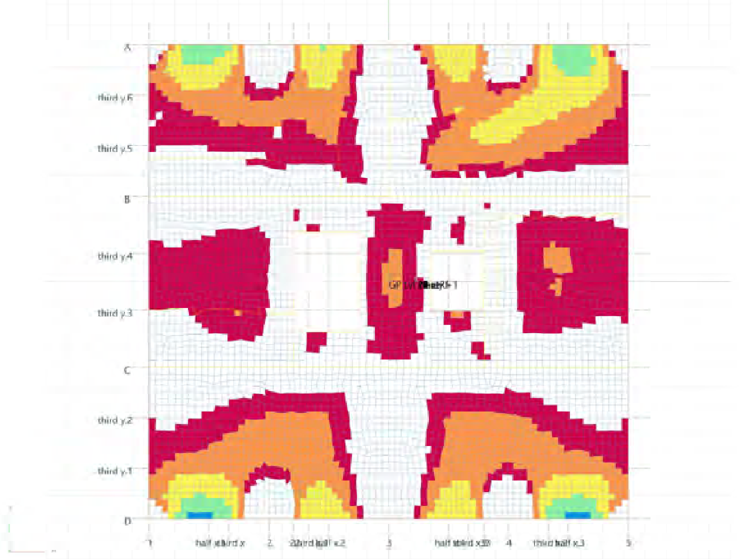
Made by ASF	Date 06-Mar-2020	Checked



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Final Design Validation
Cassette 12

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
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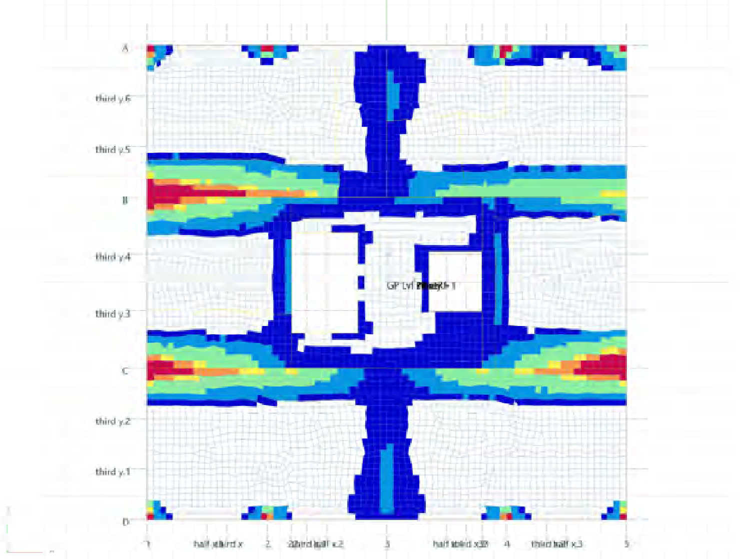

hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Mxy|
Output axis: global
88 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Drg. Ref.		
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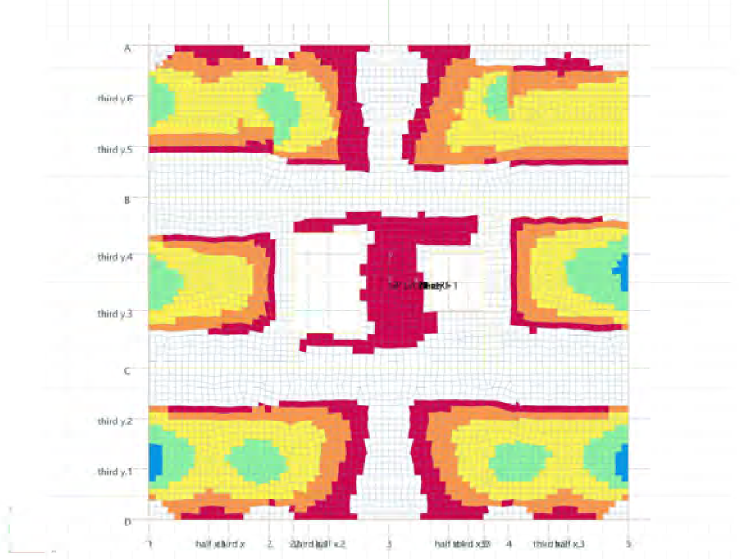

sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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D:...\cass12 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns.gwb
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Final Design Validation
Cassette 13

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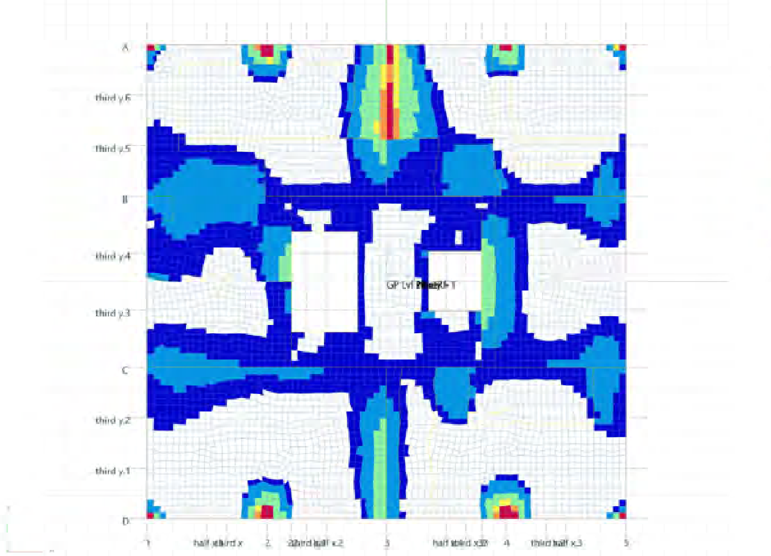

hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
71 kNm/m
42 kNm/m As=100%; no spall
36 kNm/m As=100%; T1; spall
32 kNm/m As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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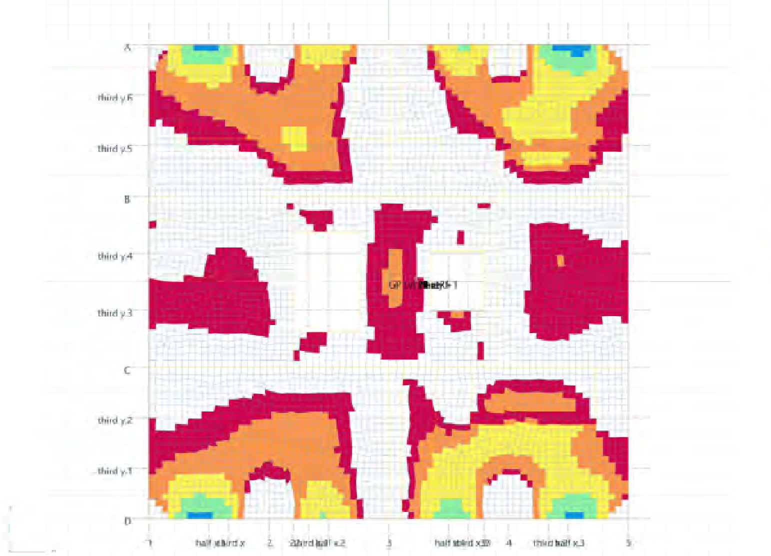
MHCLG Grenfell Tower
Final Design Validation
Cassette 13

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m spall; As=25%
-11 kNm/m spall; As=50%
-21 kNm/m spall; As=68%
-31 kNm/m As=100%
-42 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

SNC·LAVALIN ATKINS

MHCLG Grenfell Tower
Final Design Validation
Cassette 13

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
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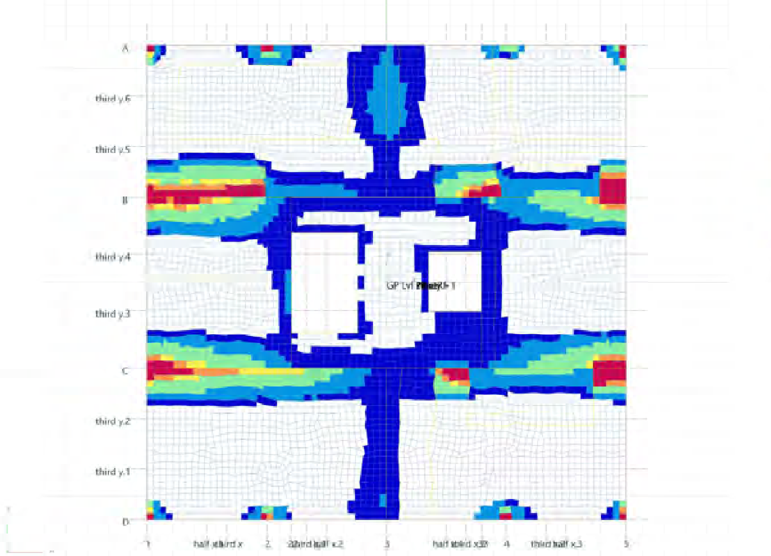

hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
92 kNm/m
42 kNm/m As=100%; no spall
36 kNm/m As=100%; T1; spall
32 kNm/m As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

SNC·LAVALIN ATKINS

MHCLG Grenfell Tower
Final Design Validation
Cassette 13

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
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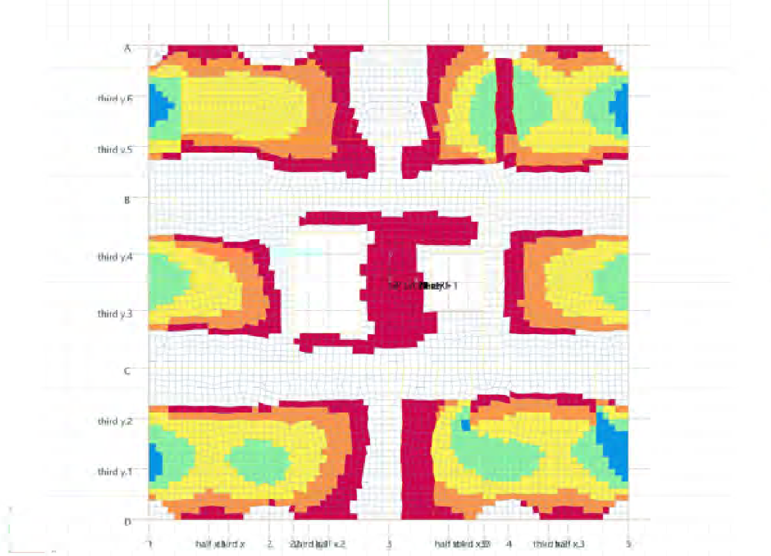
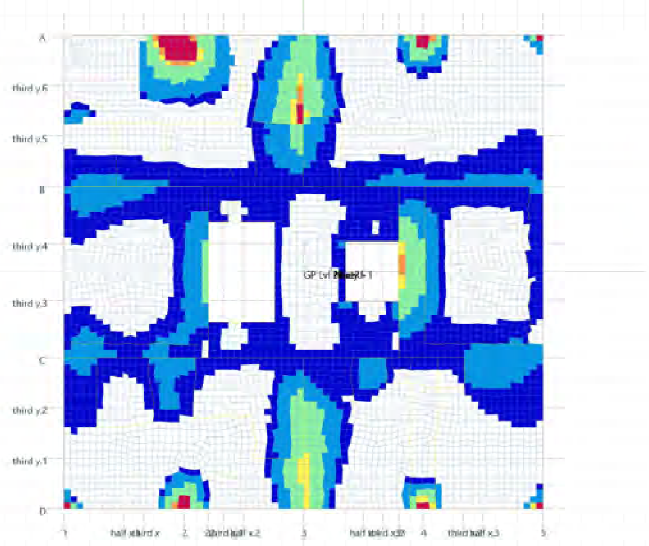


sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0 kNm/m
-5 kNm/m spall; As=25%
-11 kNm/m spall; As=50%
-21 kNm/m spall; As=68%
-31 kNm/m As=100%
-42 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

ATKINS
SNC·LAVALIN

MHCLG Grenfell Tower
Final Design Validation
Cassette 14

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



hogging
ANALYSIS LAYER
Analysis stage: 1 : 1
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
134 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D SL1
Centre values only

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cass14 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
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ATKINS
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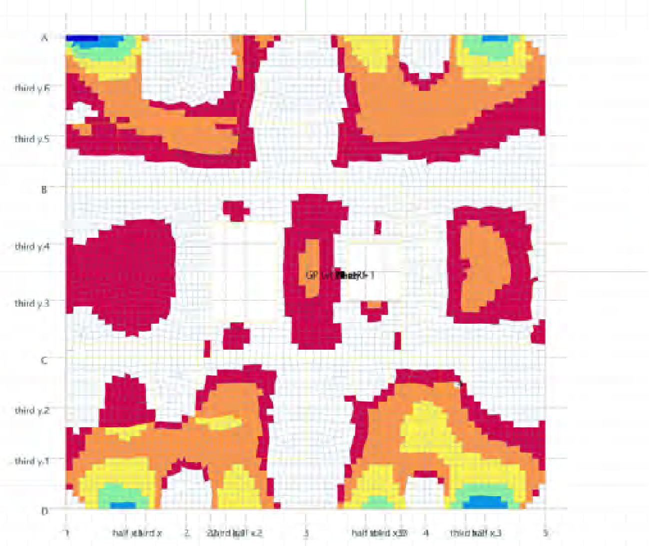
MHCLG Grenfell Tower
Final Design Validation
Cassette 14

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



sagging
ANALYSIS LAYER
Analysis stage: 1 : 1
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
-50 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D SL1
Centre values only

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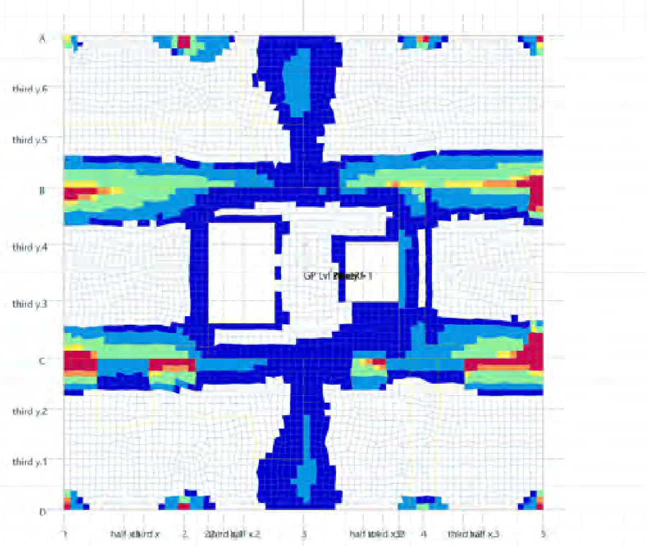
cass14 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
Printed 22-May-2020 Page 1 Time 21:38

ATKINS
SNC·LAVALIN

MHCLG Grenfell Tower
Final Design Validation
Cassette 14

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



hogging
ANALYSIS LAYER
Analysis stage: 1 : 1
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
104 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D SL1
Centre values only

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cass14 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
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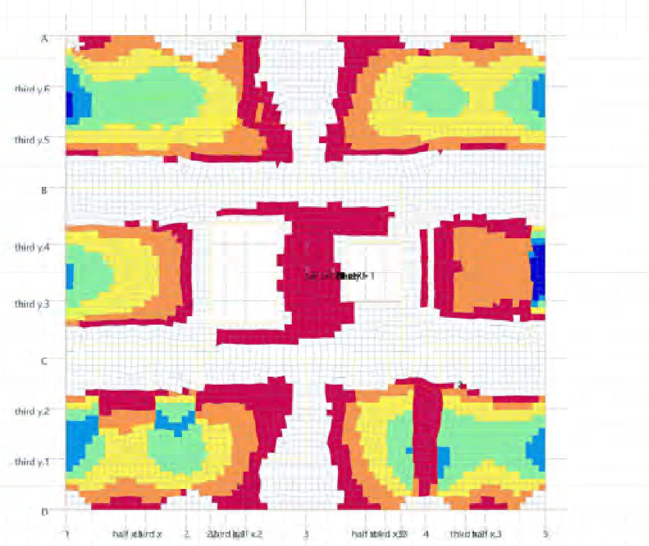
ATKINS
SNC·LAVALIN

MHCLG Grenfell Tower
Final Design Validation
Cassette 14

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



sagging
ANALYSIS LAYER
Analysis stage: 1 : 1
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
-58 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D SL1
Centre values only

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cass14 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
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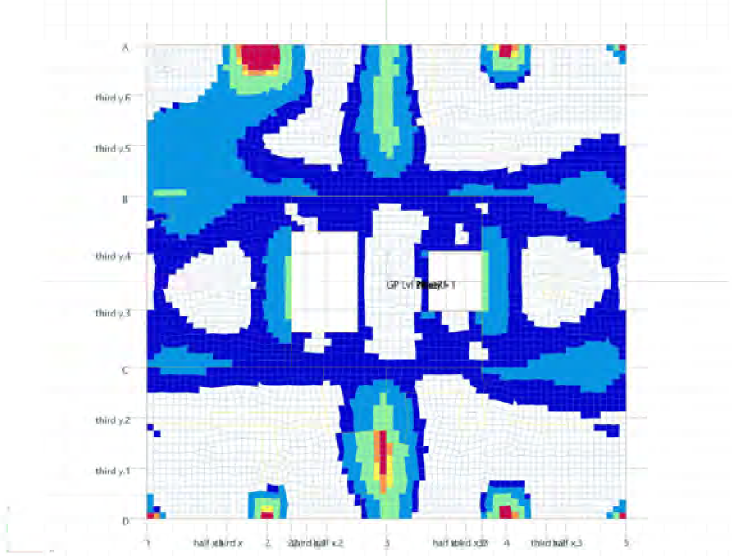
MHCLG Grenfell Tower
Final Design Validation
Cassette 16

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



hogging
ANALYSIS LAYER
Analysis stage: 1 : 1
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
130 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D SL1
Centre values only

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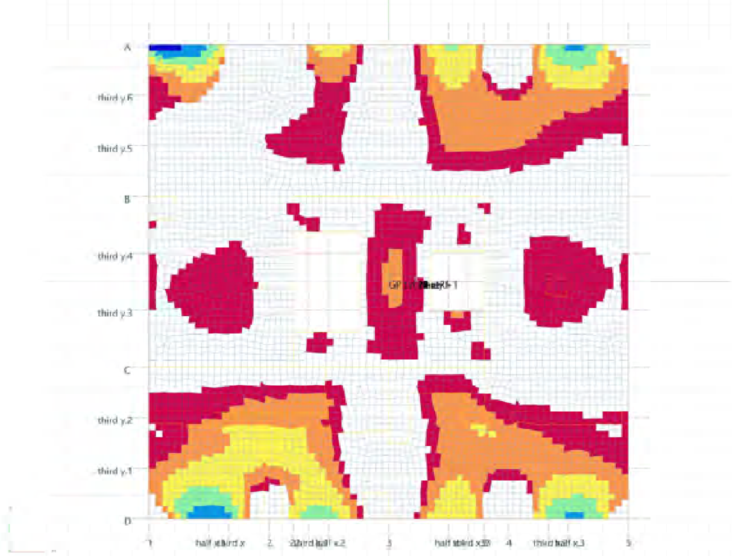
MHCLG Grenfell Tower
Final Design Validation
Cassette 16

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked

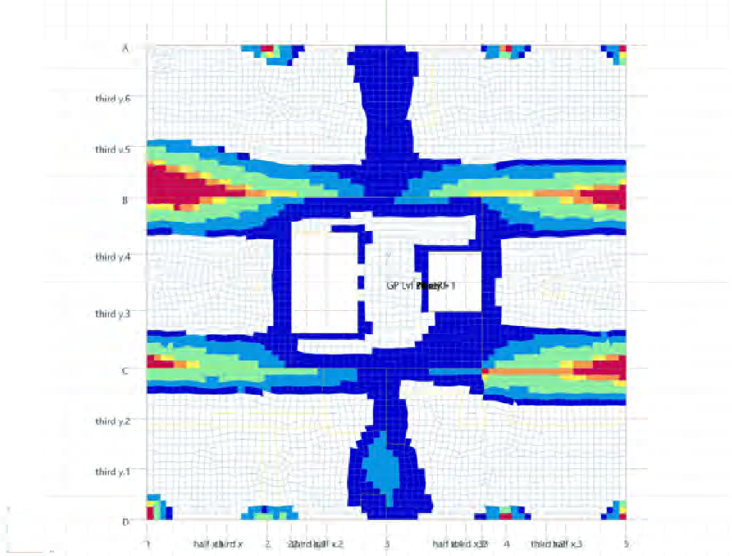


sagging
ANALYSIS LAYER
Analysis stage: 1 : 1
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
-62 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D SL1
Centre values only

SNC·LAVALIN ATKINS

MHCLG Grenfell Tower
Final Design Validation
Cassette 16

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked

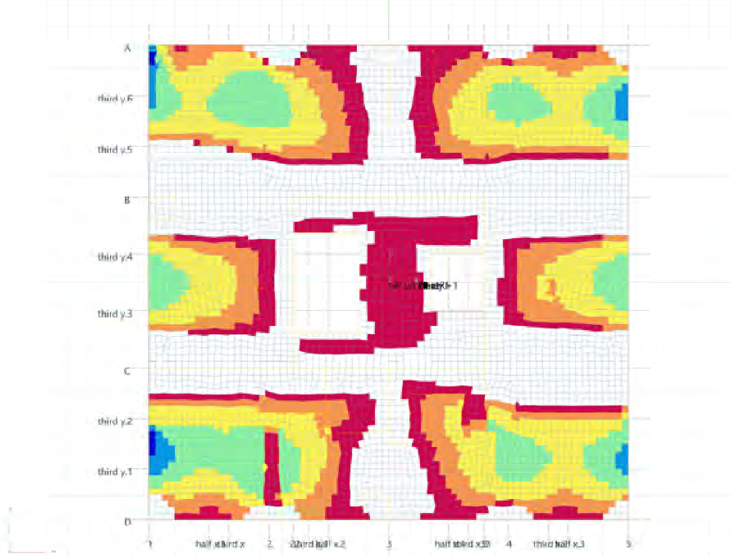


hogging
ANALYSIS LAYER
Analysis stage: 1 : 1
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
102 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D SL1
Centre values only

SNC·LAVALIN ATKINS

MHCLG Grenfell Tower
Final Design Validation
Cassette 16

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



sagging
ANALYSIS LAYER
Analysis stage: 1 : 1
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
-43 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D SL1
Centre values only

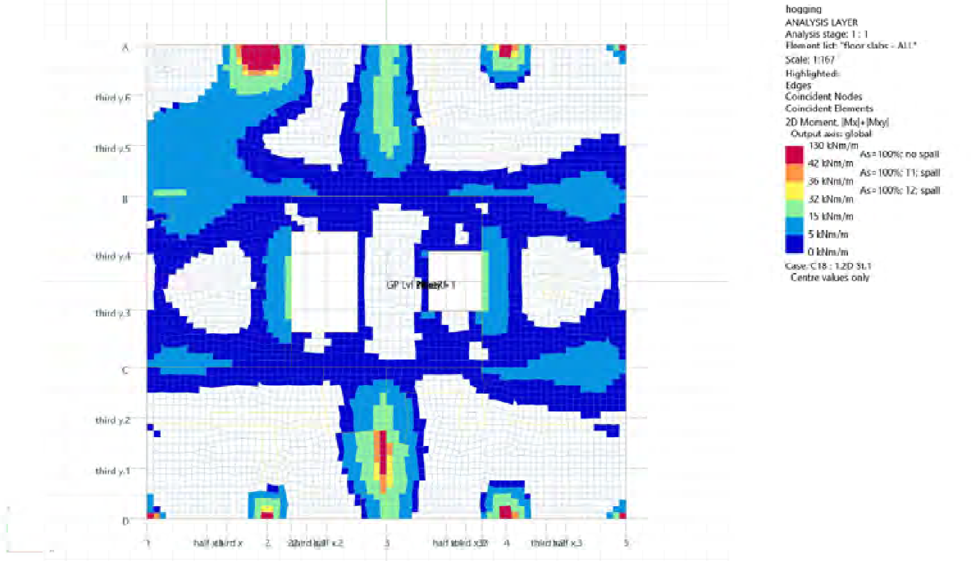
ATKINS SNC·LAVALIN

Job No. 5186875 | Sheet No. | Rev.

MHCLG Grenfell Tower
Final Design Validation
Cassette 16

Drg. Ref.

Made by ASF | Date 06-Mar-2020 | Checked



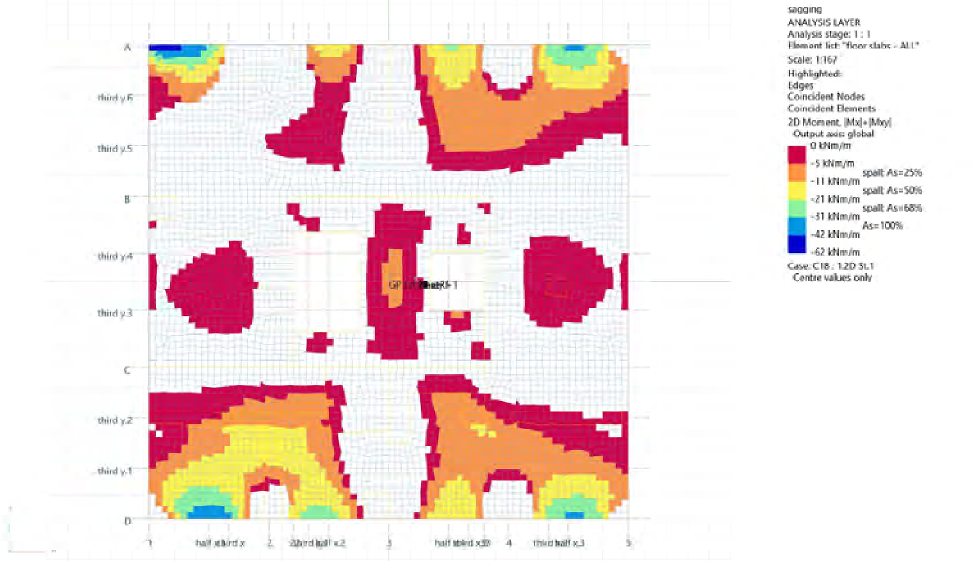
ATKINS SNC·LAVALIN

Job No. 5186875 | Sheet No. | Rev.

MHCLG Grenfell Tower
Final Design Validation
Cassette 16

Drg. Ref.

Made by ASF | Date 06-Mar-2020 | Checked



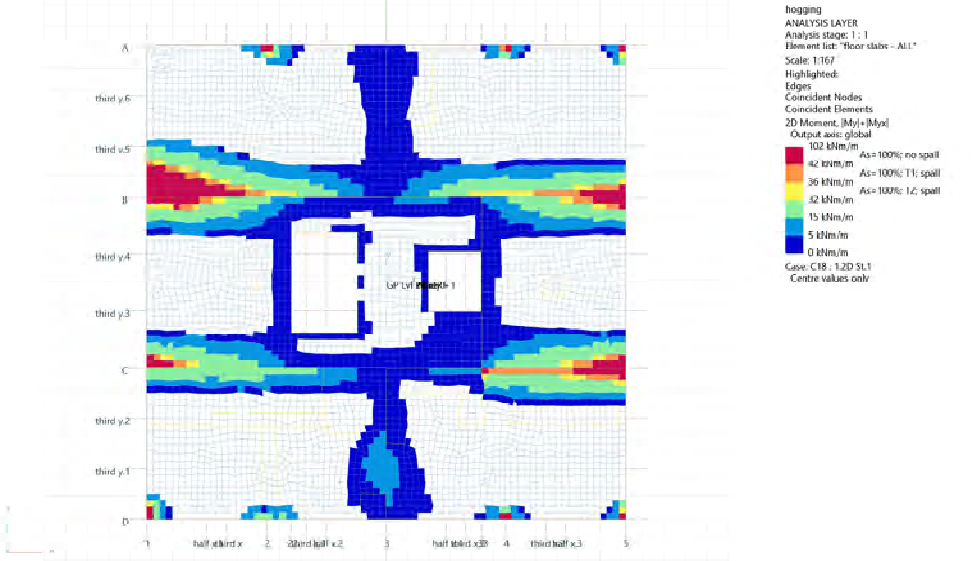
ATKINS SNC·LAVALIN

Job No. 5186875 | Sheet No. | Rev.

MHCLG Grenfell Tower
Final Design Validation
Cassette 16

Drg. Ref.

Made by ASF | Date 06-Mar-2020 | Checked



ATKINS SNC·LAVALIN

Job No. 5186875 | Sheet No. | Rev.

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Final Design Validation
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Drg. Ref.

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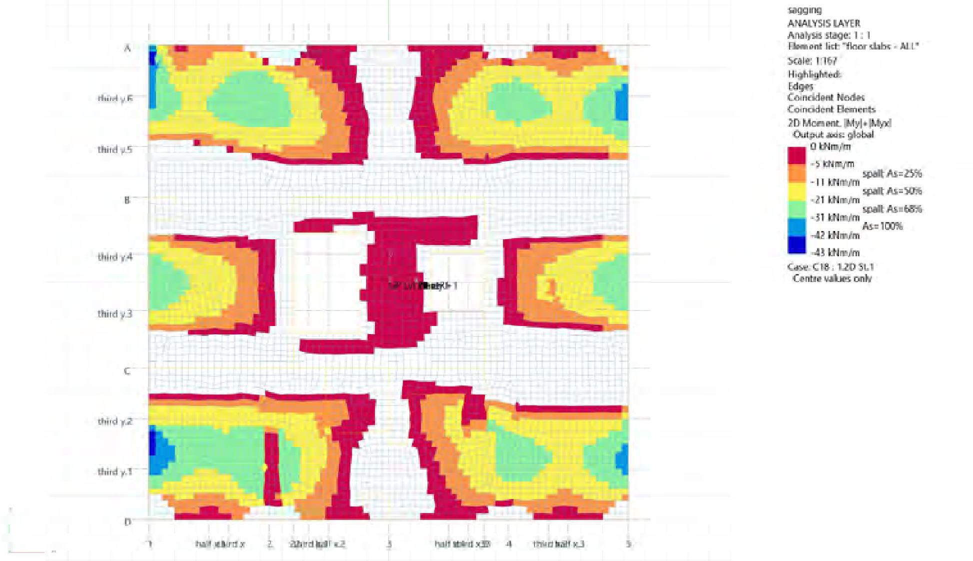

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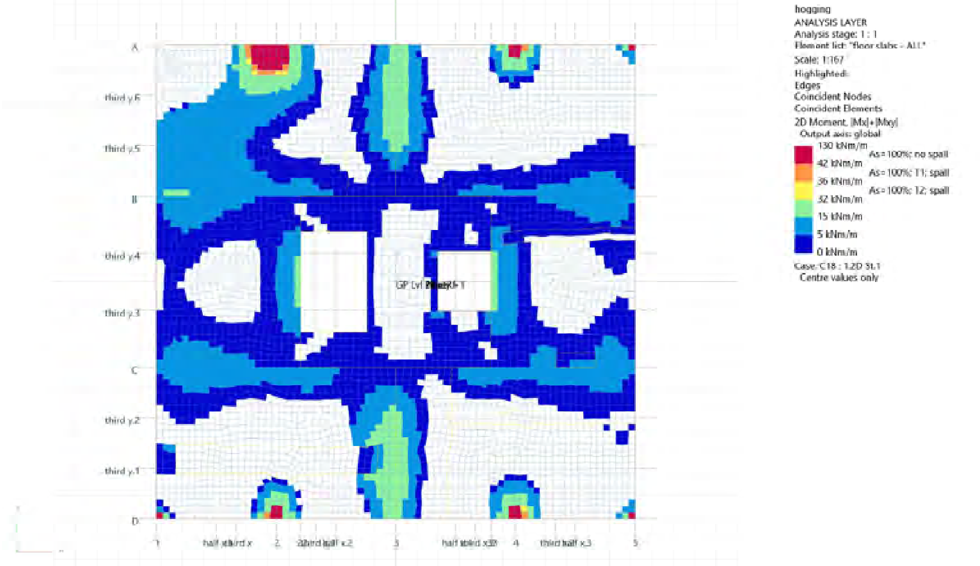
MHCLG Grenfell Tower
Final Design Validation
Cassette 17

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



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cass17 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
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Final Design Validation
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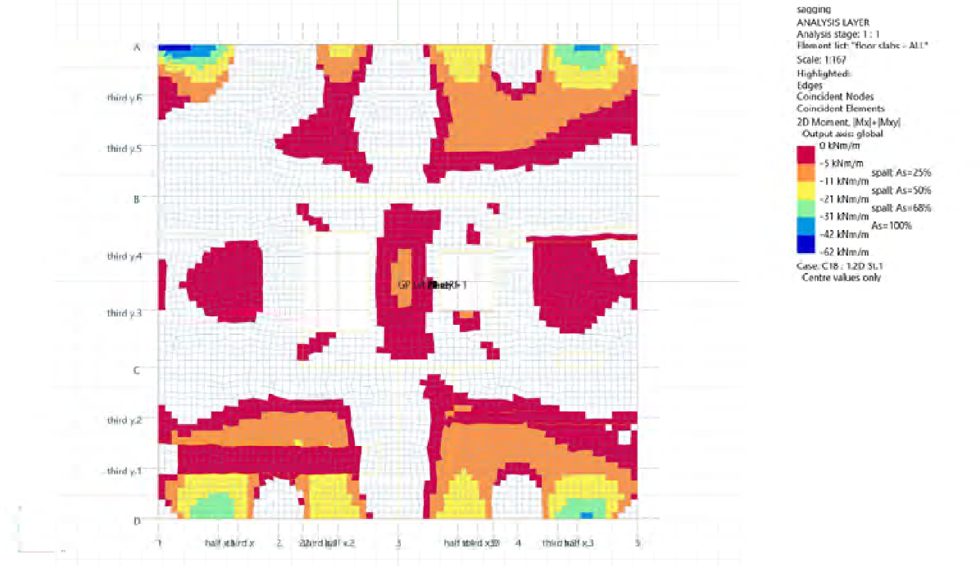
Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



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cass17 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
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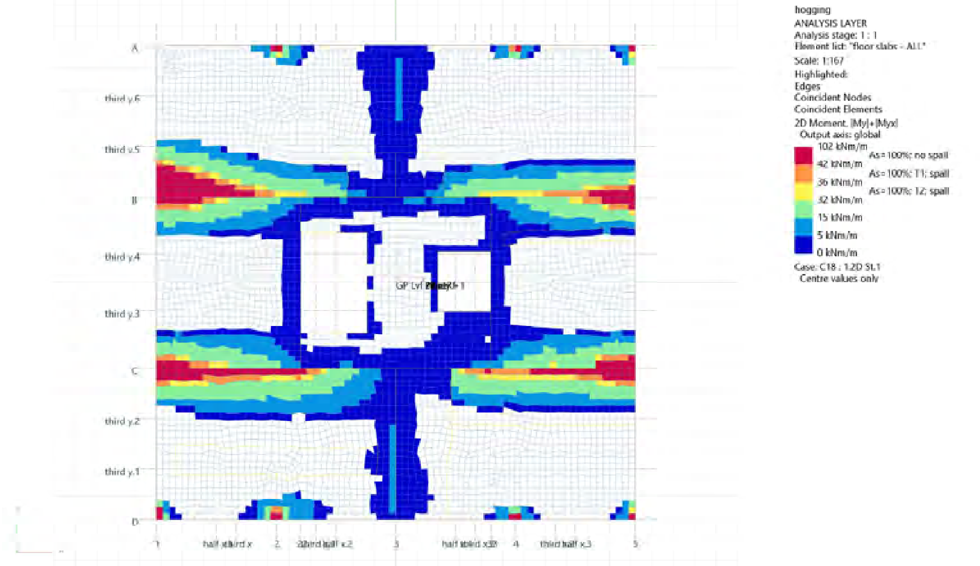
Final Design Validation
Cassette 17

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



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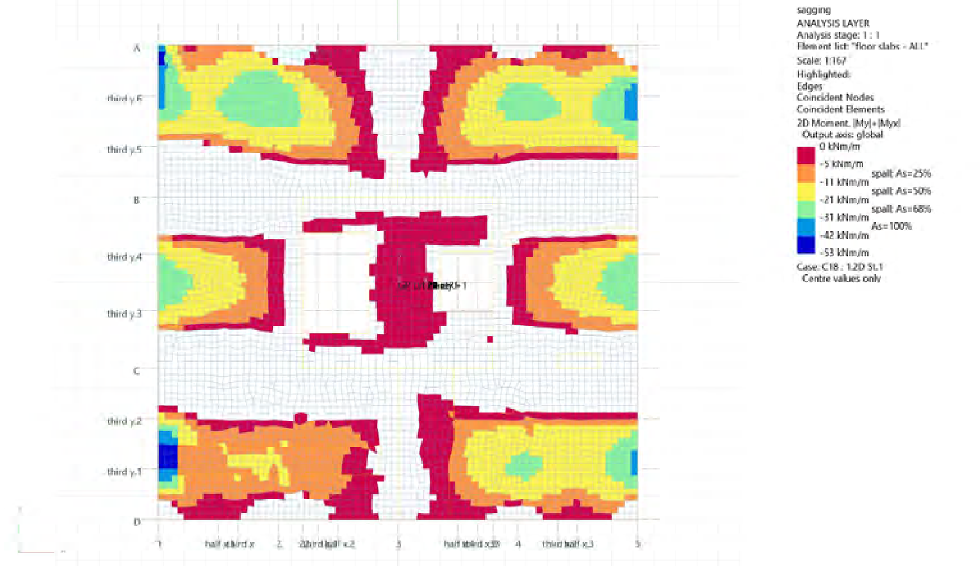
Final Design Validation
Cassette 17

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



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cass17 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
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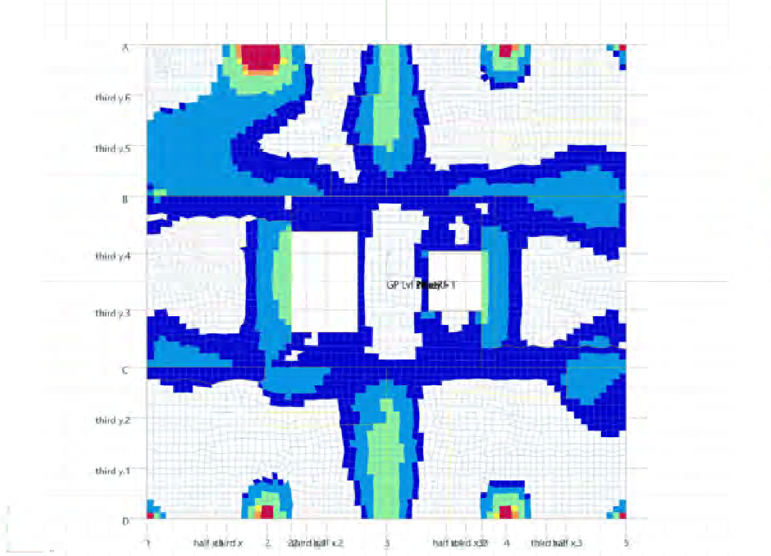
Final Design Validation
Cassette 18

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
132 kNm/m
42 kNm/m — As=100%; no spall
36 kNm/m — As=100%; T1; spall
32 kNm/m — As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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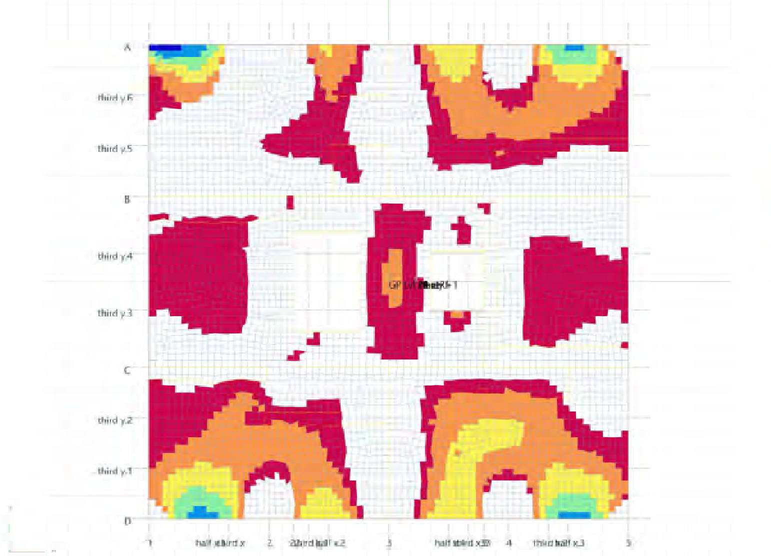
MHCLG Grenfell Tower
Final Design Validation
Cassette 18

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked

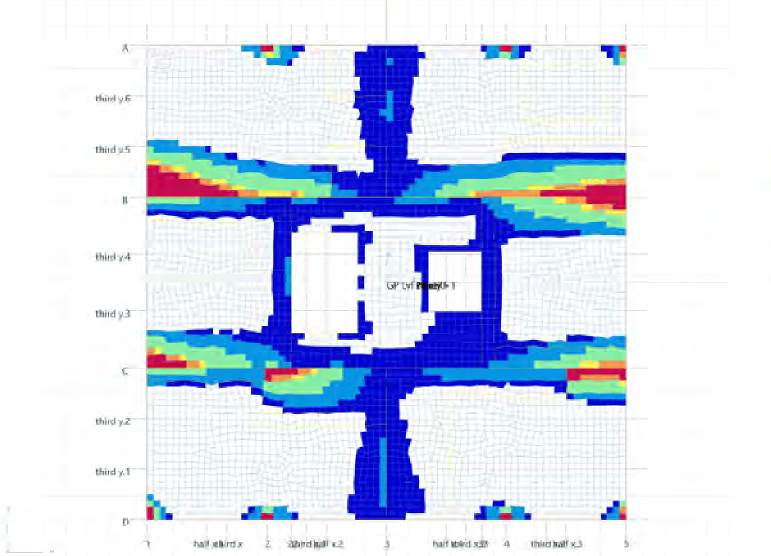


sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m — spall; As=25%
-11 kNm/m — spall; As=50%
-21 kNm/m — spall; As=68%
-31 kNm/m — As=100%
-42 kNm/m
-62 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

SNC·LAVALIN ATKINS

MHCLG Grenfell Tower
Final Design Validation
Cassette 18

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
106 kNm/m
42 kNm/m — As=100%; no spall
36 kNm/m — As=100%; T1; spall
32 kNm/m — As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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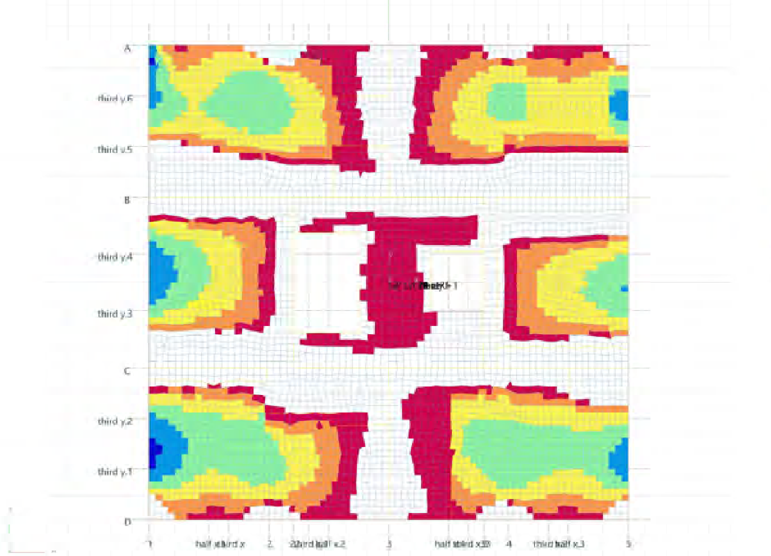
MHCLG Grenfell Tower
Final Design Validation
Cassette 18

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0 kNm/m
-5 kNm/m — spall; As=25%
-11 kNm/m — spall; As=50%
-21 kNm/m — spall; As=68%
-31 kNm/m — As=100%
-42 kNm/m
-45 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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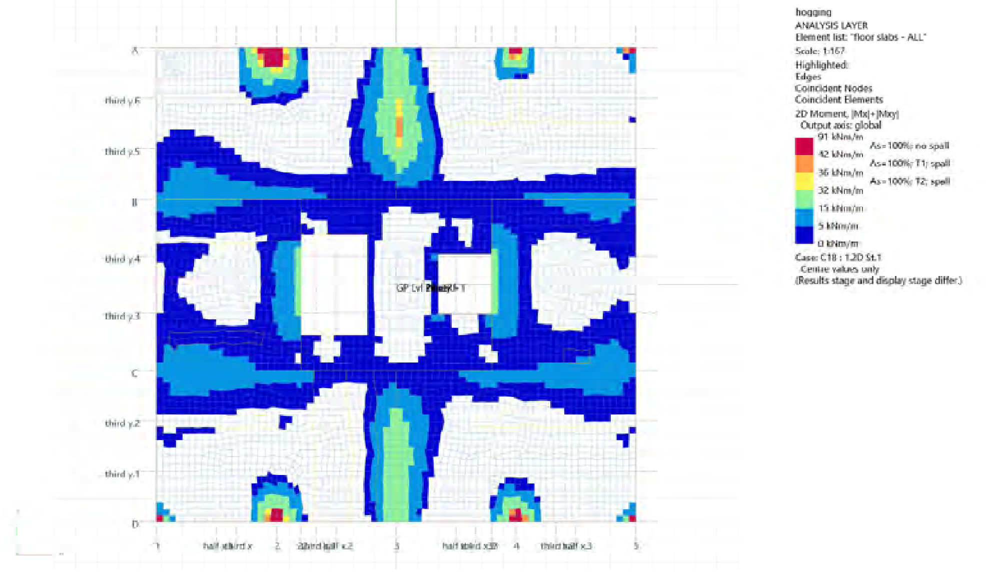
Cassette 19

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	



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cass19 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
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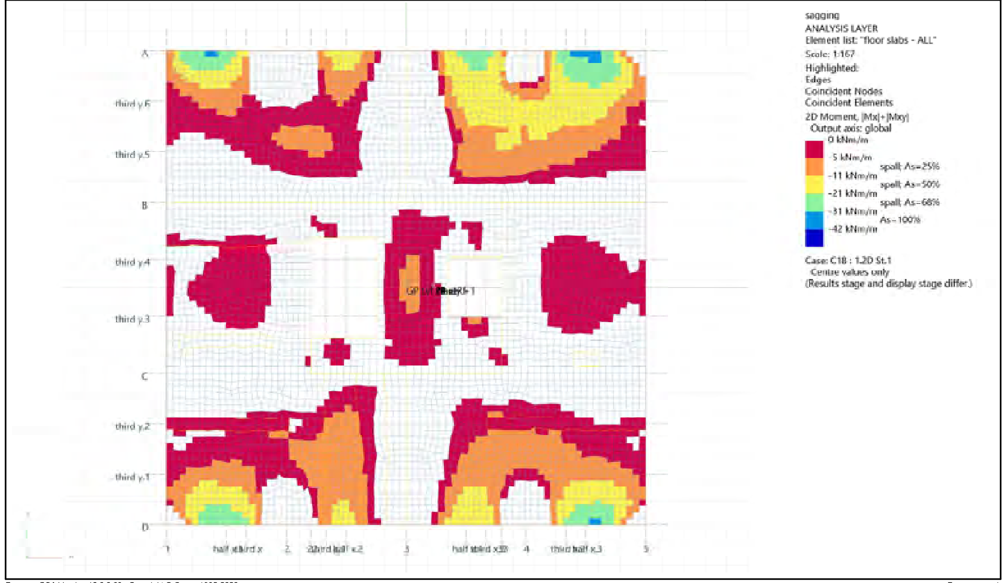
Cassette 19

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	



Program GSA Version 10.0.0.68 Copyright © Oasys 1985-2020
cass19 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
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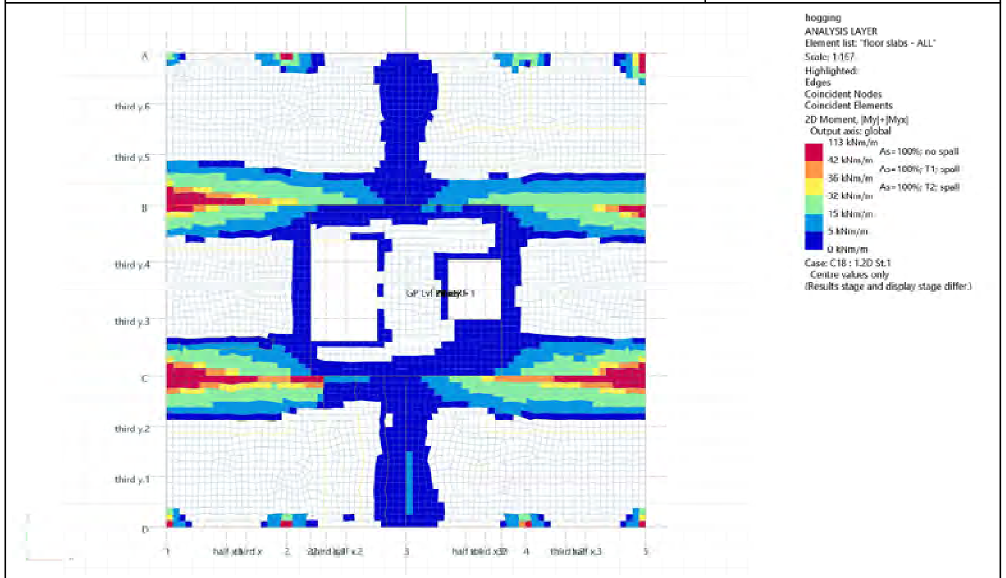
Final Design Validation
Cassette 19

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	



Program GSA Version 10.0.0.68 Copyright © Oasys 1985-2020
cass19 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
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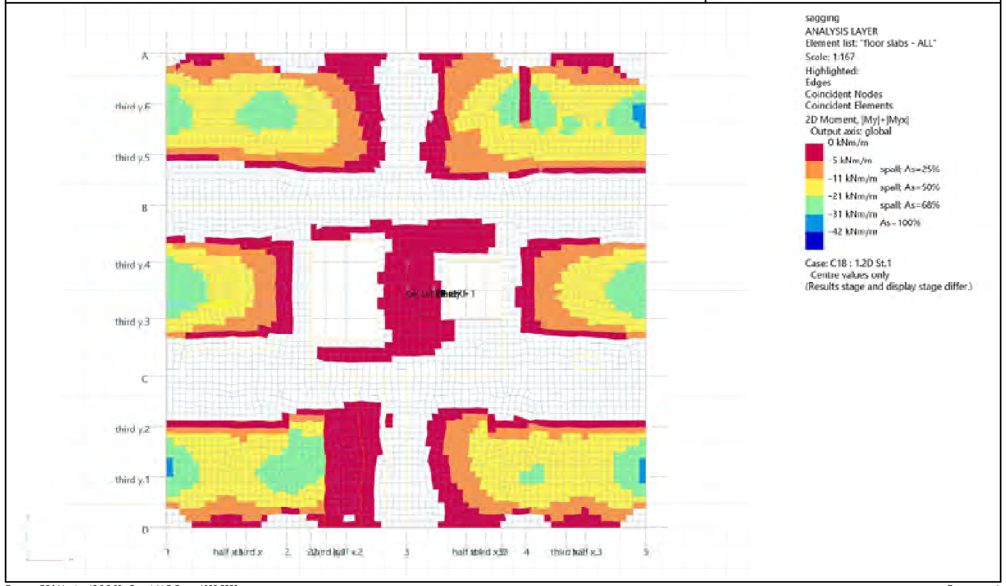
MHCLG Grenfell Tower
Final Design Validation
Cassette 19

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	



Program GSA Version 10.0.0.68 Copyright © Oasys 1985-2020
cass19 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
Printed 22-May-2020
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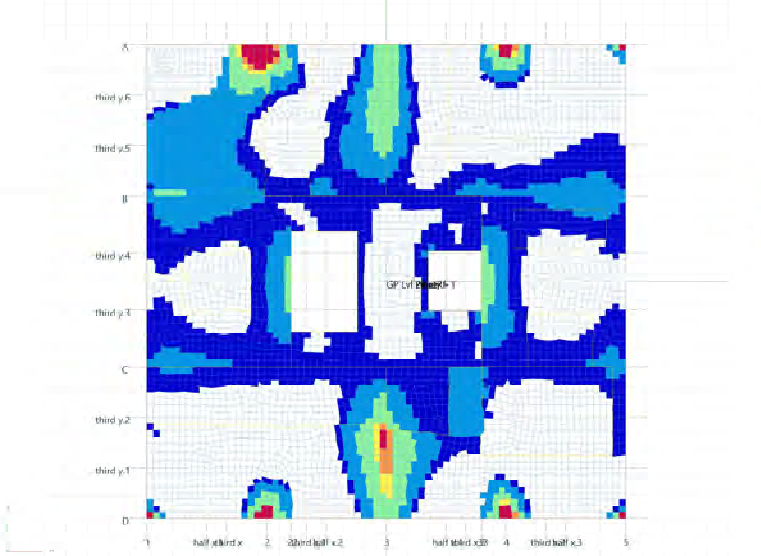
SNC·LAVALIN

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	

MHCLG Grenfell Tower
Final Design Validation
Cassette 20



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
122 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

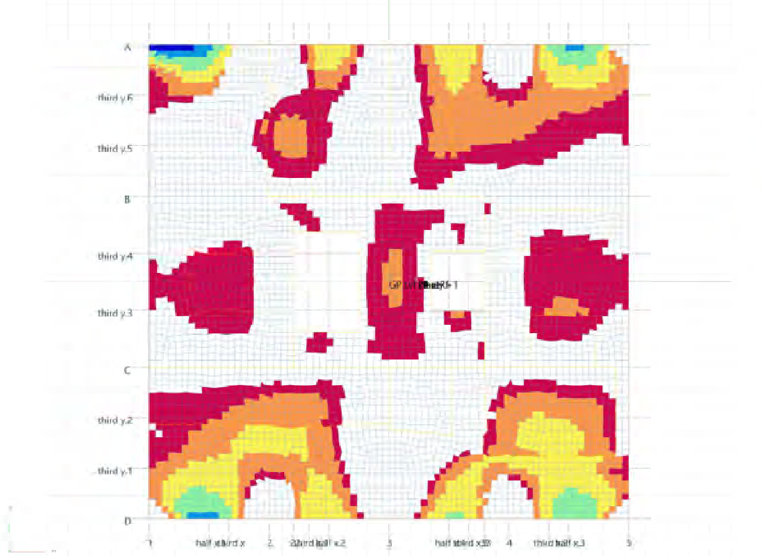
ATKINS
SNC·LAVALIN

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	

MHCLG Grenfell Tower
Final Design Validation
Cassette 20



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
-59 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

ATKINS
SNC·LAVALIN

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	

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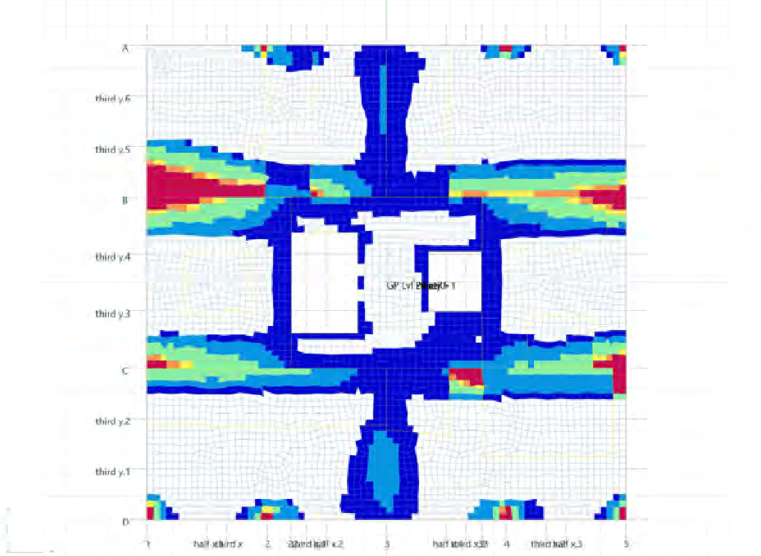
Final Design Validation
Cassette 20



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
114 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Drg. Ref.

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ASF	06-Mar-2020	

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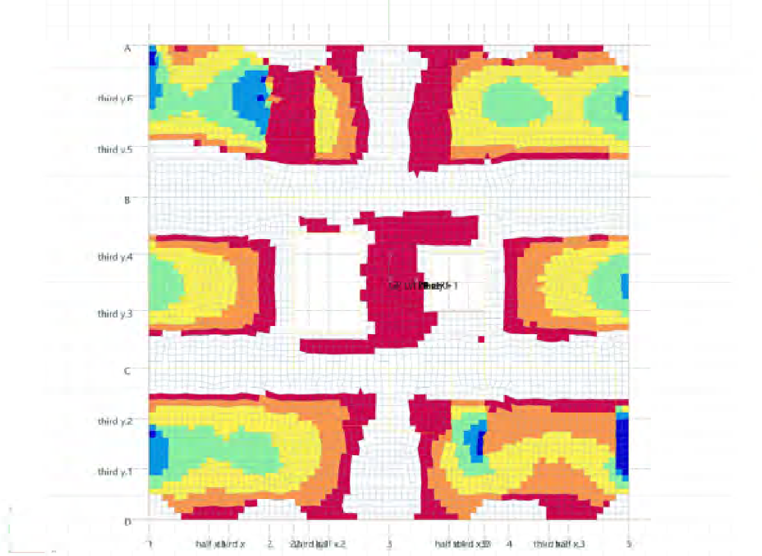
Final Design Validation
Cassette 20



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
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-42 kNm/m
-76 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

ATKINS
SNC·LAVALIN

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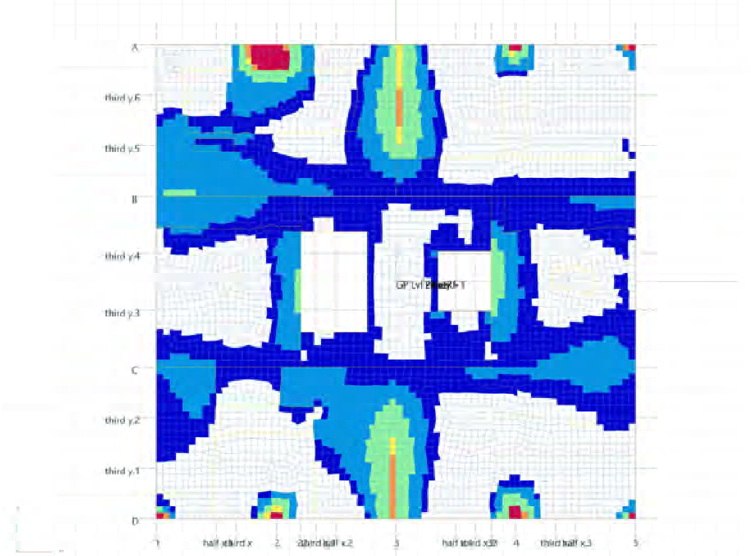
Final Design Validation
Cassette 21

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked

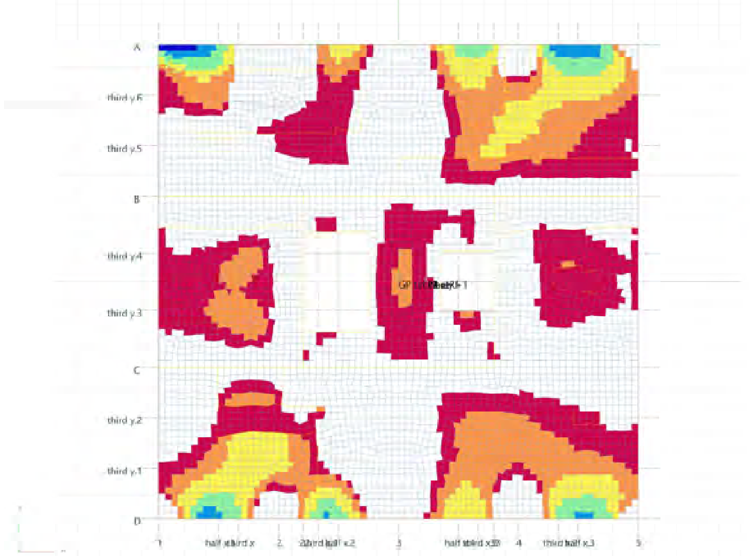


hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
130 kNm/m
42 kNm/m — As=100%; no spall
36 kNm/m — As=100%; T1; spall
32 kNm/m — As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

ATKINS
SNC·LAVALIN

MHCLG Grenfell Tower
Final Design Validation
Cassette 21

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked

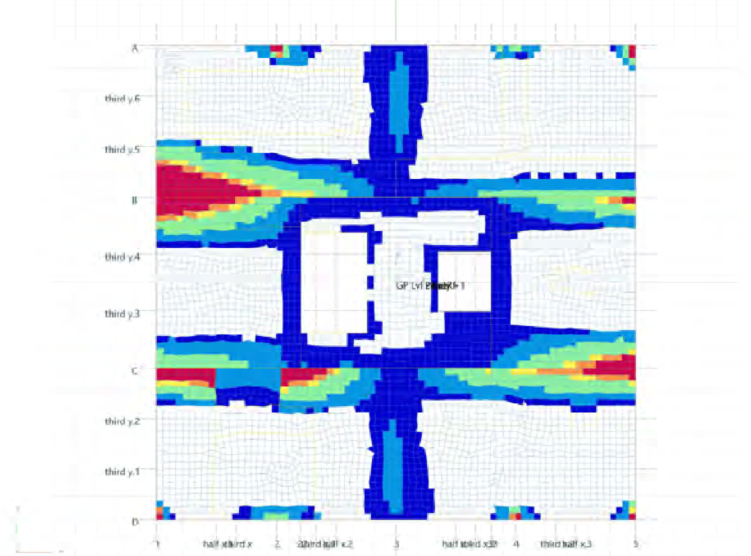


sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m — spall; As=25%
-11 kNm/m — spall; As=50%
-21 kNm/m — spall; As=68%
-31 kNm/m — As=100%
-42 kNm/m
-62 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

ATKINS
SNC·LAVALIN

MHCLG Grenfell Tower
Final Design Validation
Cassette 21

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
104 kNm/m
42 kNm/m — As=100%; no spall
36 kNm/m — As=100%; T1; spall
32 kNm/m — As=100%; T2; spall
15 kNm/m
5 kNm/m
0 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Final Design Validation
Cassette 21

Job No.	Sheet No.	Rev.
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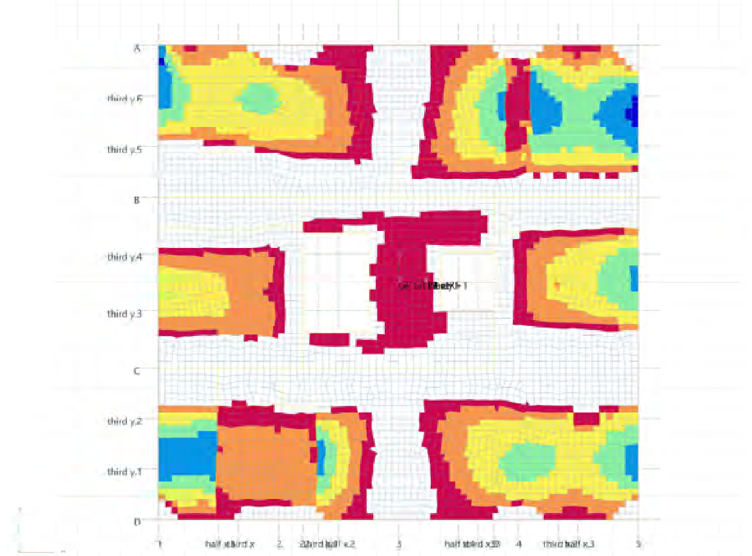
Made by ASF	Date 06-Mar-2020	Checked



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0 kNm/m
-5 kNm/m — spall; As=25%
-11 kNm/m — spall; As=50%
-21 kNm/m — spall; As=68%
-31 kNm/m — As=100%
-42 kNm/m
-45 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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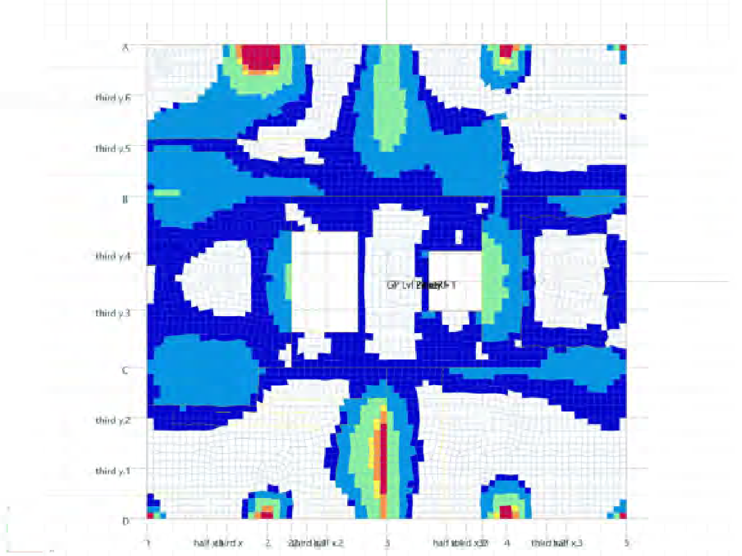
MHCLG Grenfell Tower
Final Design Validation
Cassette 22

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
130 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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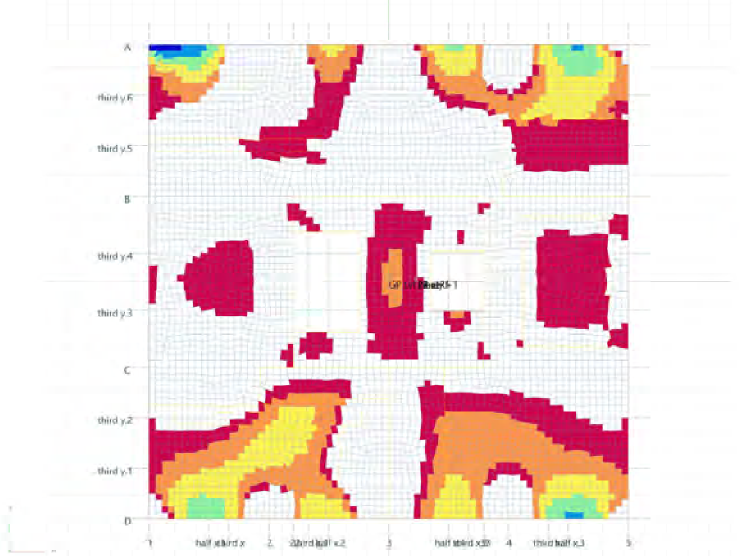
Final Design Validation
Cassette 22

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
-62 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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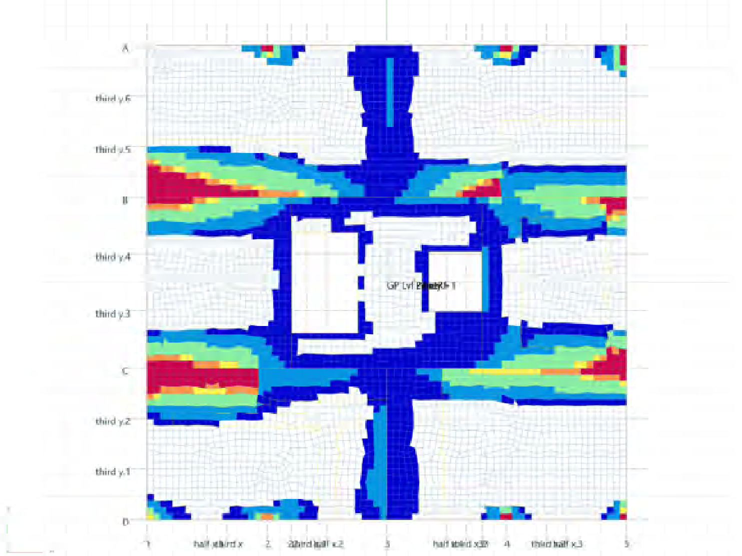
Final Design Validation
Cassette 22

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
104 kNm/m
42 kNm/m
36 kNm/m
32 kNm/m
15 kNm/m
5 kNm/m
0 kNm/m
As=100%; no spall
As=100%; T1; spall
As=100%; T2; spall
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Job No.	Sheet No.	Rev.
5186875		
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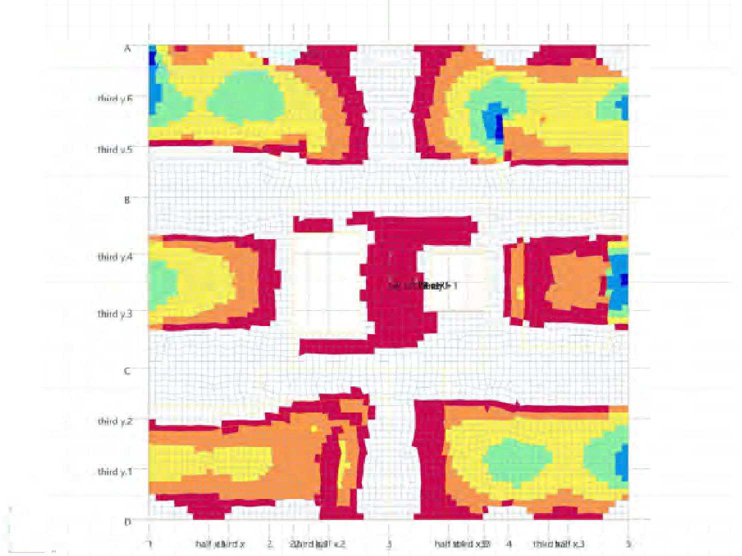

sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0 kNm/m
-5 kNm/m
-11 kNm/m
-21 kNm/m
-31 kNm/m
-42 kNm/m
-49 kNm/m
spall; As=25%
spall; As=50%
spall; As=68%
As=100%
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Cassette 23

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Drg. Ref.

Made by	Date	Checked
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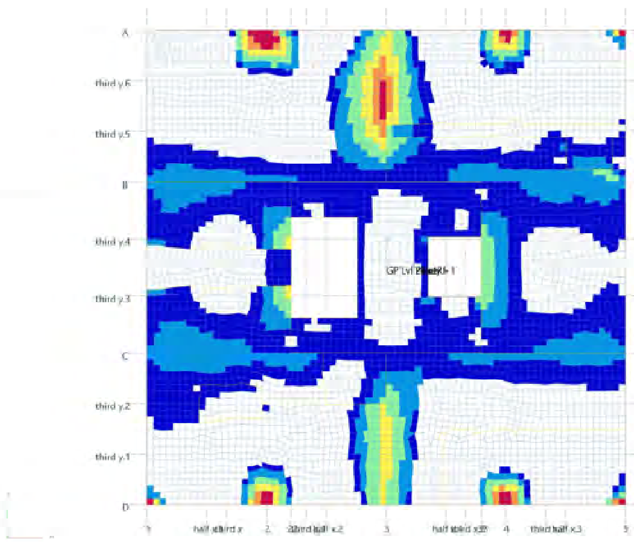

hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:166.500
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
94.314 kNm/m
As=100%
42.000 kNm/m
spall; As=68%
31.000 kNm/m
spall; As=50%
21.000 kNm/m
spall; As=25%
11.000 kNm/m
5.000 kNm/m
0.000 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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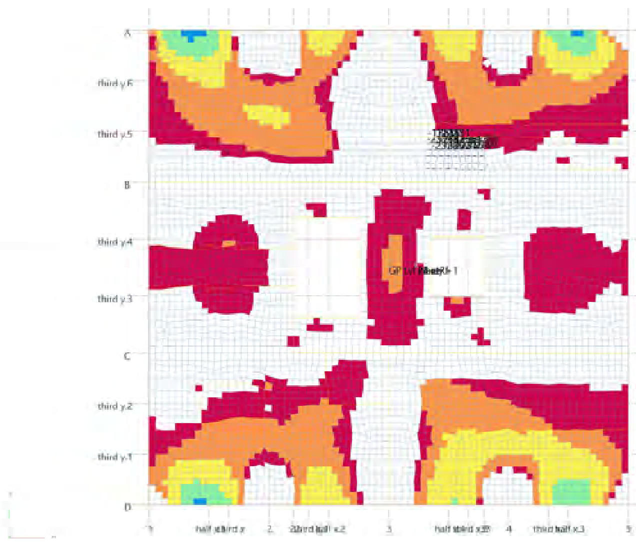
Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:166.500
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
0.000 kNm/m
-5.000 kNm/m
spall; As=25%
-11.000 kNm/m
spall; As=50%
-21.000 kNm/m
spall; As=68%
-31.000 kNm/m
As=100%
-42.000 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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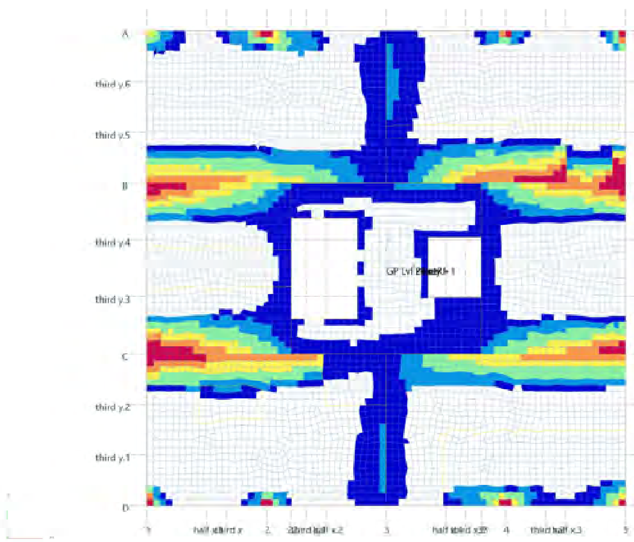
Final Design Validation
Cassette 23

Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	



hogging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:166.500
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
71.471 kNm/m
As=100%
42.000 kNm/m
spall; As=68%
31.000 kNm/m
spall; As=50%
21.000 kNm/m
spall; As=25%
11.000 kNm/m
5.000 kNm/m
0.000 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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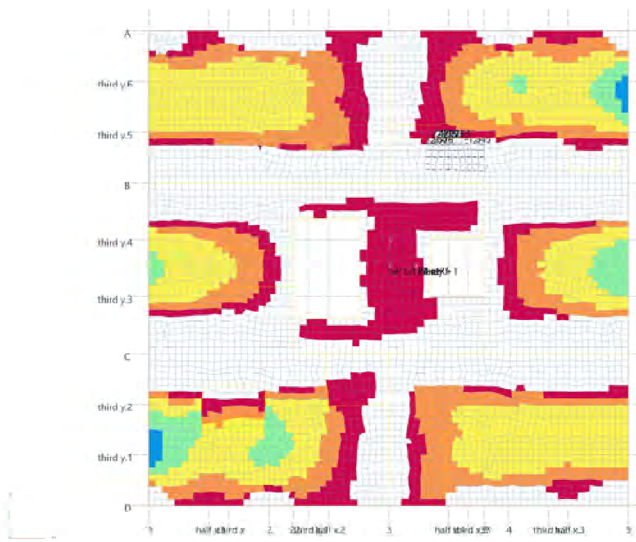
ASF	06-Mar-2020	



sagging
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:166.500
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
0.000 kNm/m
-5.000 kNm/m
spall; As=25%
-11.000 kNm/m
spall; As=50%
-21.000 kNm/m
spall; As=68%
-31.000 kNm/m
As=100%
-42.000 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Final Design Validation
Cassette 24

Job No.	Sheet No.	Rev.
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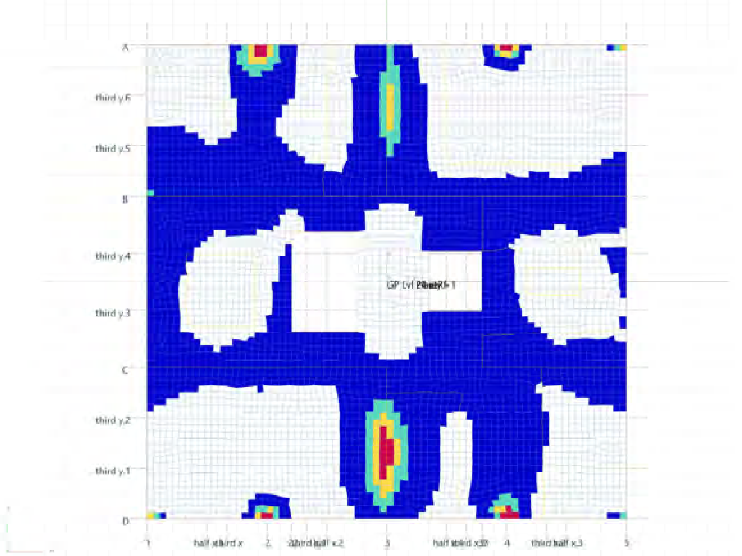

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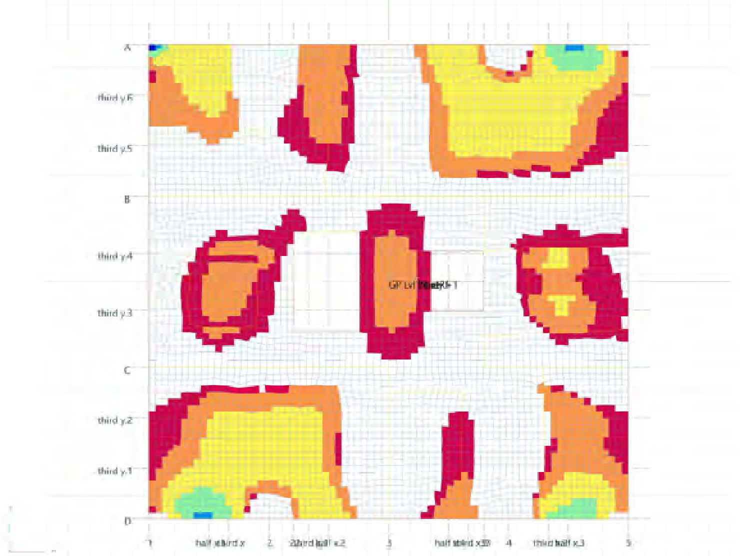
Final Design Validation
Cassette 24

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



Program GSA Version 10.0.0.68 Copyright © Oasys 1985-2020
cass24 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
Printed 03-Jun-2020
Page 1
Time 14:34

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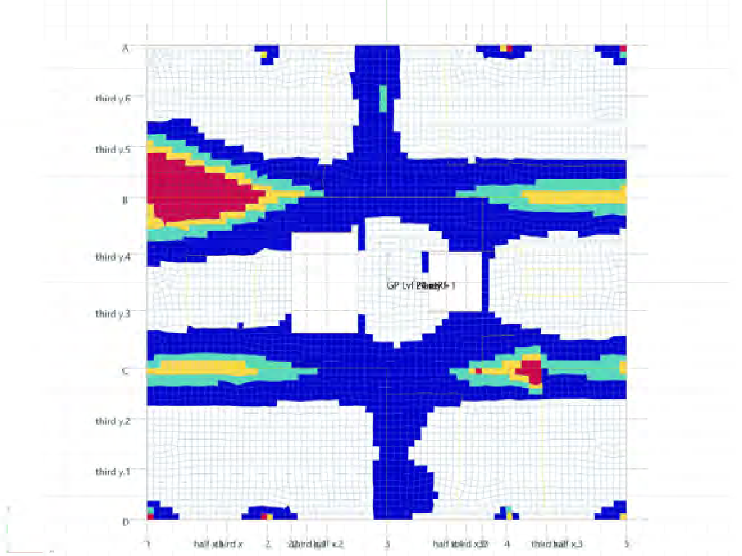
Final Design Validation
Cassette 24

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



Program GSA Version 10.0.0.68 Copyright © Oasys 1985-2020
cass24 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
Printed 03-Jun-2020
Page 1
Time 14:34

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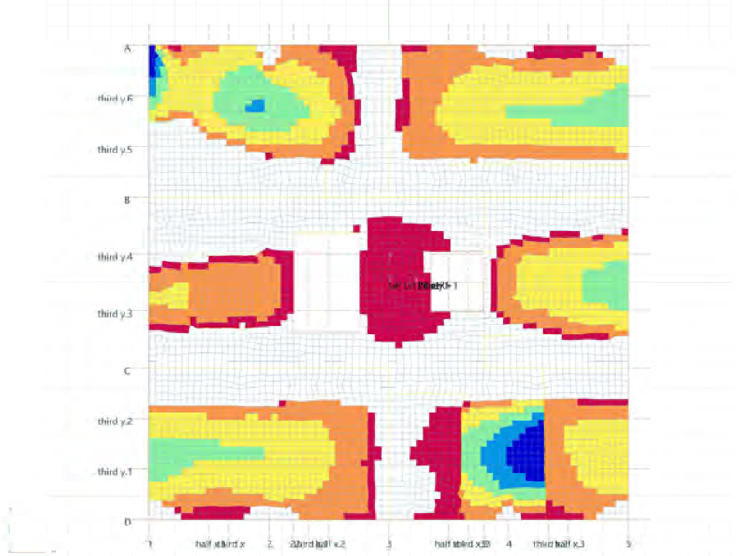
Final Design Validation
Cassette 24

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



Program GSA Version 10.0.0.68 Copyright © Oasys 1985-2020
cass24 2020-05-05 Grenfell FDV - Global model - UNANALYSED - split columns - C10 spring.gwb
Printed 03-Jun-2020
Page 1
Time 14:34

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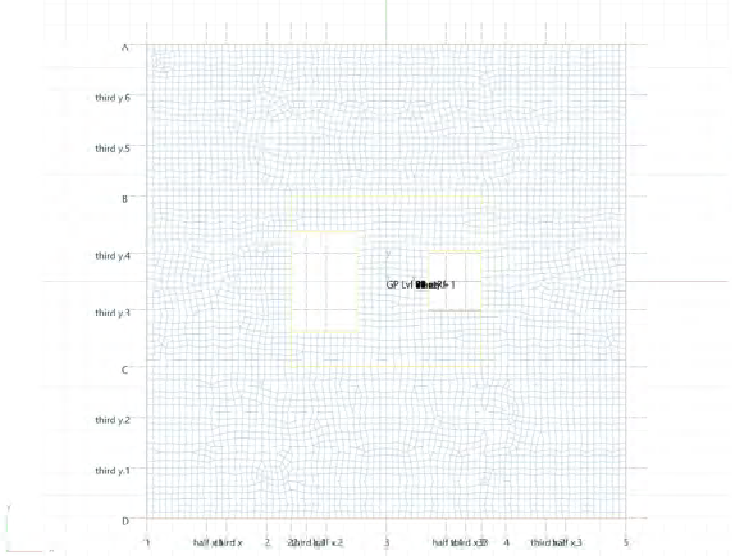
Final Design Validation
Cassette 05

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



Qmax
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
Minimum 2D Force, Nmin
Output axis: local
602 kN/m
2VRdc.adj
174 kN/m
VRdc.adj
87 kN/m
VRd.min.adj
52 kN/m
37 kN/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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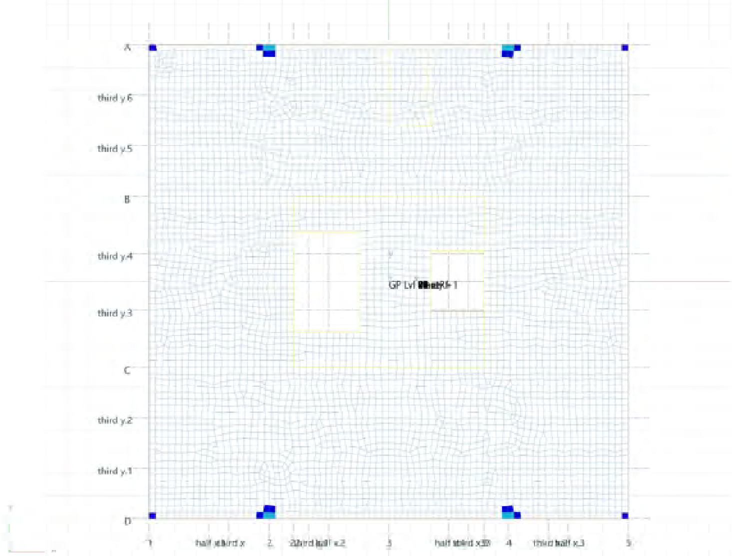
Final Design Validation
Cassette 07

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



Qmax
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
602 kNm/m
2VRdc.adj
174 kNm/m
VRdc.adj
87 kNm/m
VRd.min.adj
52 kNm/m
37 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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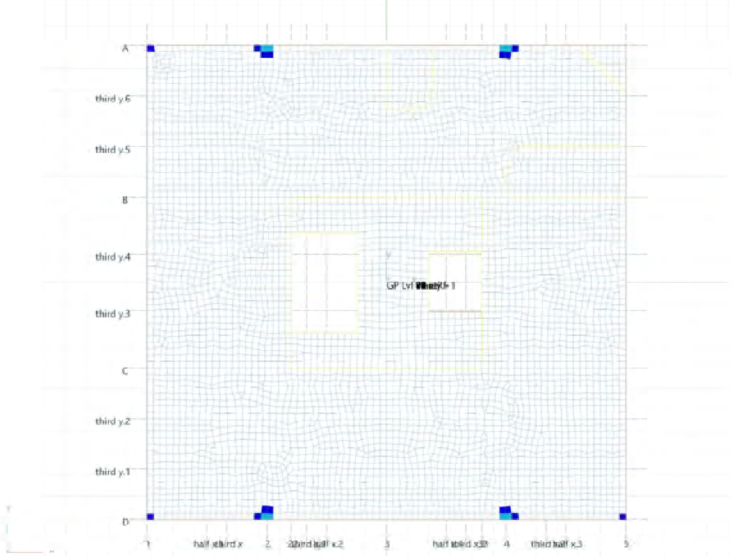
Final Design Validation
Cassette 06

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



Qmax
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
602 kNm/m
2VRdc.adj
174 kNm/m
VRdc.adj
87 kNm/m
VRd.min.adj
52 kNm/m
37 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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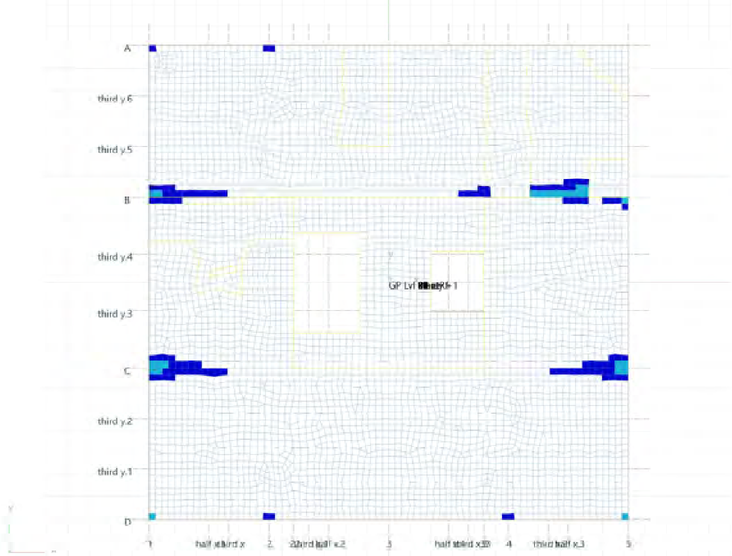
Final Design Validation
Cassette 08

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



Qmax
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
602 kNm/m
2VRdc.adj
174 kNm/m
VRdc.adj
87 kNm/m
VRd.min.adj
52 kNm/m
37 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Cassette 9

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
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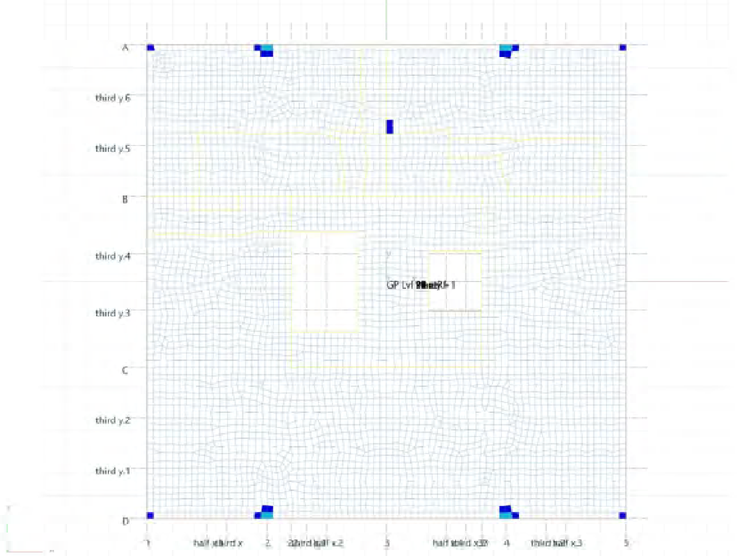

Qmax
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
602 kNm/m
2VRdc.adj
174 kNm/m
VRdc.adj
87 kNm/m
VRd.min.adj
52 kNm/m
37 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Cassette 11

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
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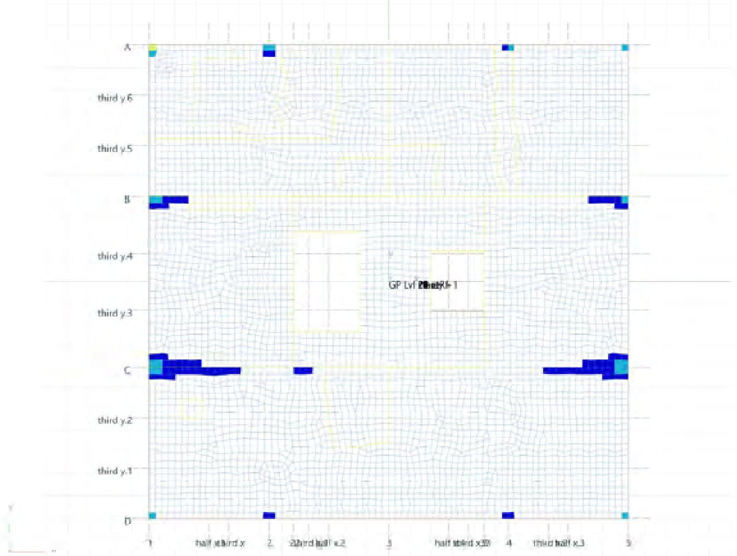

Qmax
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |My|+|Myx|
Output axis: global
602 kNm/m
2VRdc.adj
174 kNm/m
VRdc.adj
87 kNm/m
VRd.min.adj
52 kNm/m
37 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Cassette 10

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
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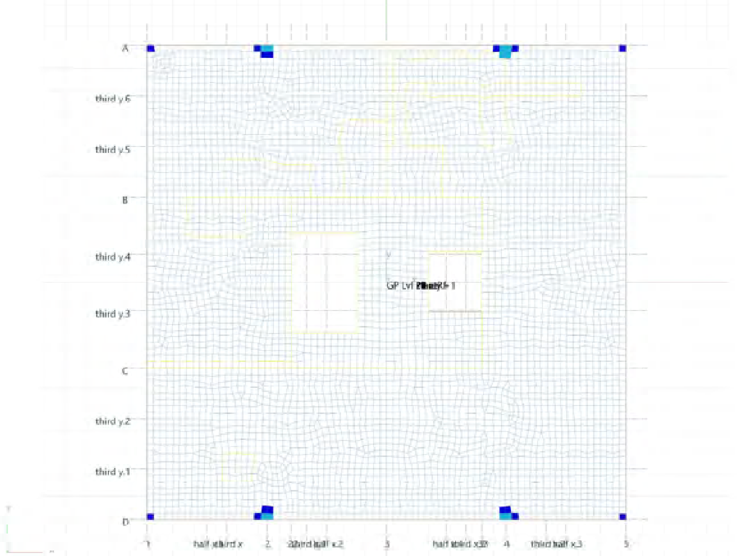

Qmax
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
602 kNm/m
2VRdc.adj
174 kNm/m
VRdc.adj
87 kNm/m
VRd.min.adj
52 kNm/m
37 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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Cassette 12

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
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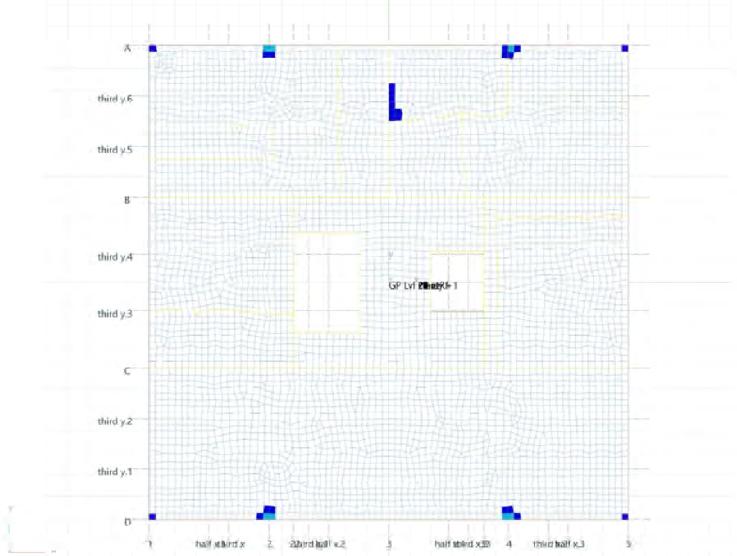

Qmax
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
602 kNm/m
2VRdc.adj
174 kNm/m
VRdc.adj
87 kNm/m
VRd.min.adj
52 kNm/m
37 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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5186875		

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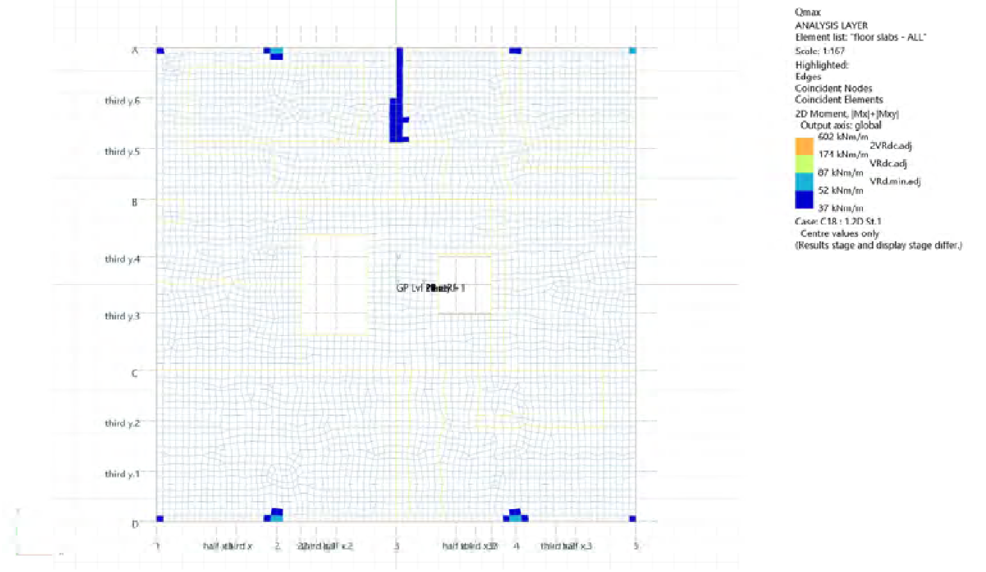
Cassette 13



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Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

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ASF	06-Mar-2020	

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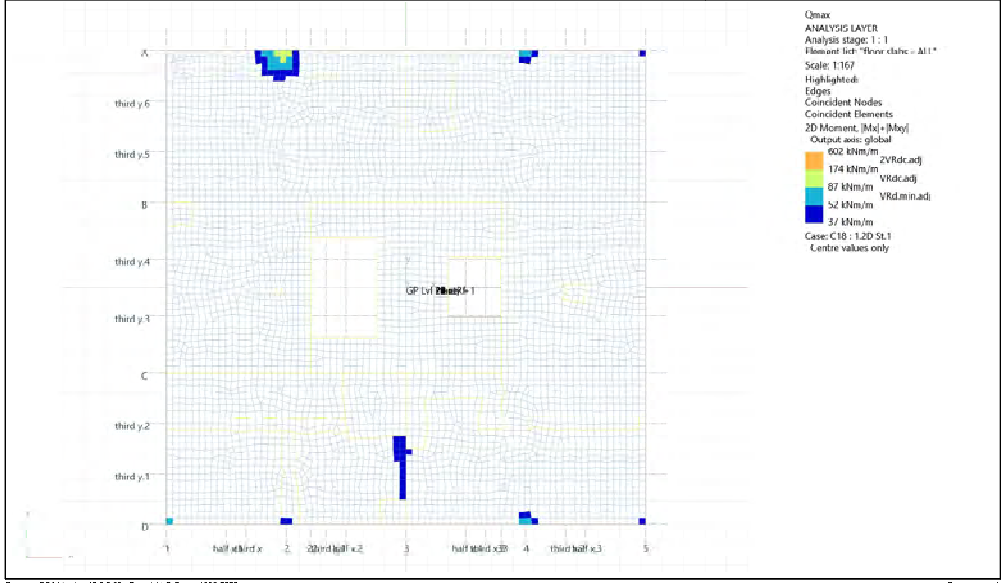
Final Design Validation
Cassette 16



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Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

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ASF	06-Mar-2020	

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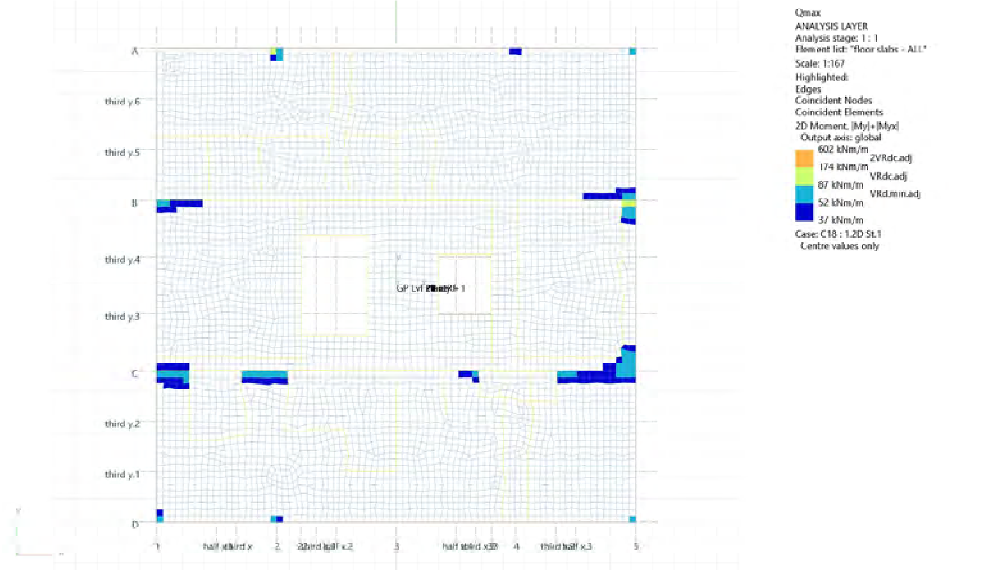
Final Design Validation
Cassette 14



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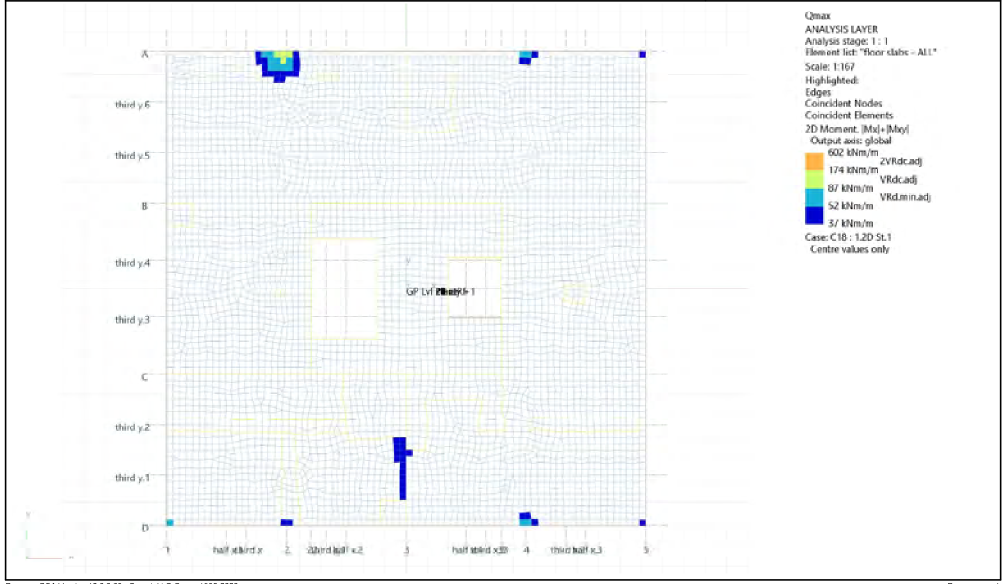
Job No.	Sheet No.	Rev.
5186875		

Drg. Ref.

Made by	Date	Checked
ASF	06-Mar-2020	

MHCLG Grenfell Tower
Final Design Validation
Cassette 16



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Job No.	Sheet No.	Rev.
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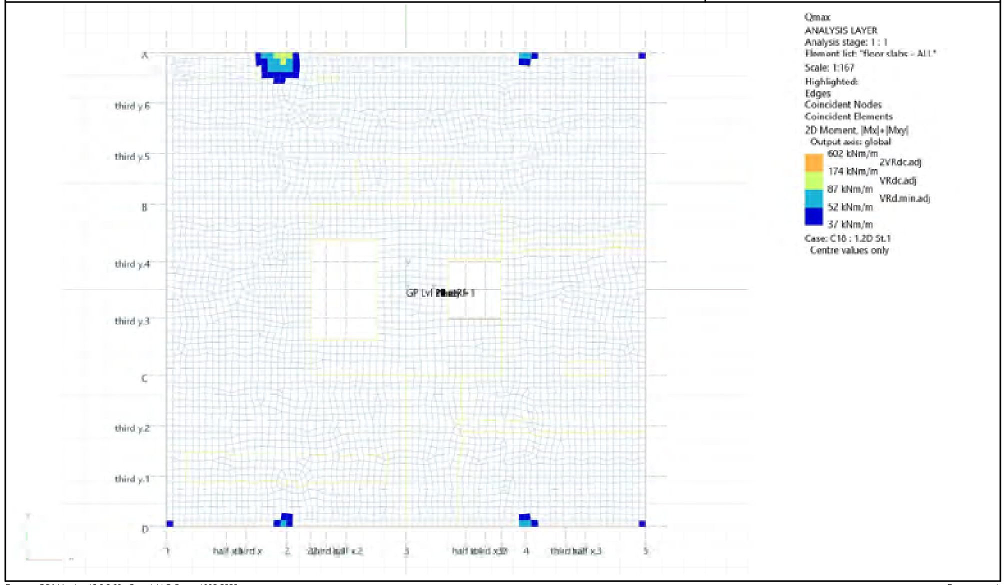
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



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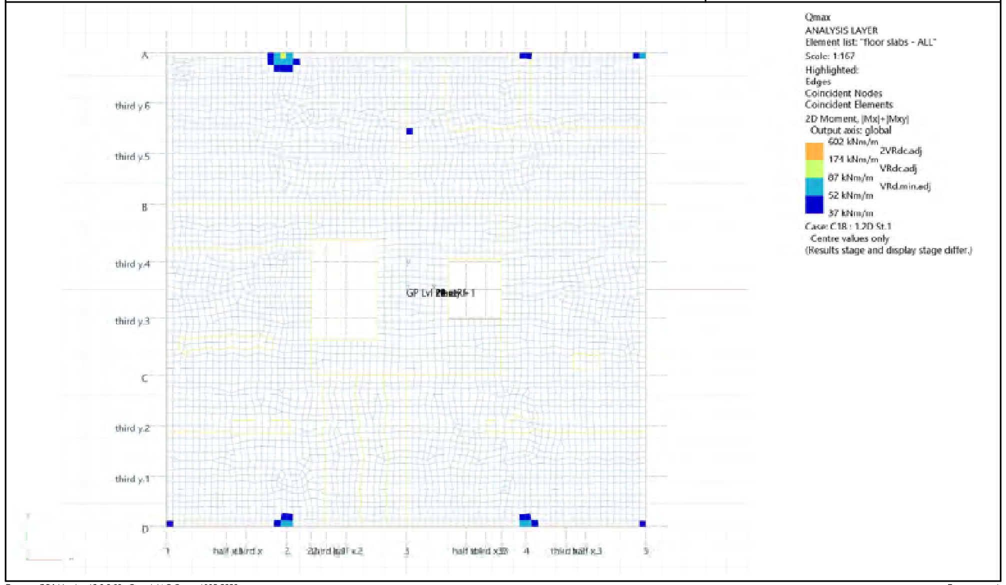
MHCLG Grenfell Tower
Final Design Validation
Cassette 19

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



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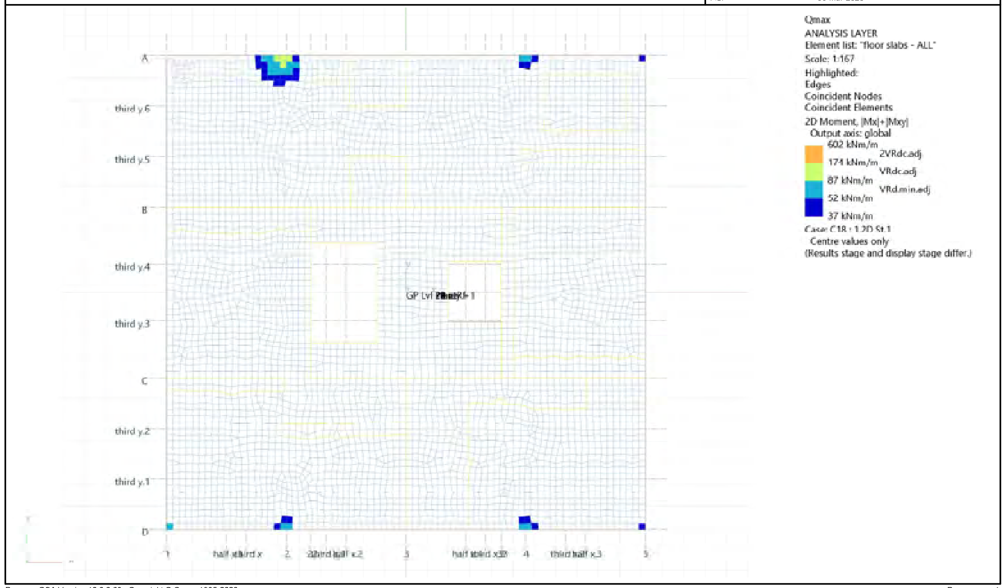
MHCLG Grenfell Tower
Final Design Validation
Cassette 18

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



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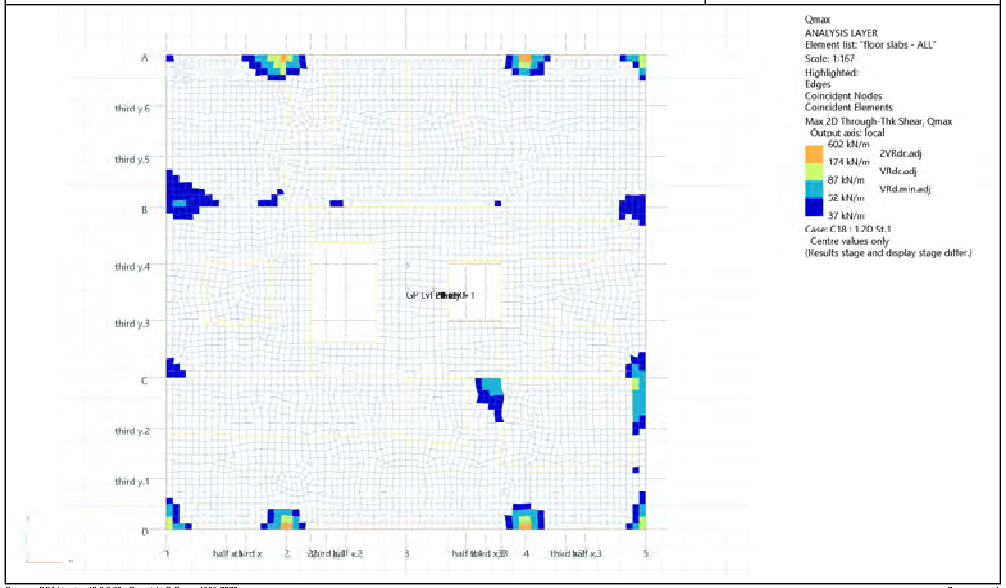
MHCLG Grenfell Tower
Final Design Validation
Cassette 20

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



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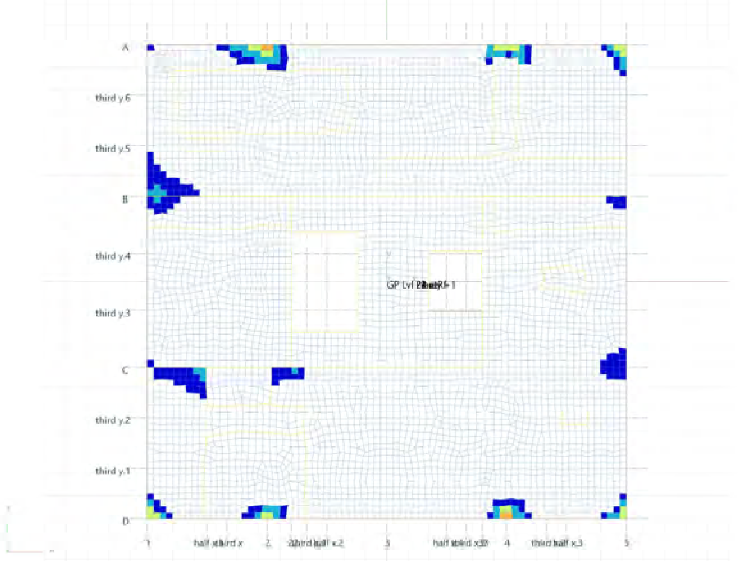
MHCLG Grenfell Tower
Final Design Validation
Cassette 21

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



Qmax
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
Max 2D Through-Thk Shear, Qmax
Output axis: local
602 kN/m
2VRdc.adj
174 kN/m
VRdc.adj
87 kN/m
VRd.min.adj
52 kN/m
37 kN/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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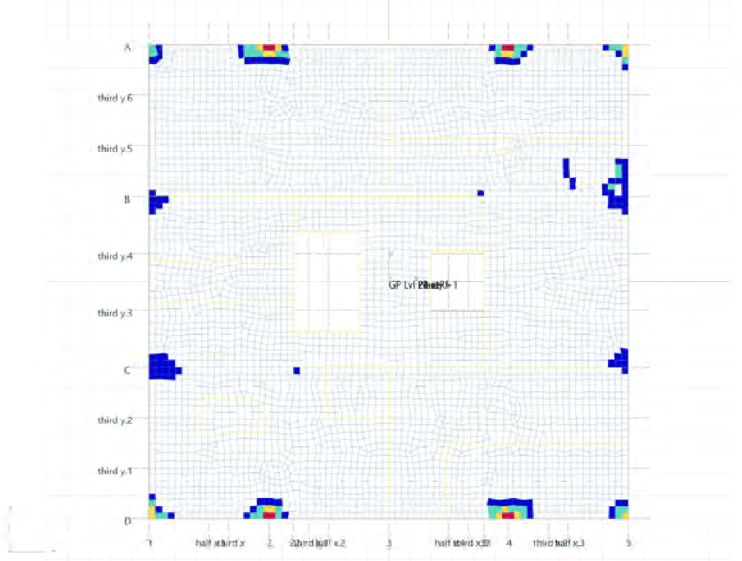
MHCLG Grenfell Tower
Final Design Validation
Cassette 23

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



Qmax
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
Max 2D Through-Thk Shear, Qmax
Output axis: local
602 kN/m
VRd.max.adj
174 kN/m
2VRdc.adj
87 kN/m
VRdc.adj
52 kN/m
VRd.min.adj
37 kN/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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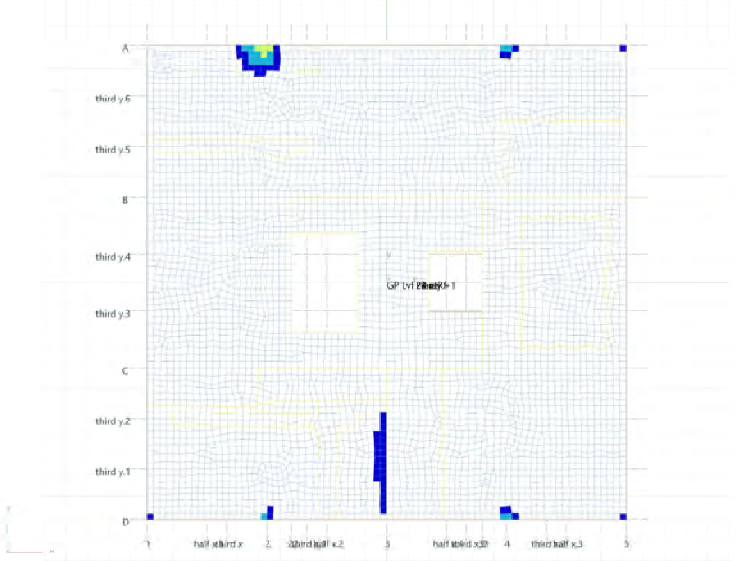
MHCLG Grenfell Tower
Final Design Validation
Cassette 22

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked



Qmax
ANALYSIS LAYER
Element list: "floor slabs - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
2D Moment, |Mx|+|Mxy|
Output axis: global
602 kNm/m
2VRdc.adj
174 kNm/m
VRdc.adj
87 kNm/m
VRd.min.adj
52 kNm/m
37 kNm/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

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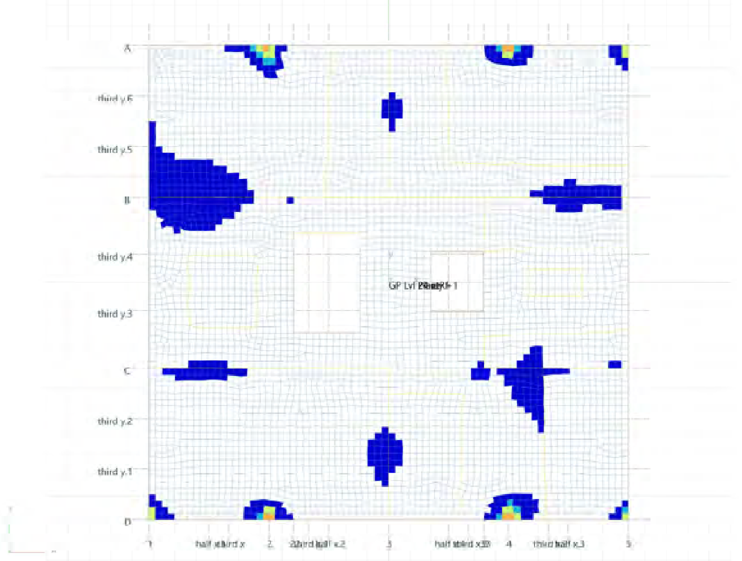
MHCLG Grenfell Tower
Final Design Validation
Cassette 24

Job No.	Sheet No.	Rev.
5186875		
Drg. Ref.		
Made by ASF	Date 06-Mar-2020	Checked

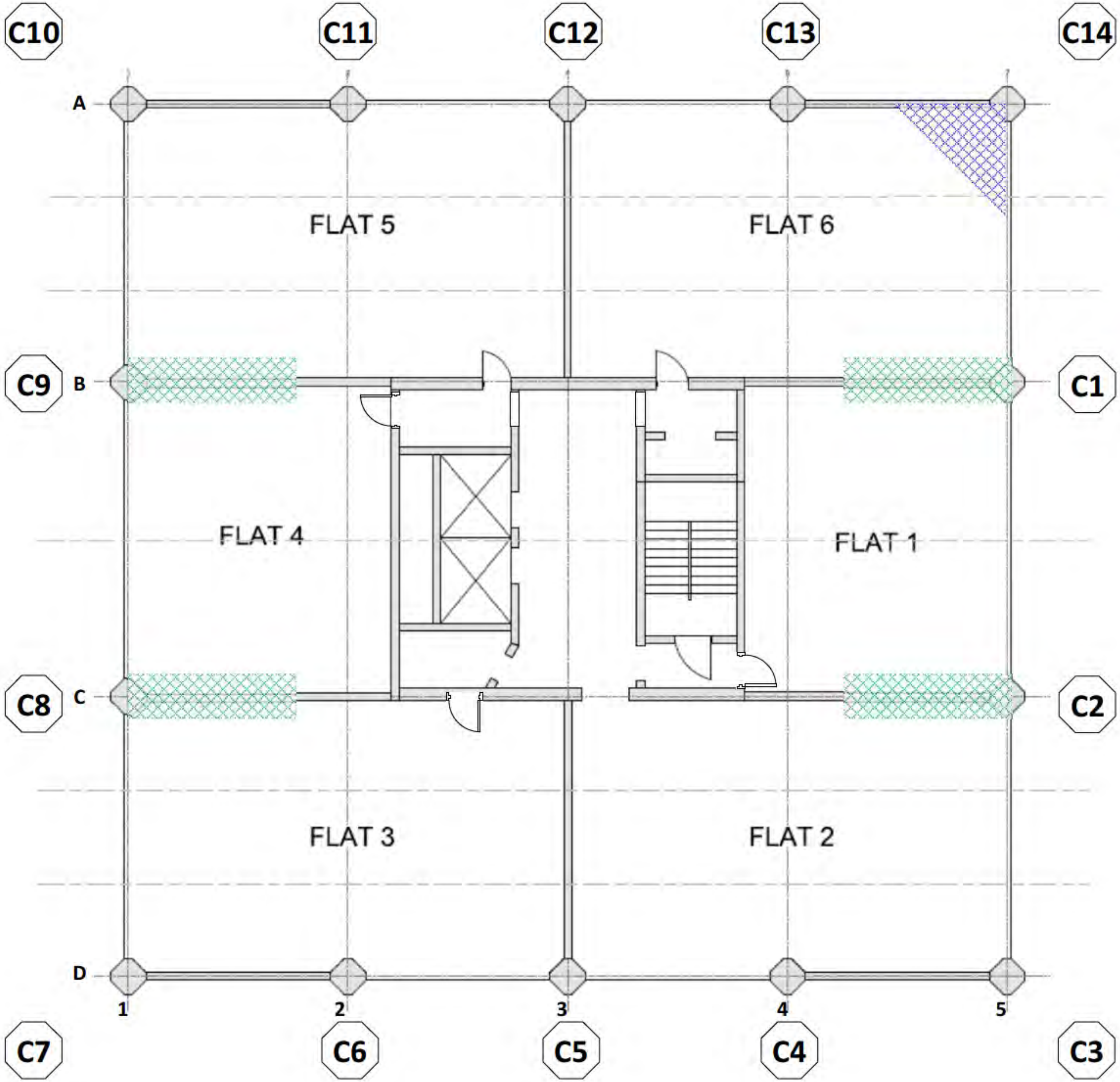


Qmax
ANALYSIS LAYER
Element list: "floorplates - ALL"
Scale: 1:167
Highlighted:
Edges
Coincident Nodes
Coincident Elements
Max 2D Through-Thk Shear, Qmax
Output axis: local
2268 kN/m
385 kN/m
193 kN/m
154 kN/m
75 kN/m
Case: C18 : 1.2D St.1
Centre values only
(Results stage and display stage differ.)

Appendix C. Interpretation of analysis

C.1. Introduction

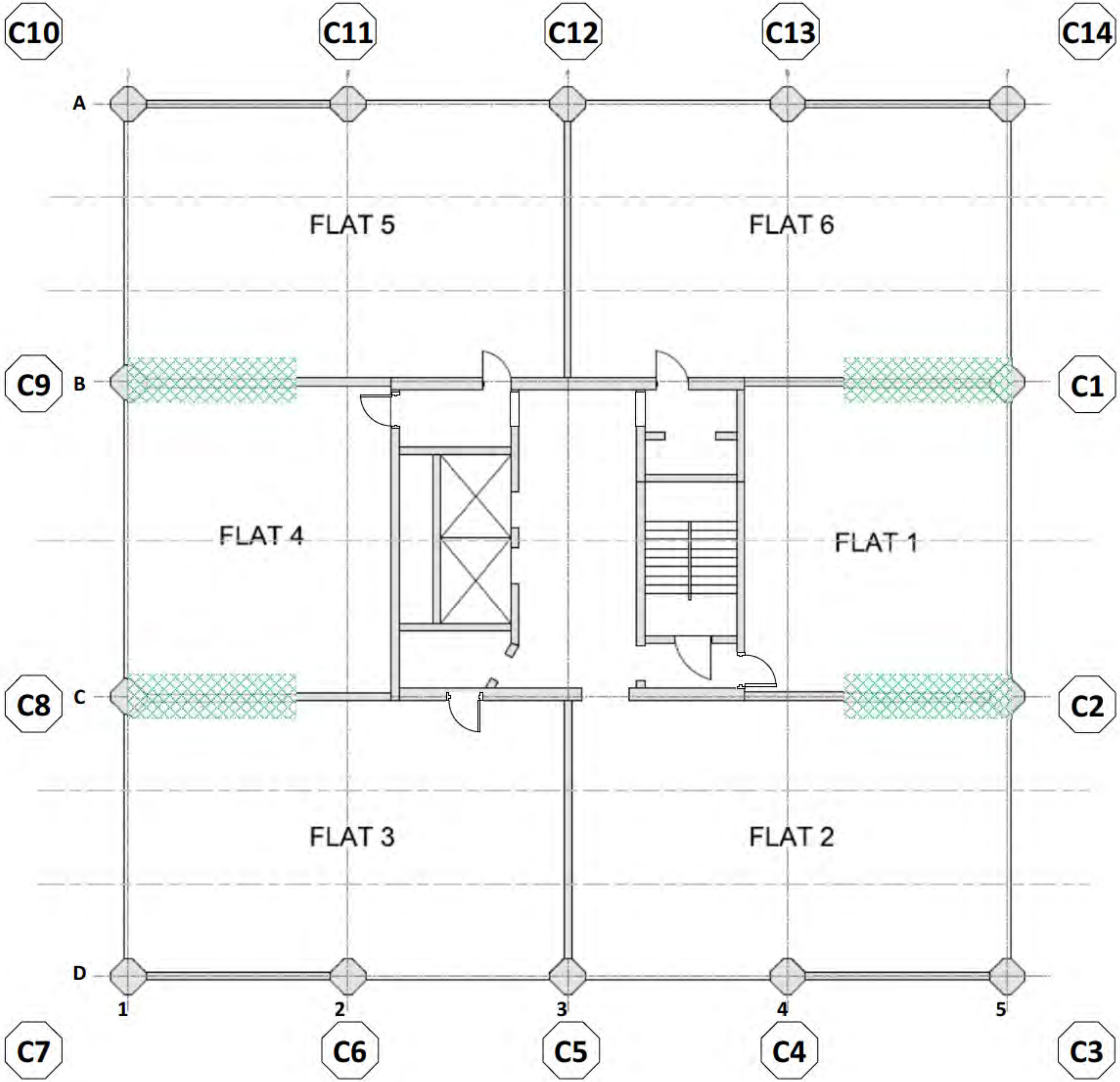
The diagrams in this Appendix interpret the results of the analysis and indicate where the slabs are overstressed and that it is expected that the temporary works design be able to support the slab zones in question.



Slab at **Lvl 06**

KEY

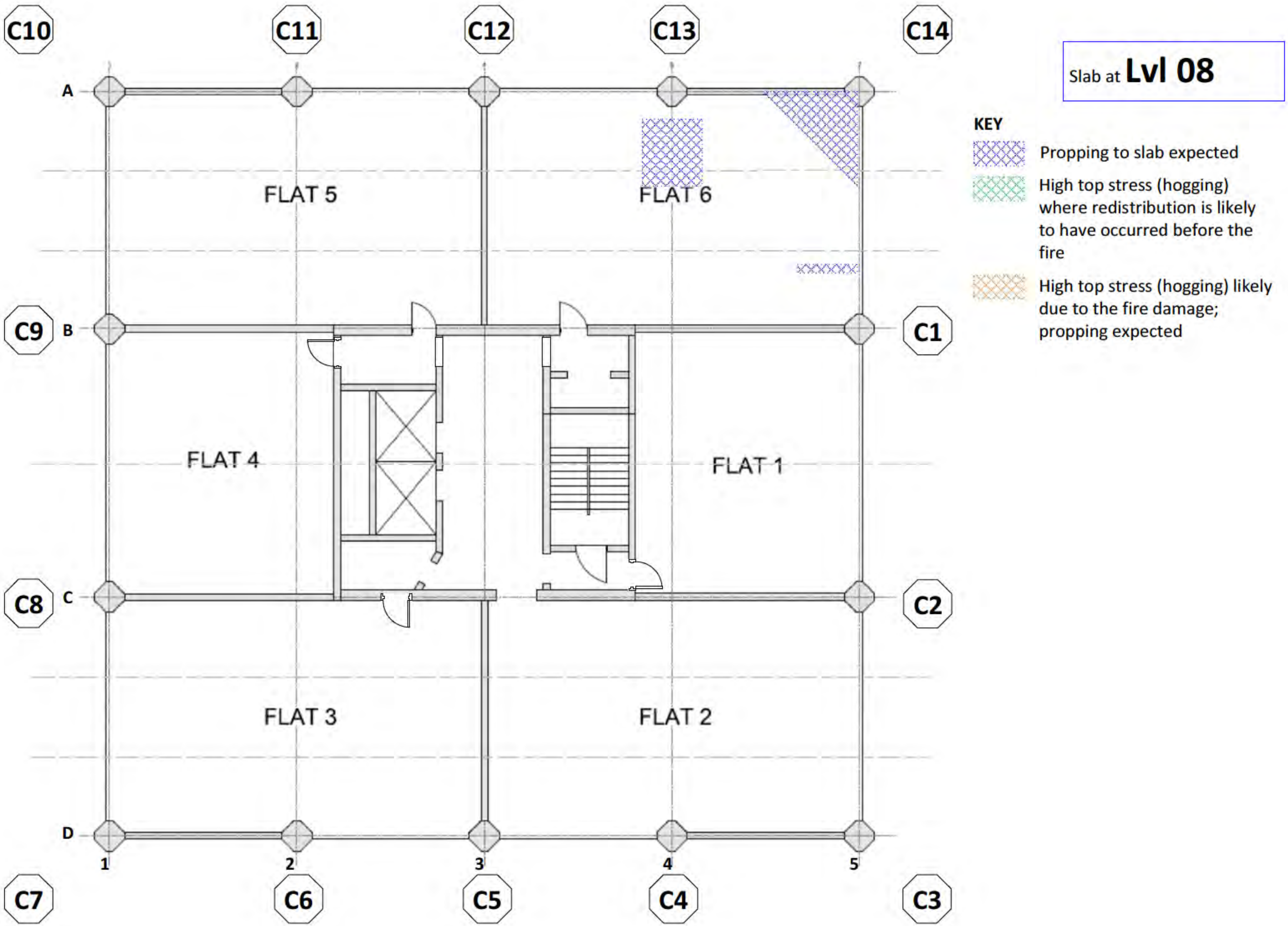
- Propping to slab expected
- High top stress (hogging) where redistribution is likely to have occurred before the fire
- High top stress (hogging) likely due to the fire damage; propping expected



Slab at **Lvl 07**

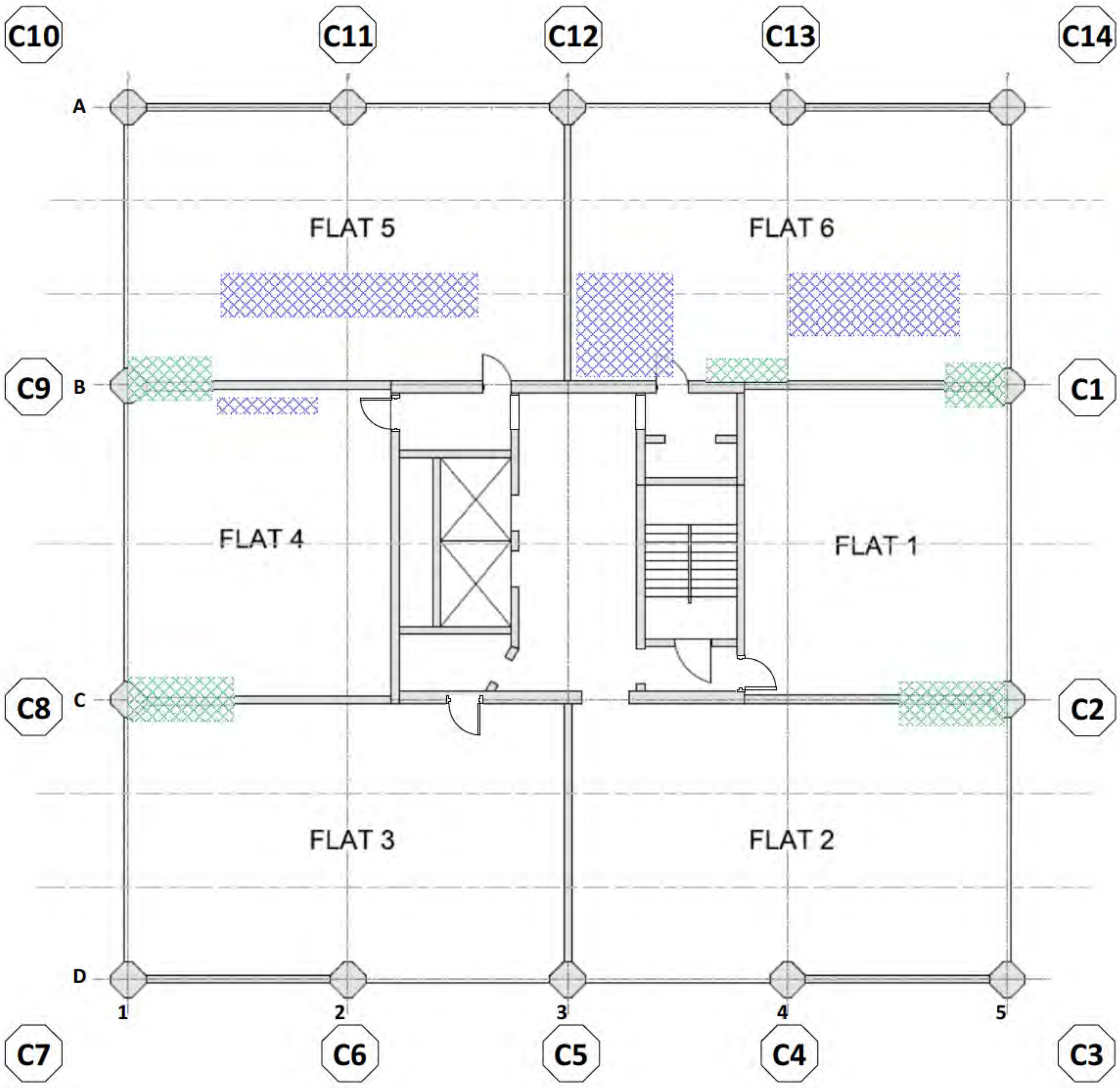
KEY

- Propping to slab expected
- High top stress (hogging) where redistribution is likely to have occurred before the fire
- High top stress (hogging) likely due to the fire damage; propping expected



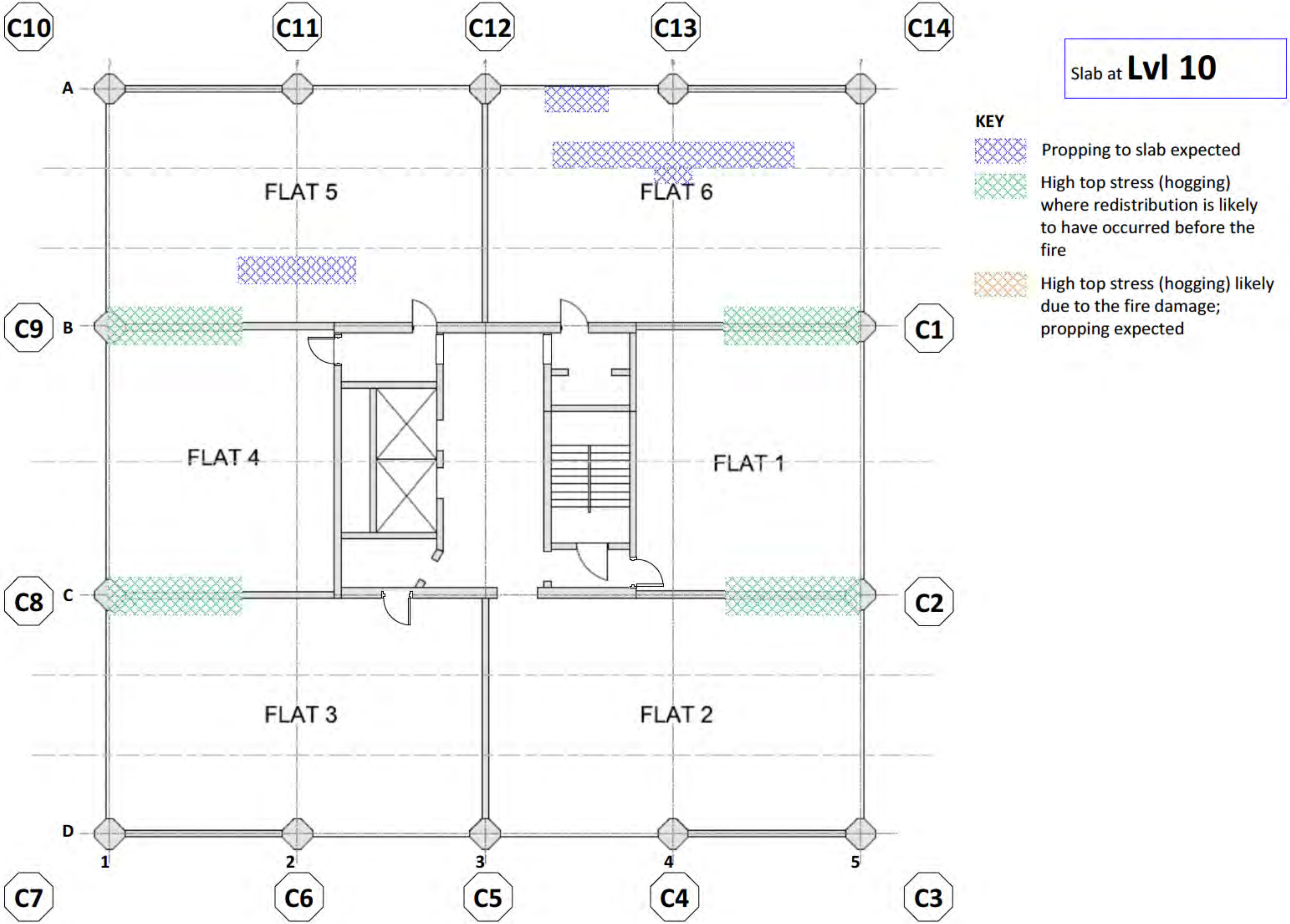
Slab at Lvl 08
KEY
Propping to slab expected
High top stress (hogging) where redistribution is likely to have occurred before the fire
High top stress (hogging) likely due to the fire damage; propping expected
C10
C11
C12
C13
C14
C9
C1
C8
C2
C7
C6
C5
C4
C3
A
B
C
D
1
2
3
4
5
FLAT 5
FLAT 6
FLAT 4
FLAT 1
FLAT 3
FLAT 2

Slab at **Lvl 09**



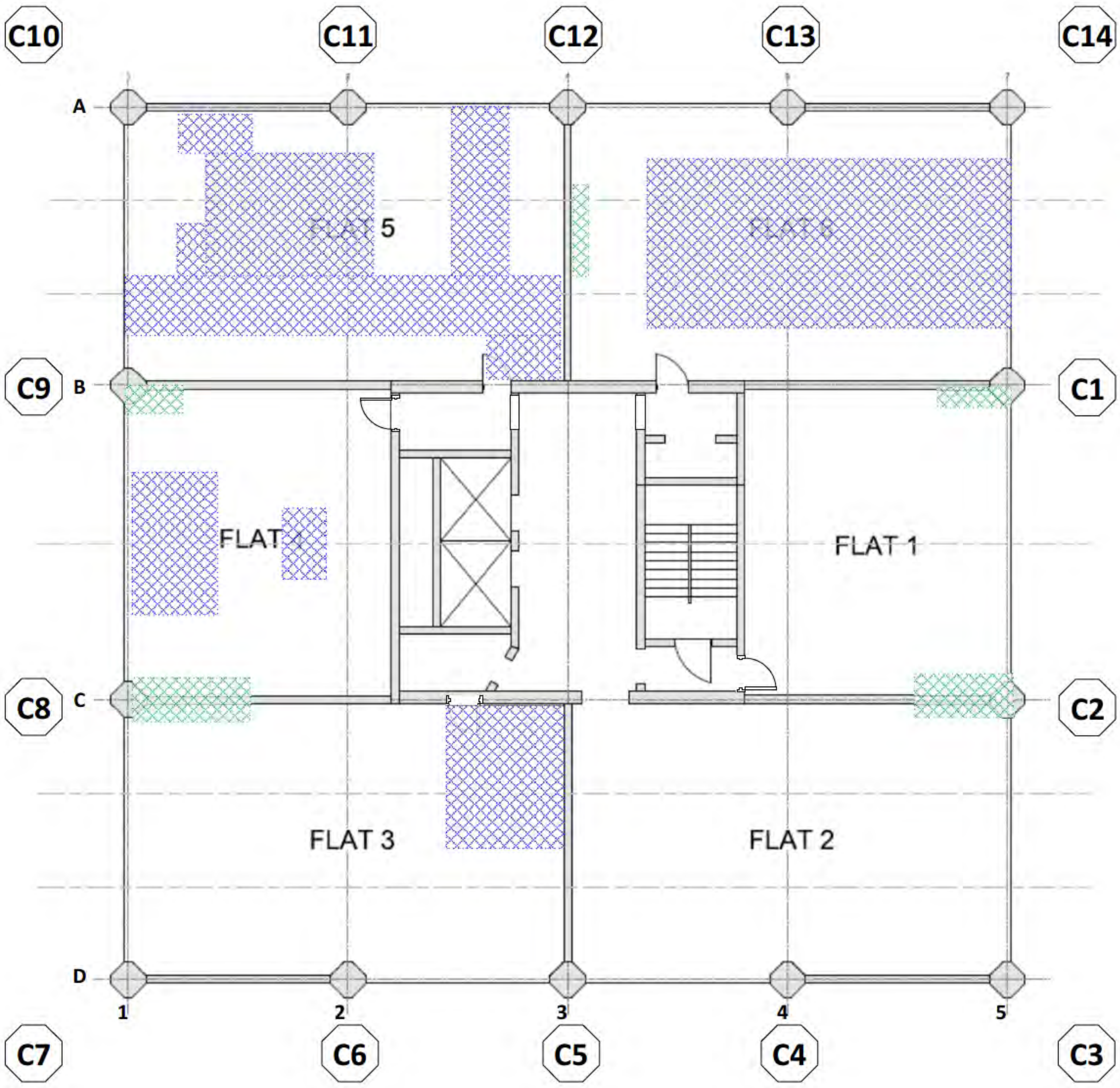
KEY

- Propping to slab expected
- High top stress (hogging) where redistribution is likely to have occurred before the fire
- High top stress (hogging) likely due to the fire damage; propping expected



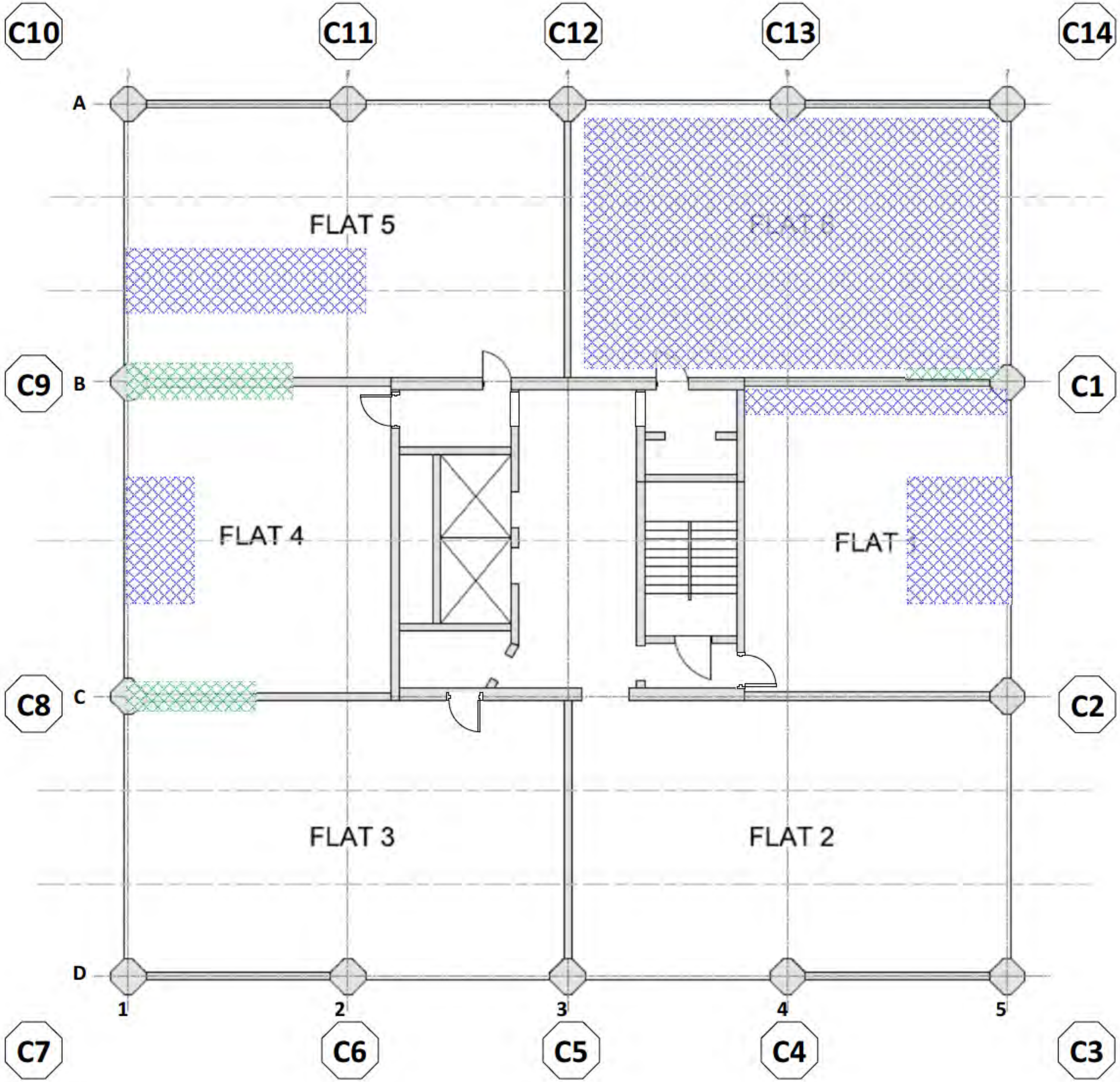
C10
C11
C12
C13
C14
Slab at Lvl 10
KEY
Propping to slab expected
High top stress (hogging) where redistribution is likely to have occurred before the fire
High top stress (hogging) likely due to the fire damage; propping expected
A
B
C
D
1
2
3
4
5
FLAT 5
FLAT 6
FLAT 4
FLAT 1
FLAT 3
FLAT 2
C9
C1
C8
C2
C7
C6
C5
C4
C3

Slab at **Lvl 11**



KEY

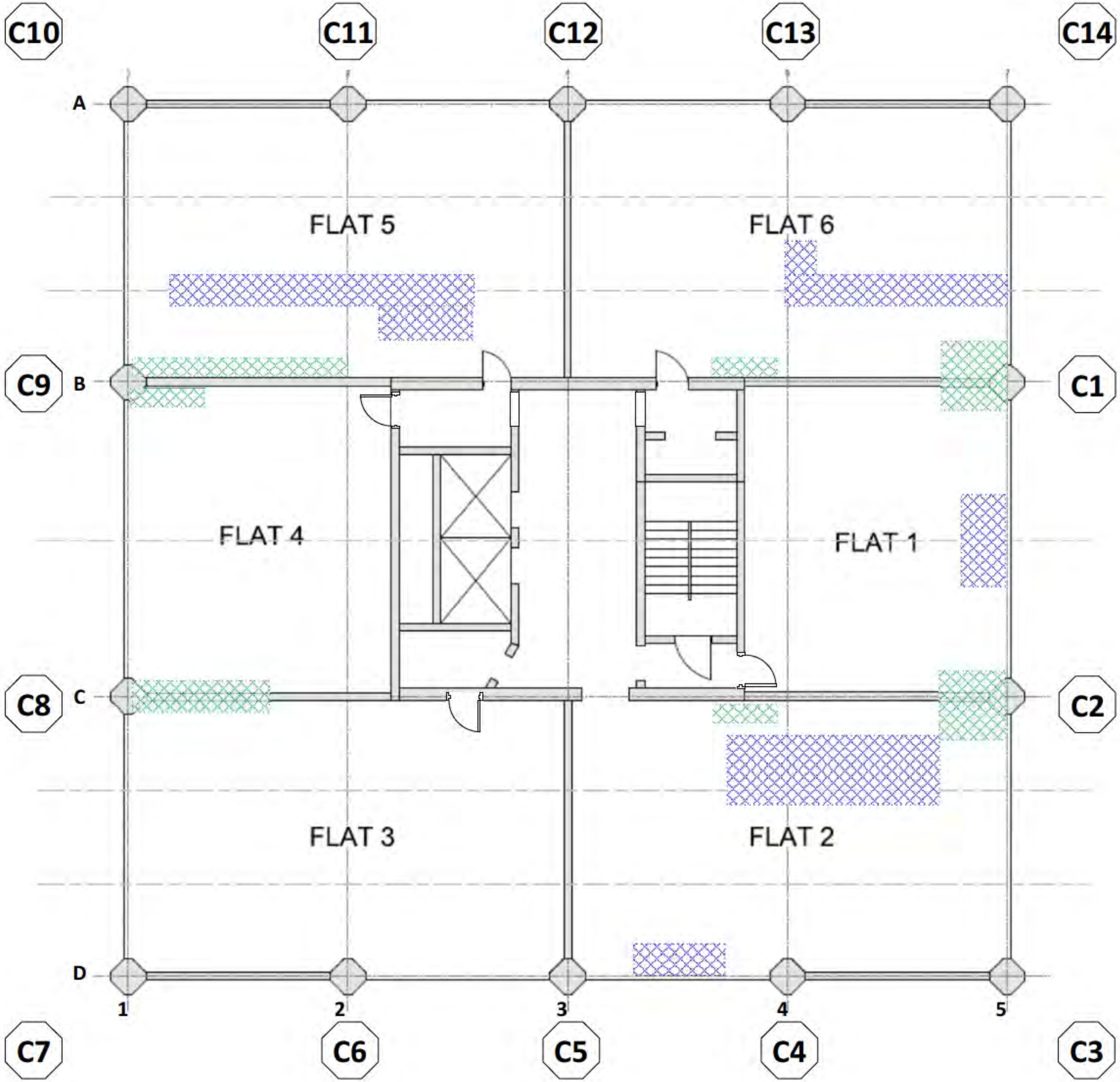
- Propping to slab expected
- High top stress (hogging) where redistribution is likely to have occurred before the fire
- High top stress (hogging) likely due to the fire damage; propping expected



Slab at **Lvl 12**

KEY

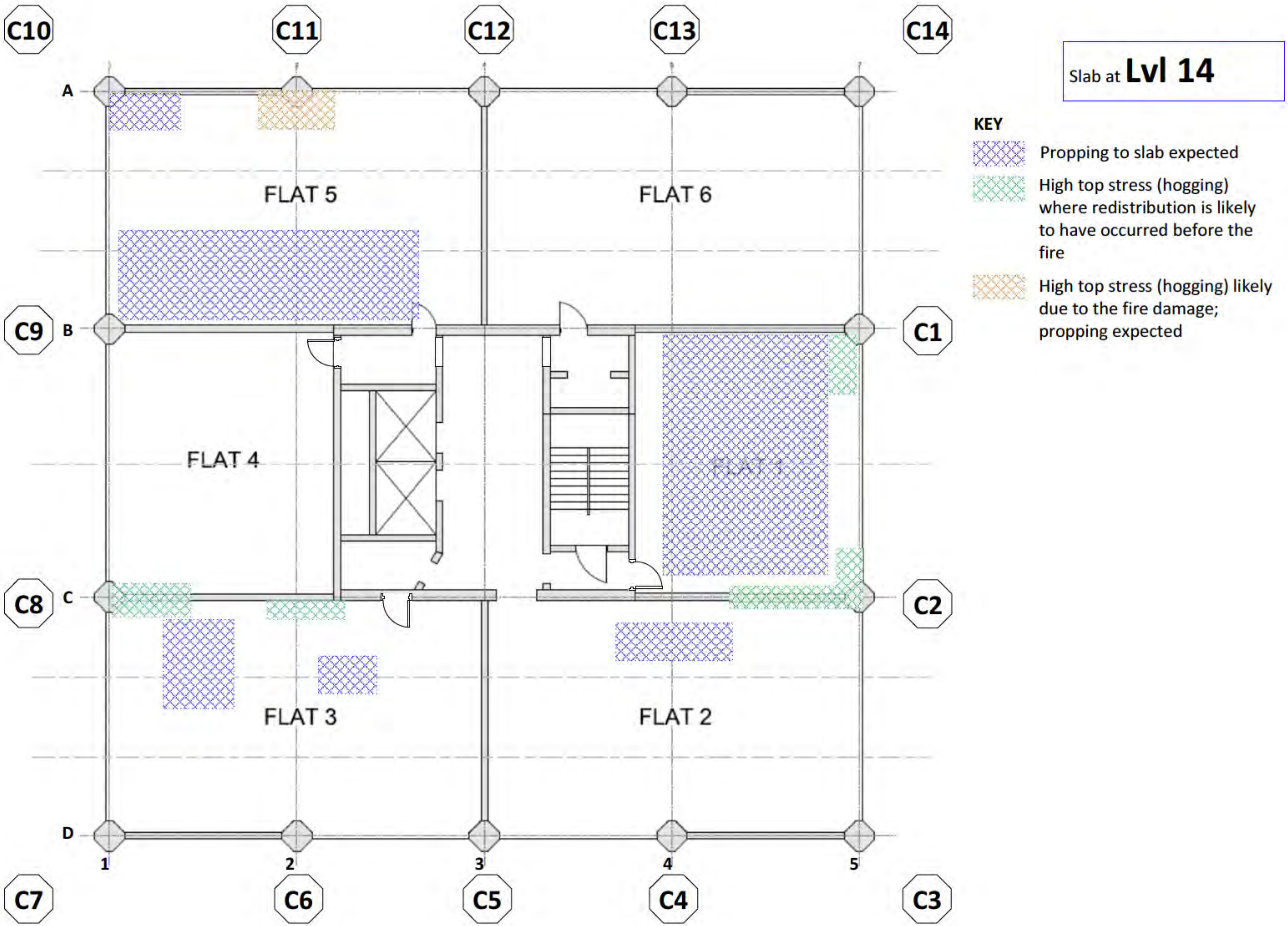
- Propping to slab expected
- High top stress (hogging) where redistribution is likely to have occurred before the fire
- High top stress (hogging) likely due to the fire damage; propping expected

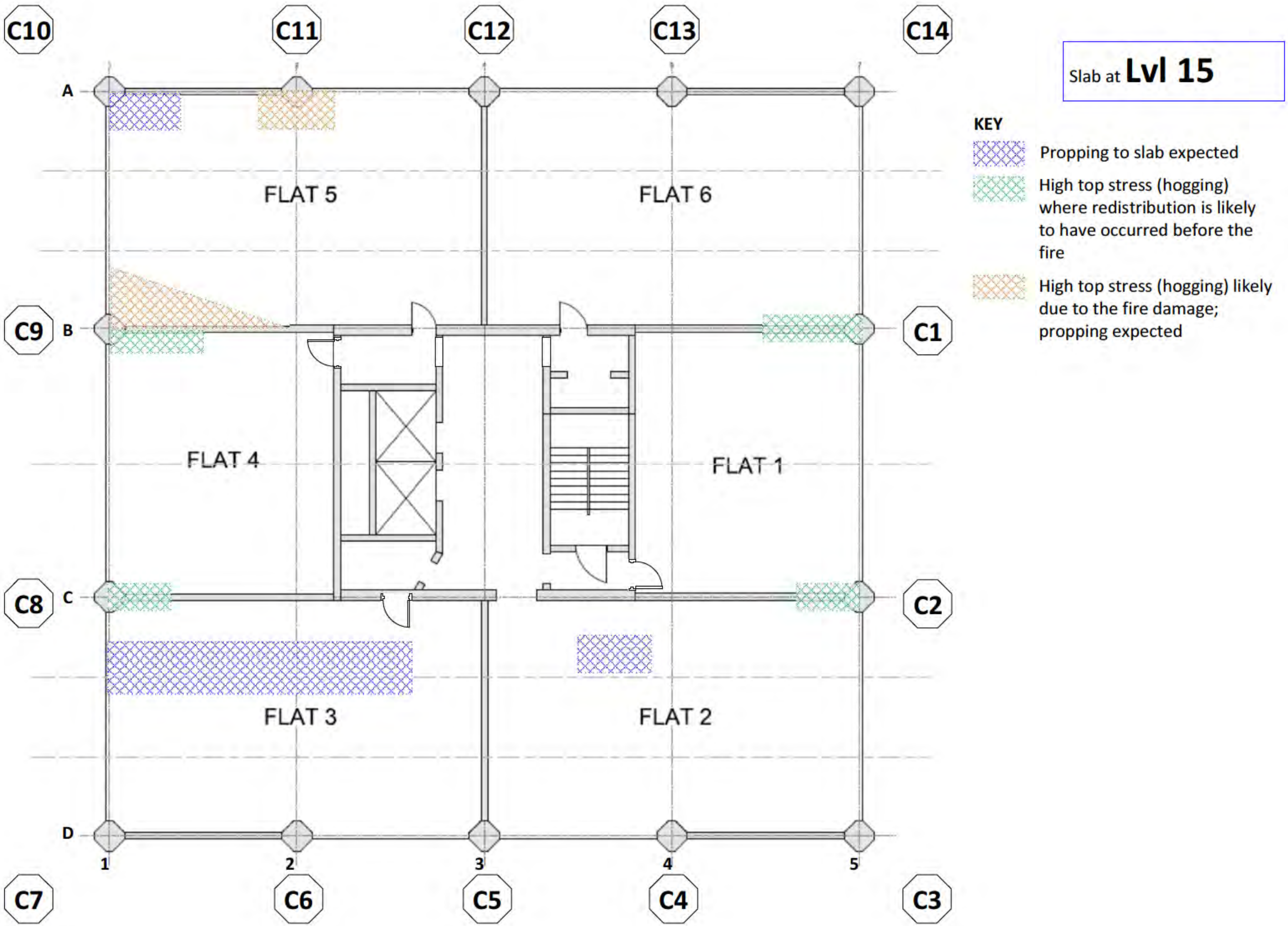


Slab at **Lvl 13**

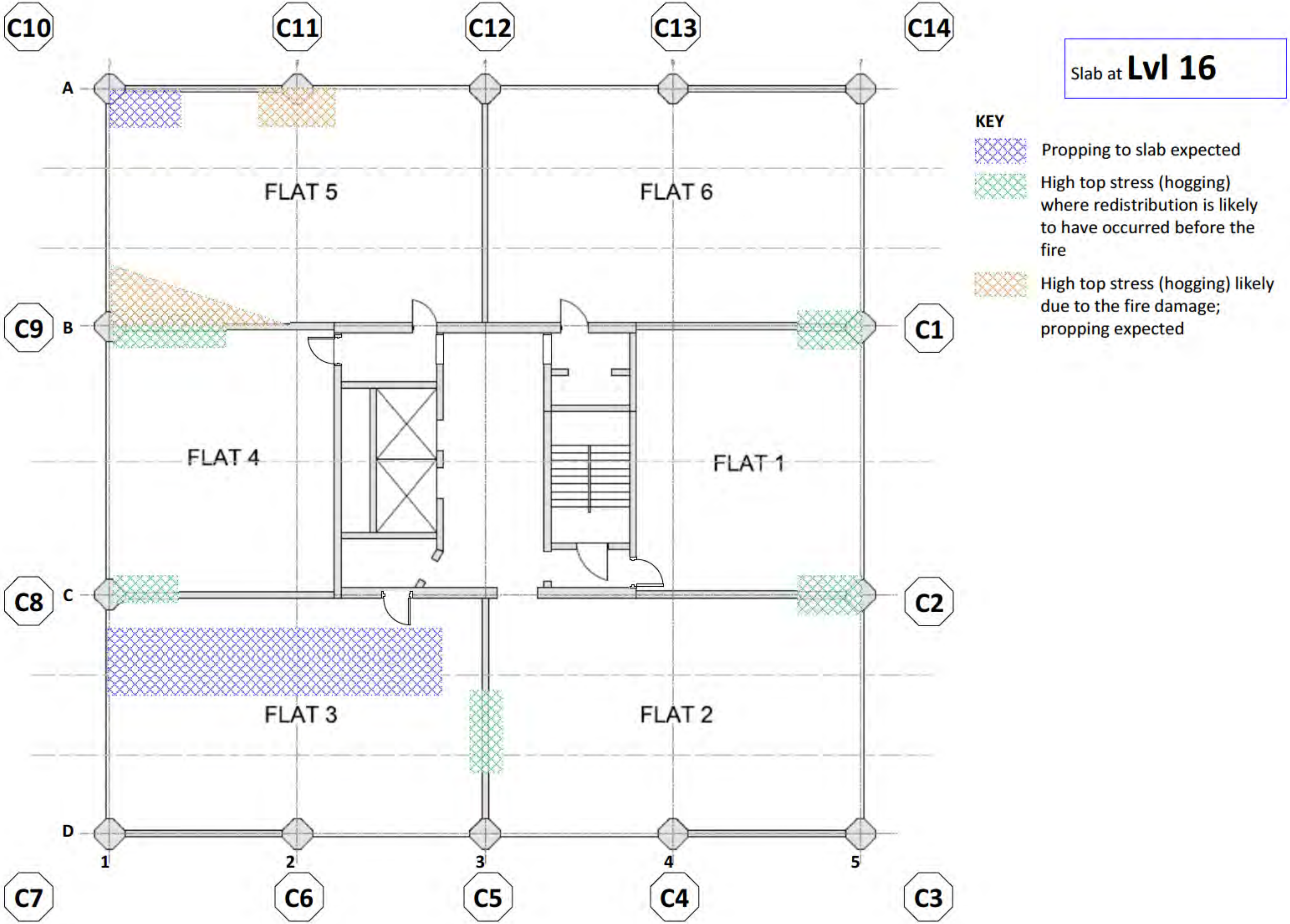
KEY

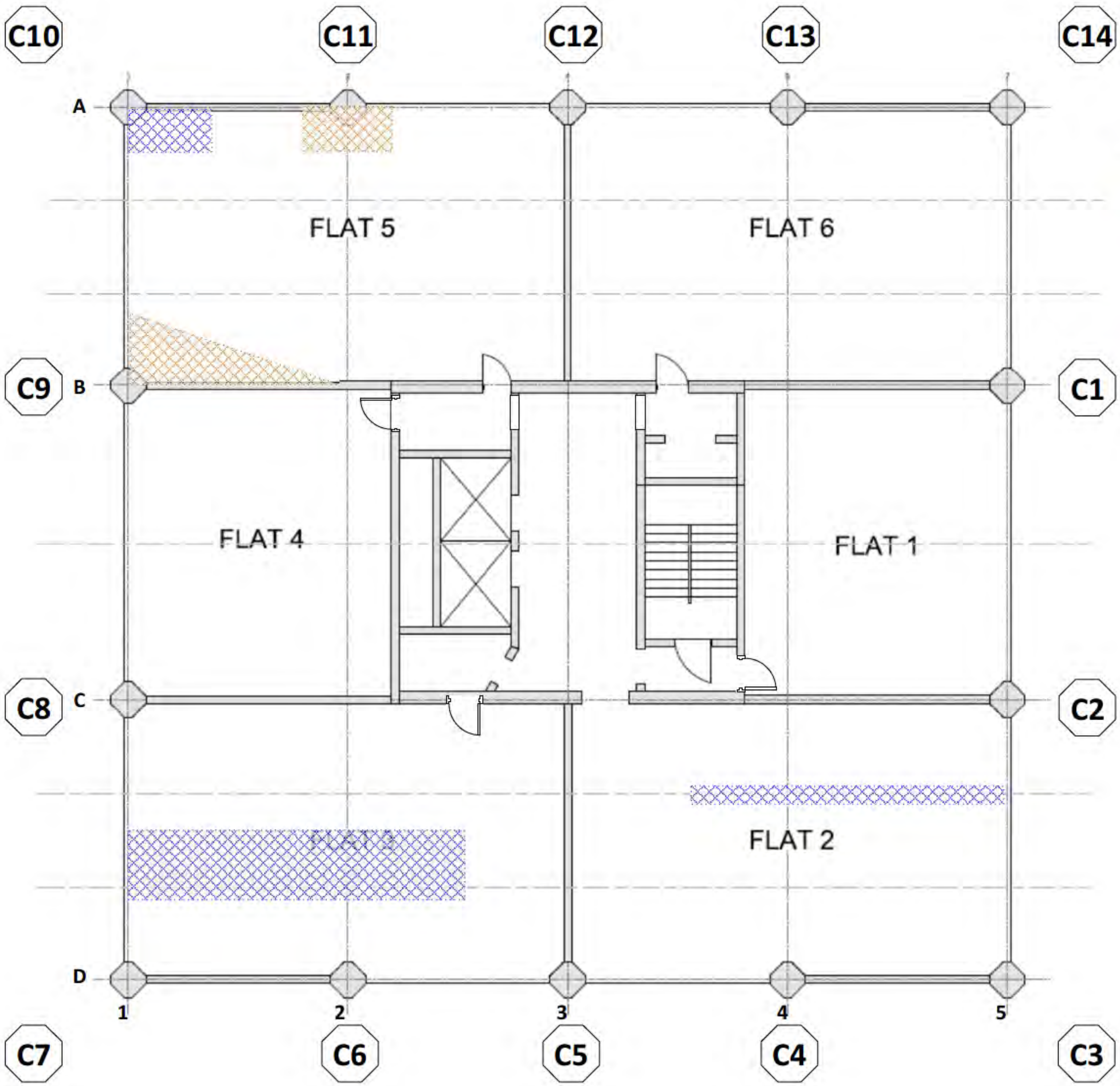
- Propping to slab expected
- High top stress (hogging) where redistribution is likely to have occurred before the fire
- High top stress (hogging) likely due to the fire damage; propping expected


Slab at Lvl 14
KEY
Propping to slab expected
High top stress (hogging) where redistribution is likely to have occurred before the fire
High top stress (hogging) likely due to the fire damage; propping expected
C10
C11
C12
C13
C14
C9
C1
C8
C2
C7
C6
C5
C4
C3
A
B
C
D
1
2
3
4
5
FLAT 5
FLAT 6
FLAT 4
FLAT 1
FLAT 3
FLAT 2



Slab at Lvl 15
KEY
Propping to slab expected
High top stress (hogging) where redistribution is likely to have occurred before the fire
High top stress (hogging) likely due to the fire damage; propping expected
C10
C11
C12
C13
C14
A
B
C
D
1
2
3
4
5
C9
C1
C8
C2
C7
C6
C5
C4
C3
FLAT 5
FLAT 6
FLAT 4
FLAT 1
FLAT 3
FLAT 2


Slab at Lvl 16
KEY
Propping to slab expected
High top stress (hogging) where redistribution is likely to have occurred before the fire
High top stress (hogging) likely due to the fire damage; propping expected
C10
C11
C12
C13
C14
C9
C1
C8
C2
C7
C6
C5
C4
C3
A
B
C
D
1
2
3
4
5
FLAT 5
FLAT 6
FLAT 4
FLAT 1
FLAT 3
FLAT 2

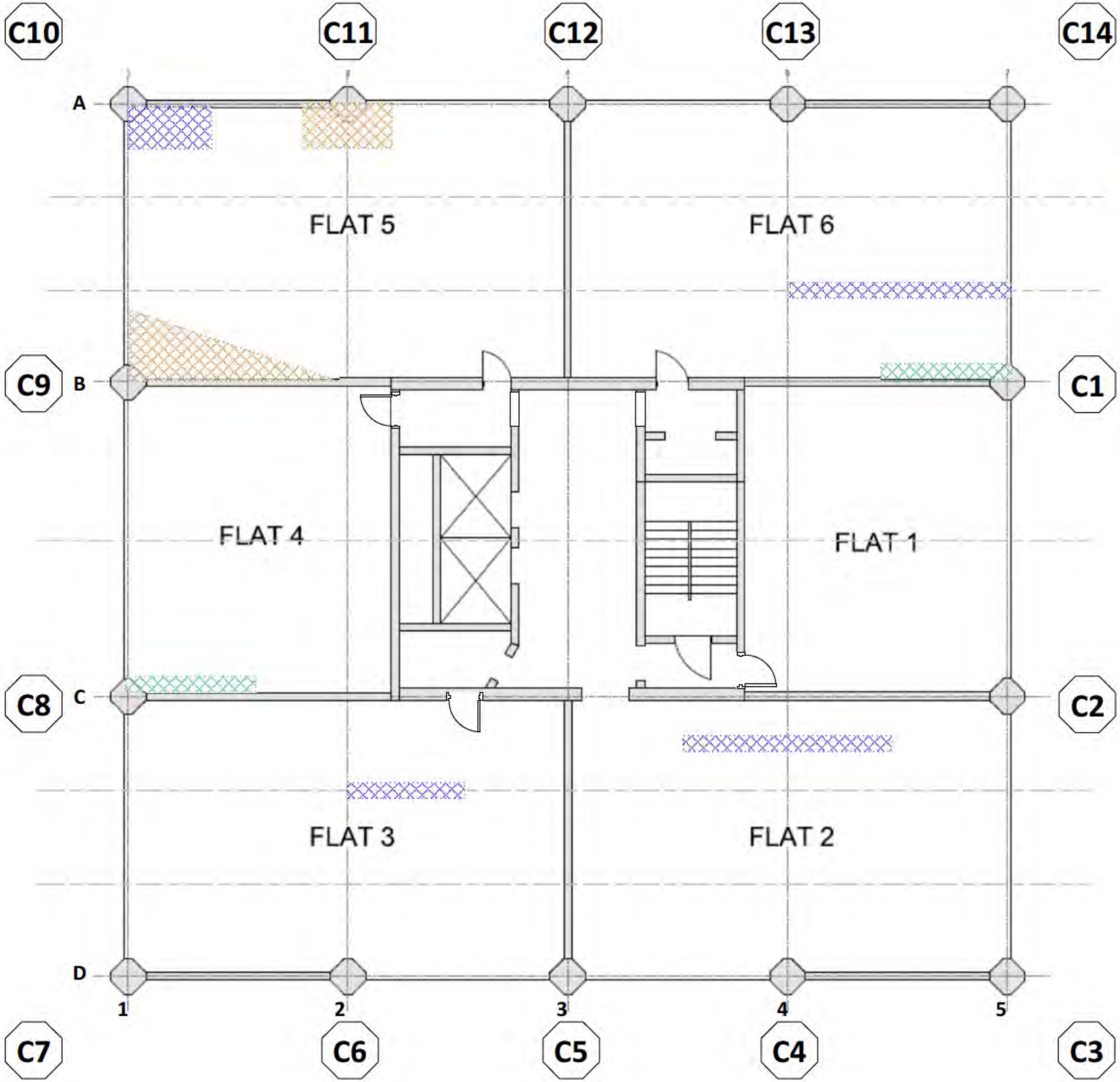


Slab at **Lvl 17**

KEY

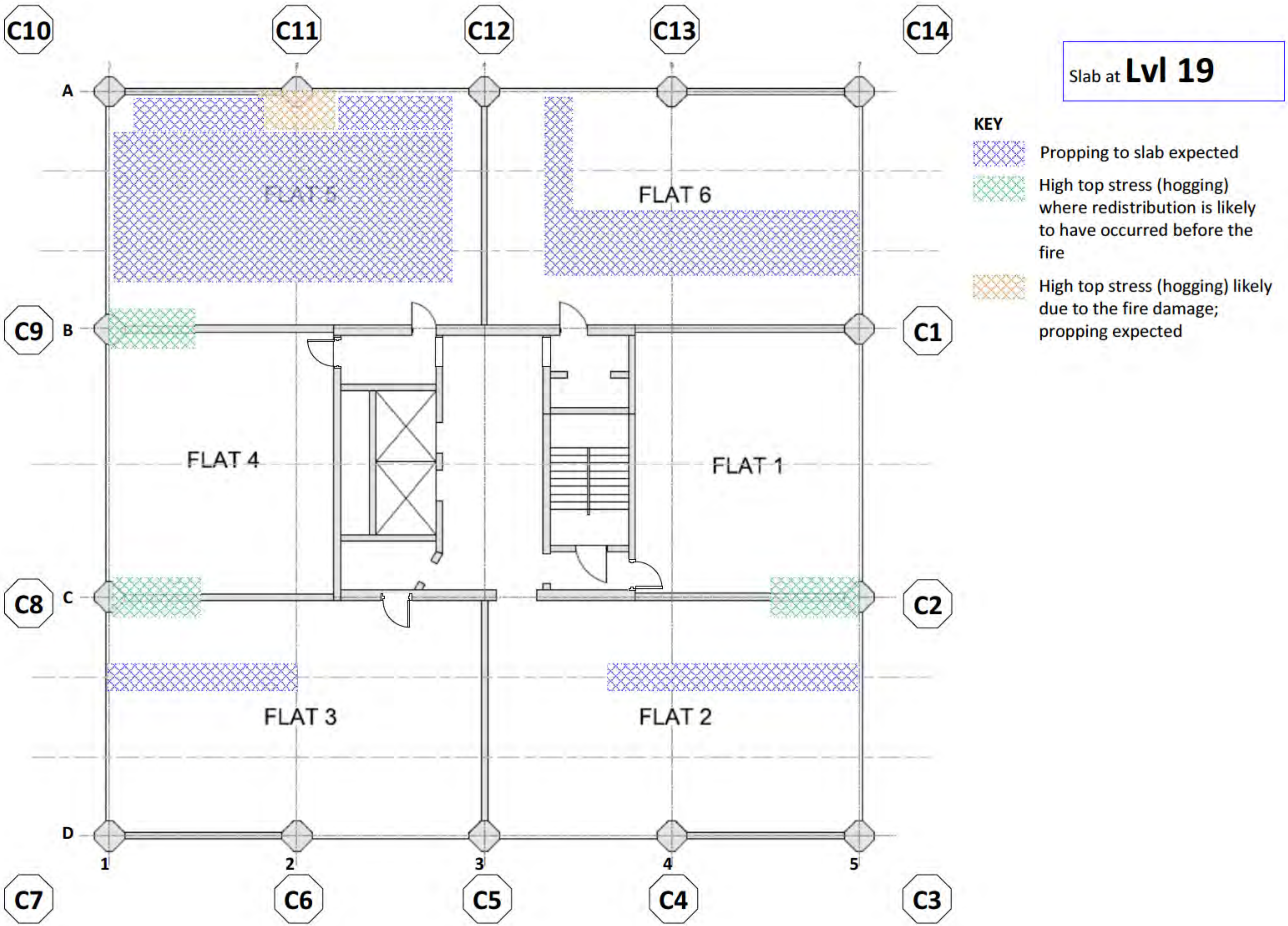
- Propping to slab expected
- High top stress (hogging) where redistribution is likely to have occurred before the fire
- High top stress (hogging) likely due to the fire damage; propping expected

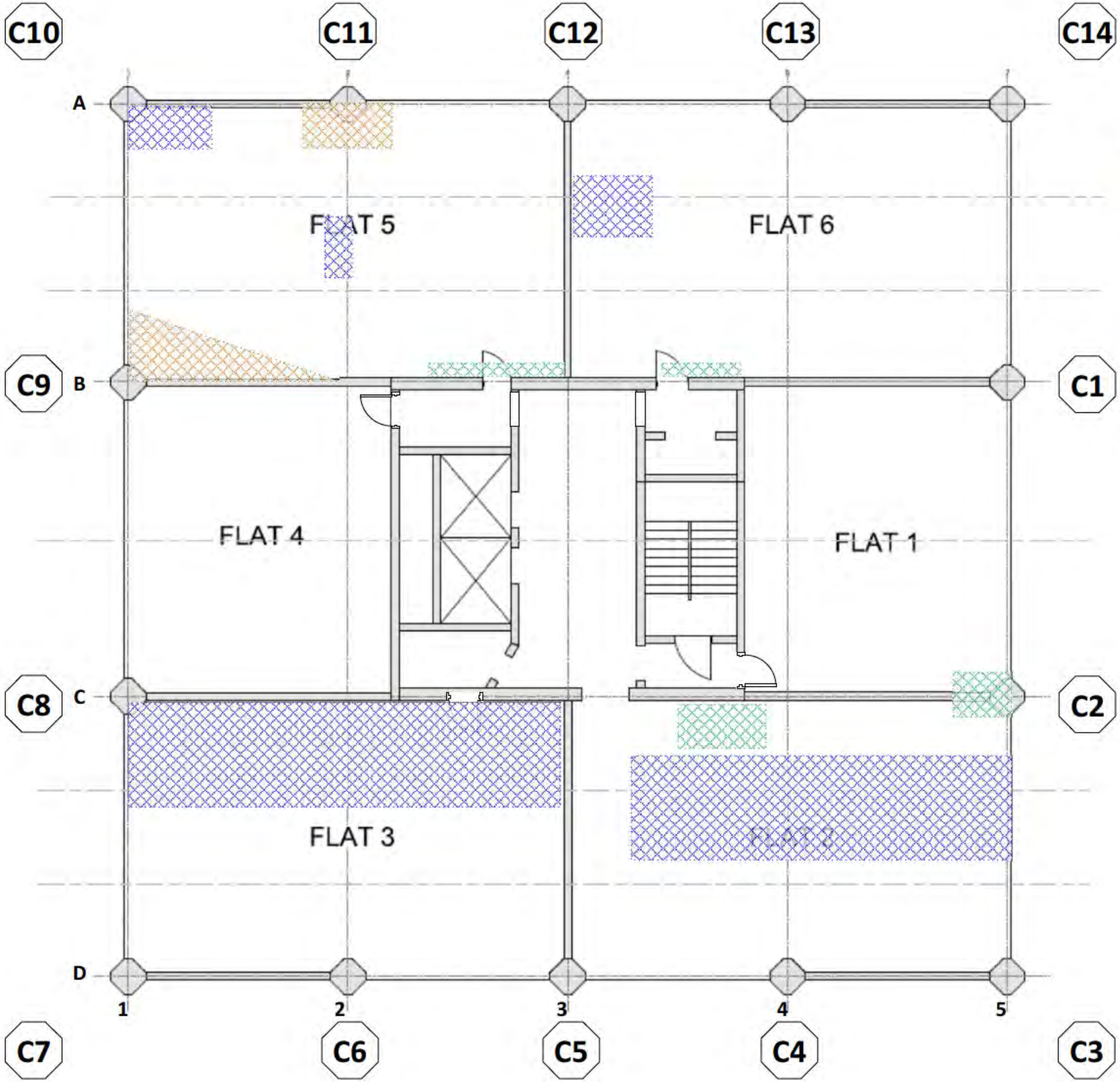
Slab at **Lvl 18**



KEY

- Propping to slab expected
- High top stress (hogging) where redistribution is likely to have occurred before the fire
- High top stress (hogging) likely due to the fire damage; propping expected

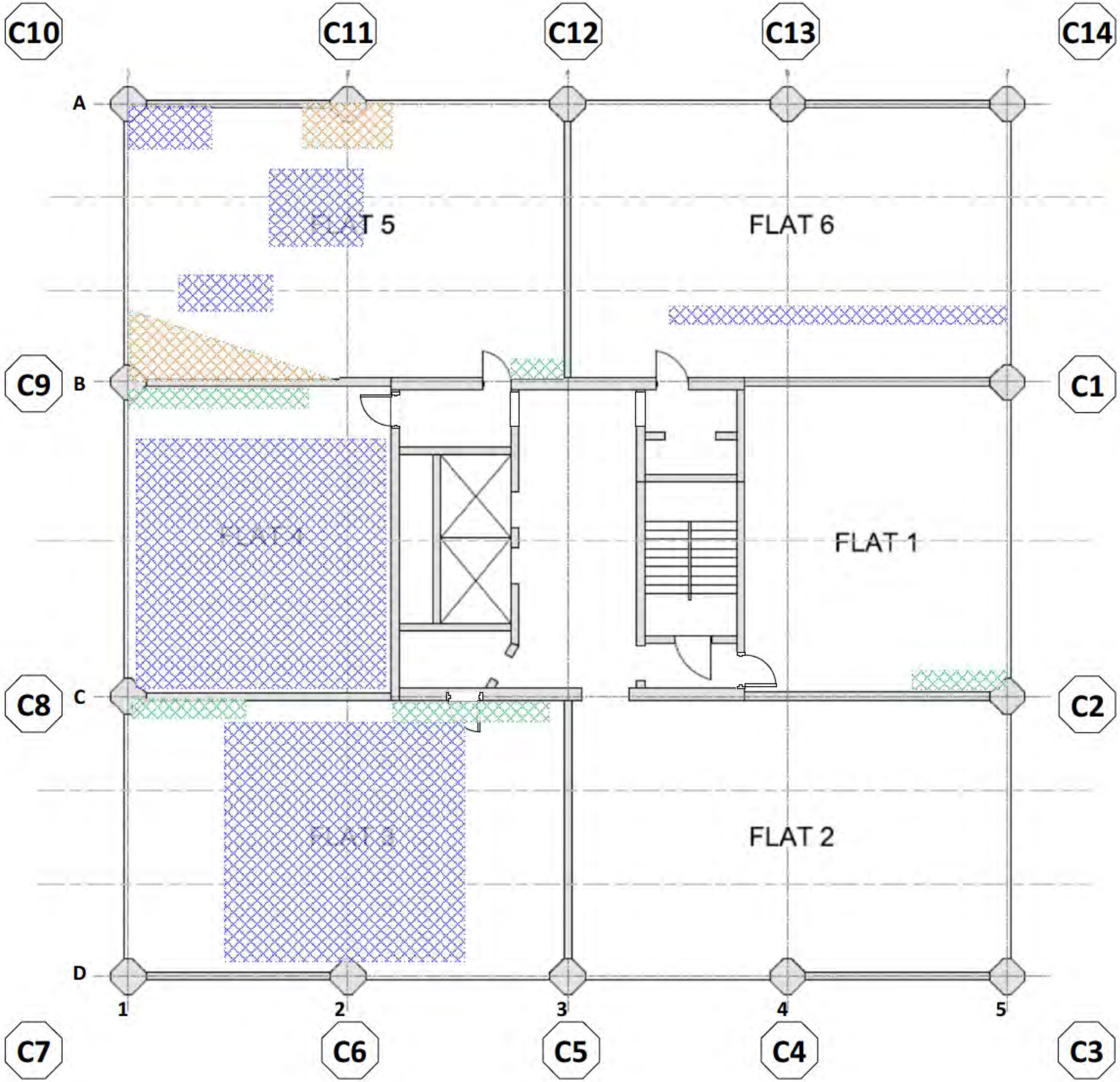

Slab at Lvl 19
KEY
Propping to slab expected
High top stress (hogging) where redistribution is likely to have occurred before the fire
High top stress (hogging) likely due to the fire damage; propping expected
C10
C11
C12
C13
C14
C9
C1
C8
C2
C7
C6
C5
C4
C3
A
B
C
D
1
2
3
4
5
FLAT 5
FLAT 6
FLAT 4
FLAT 1
FLAT 3
FLAT 2



Slab at **Lvl 20**

KEY

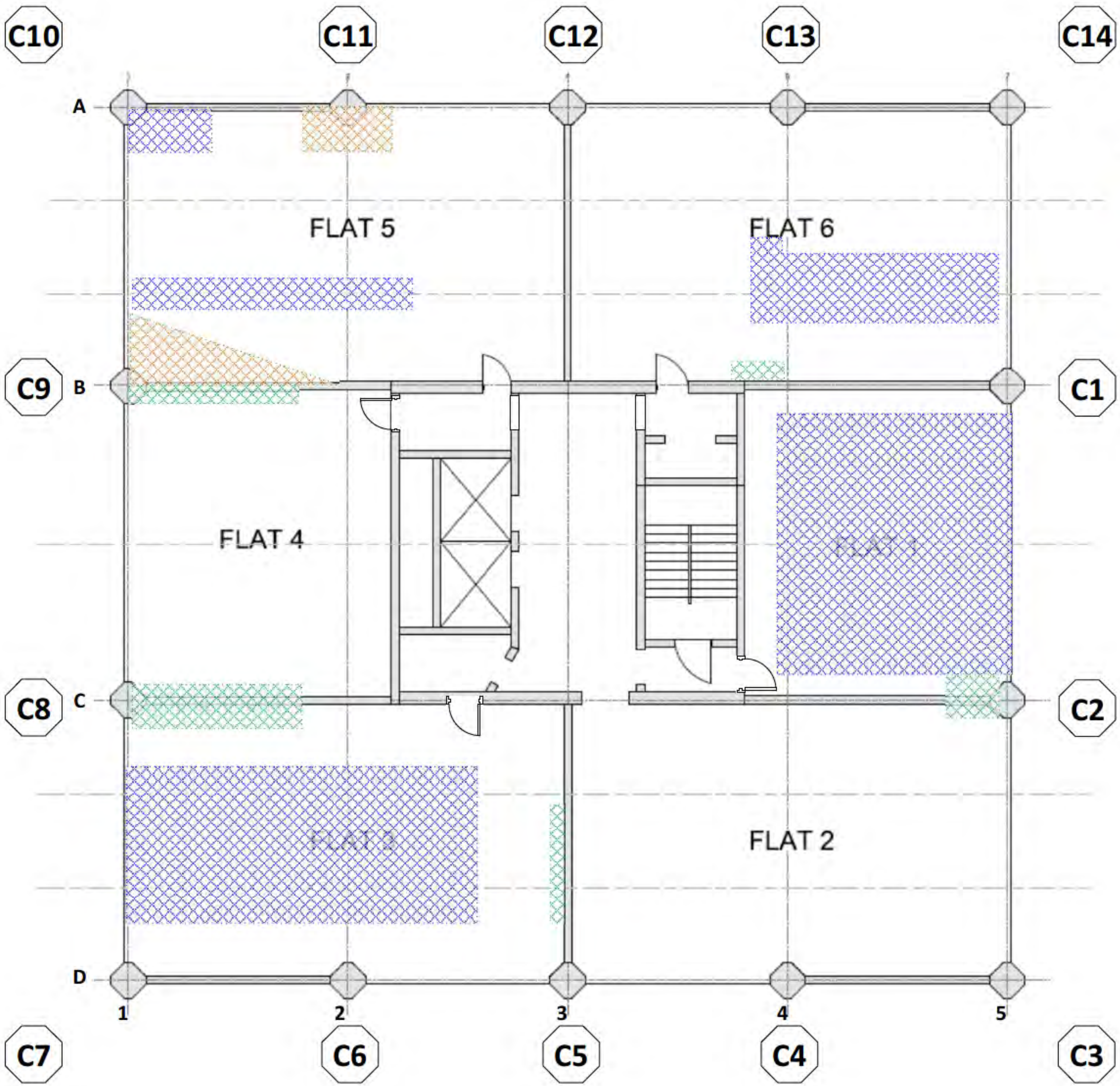
- Propping to slab expected
- High top stress (hogging) where redistribution is likely to have occurred before the fire
- High top stress (hogging) likely due to the fire damage; propping expected



Slab at **Lvl 21**

KEY

- Propping to slab expected
- High top stress (hogging) where redistribution is likely to have occurred before the fire
- High top stress (hogging) likely due to the fire damage; propping expected

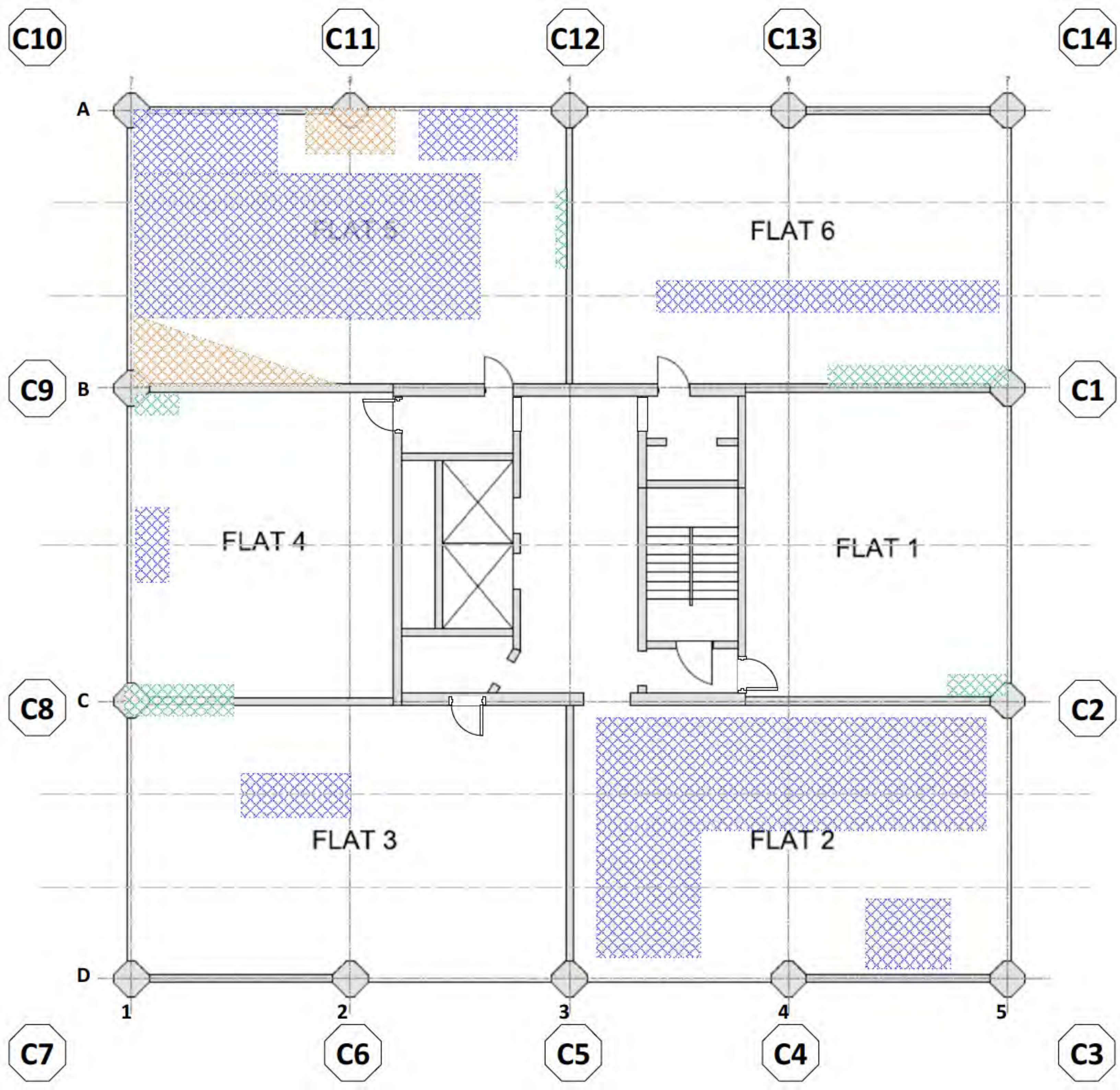


Slab at **Lvl 22**

KEY

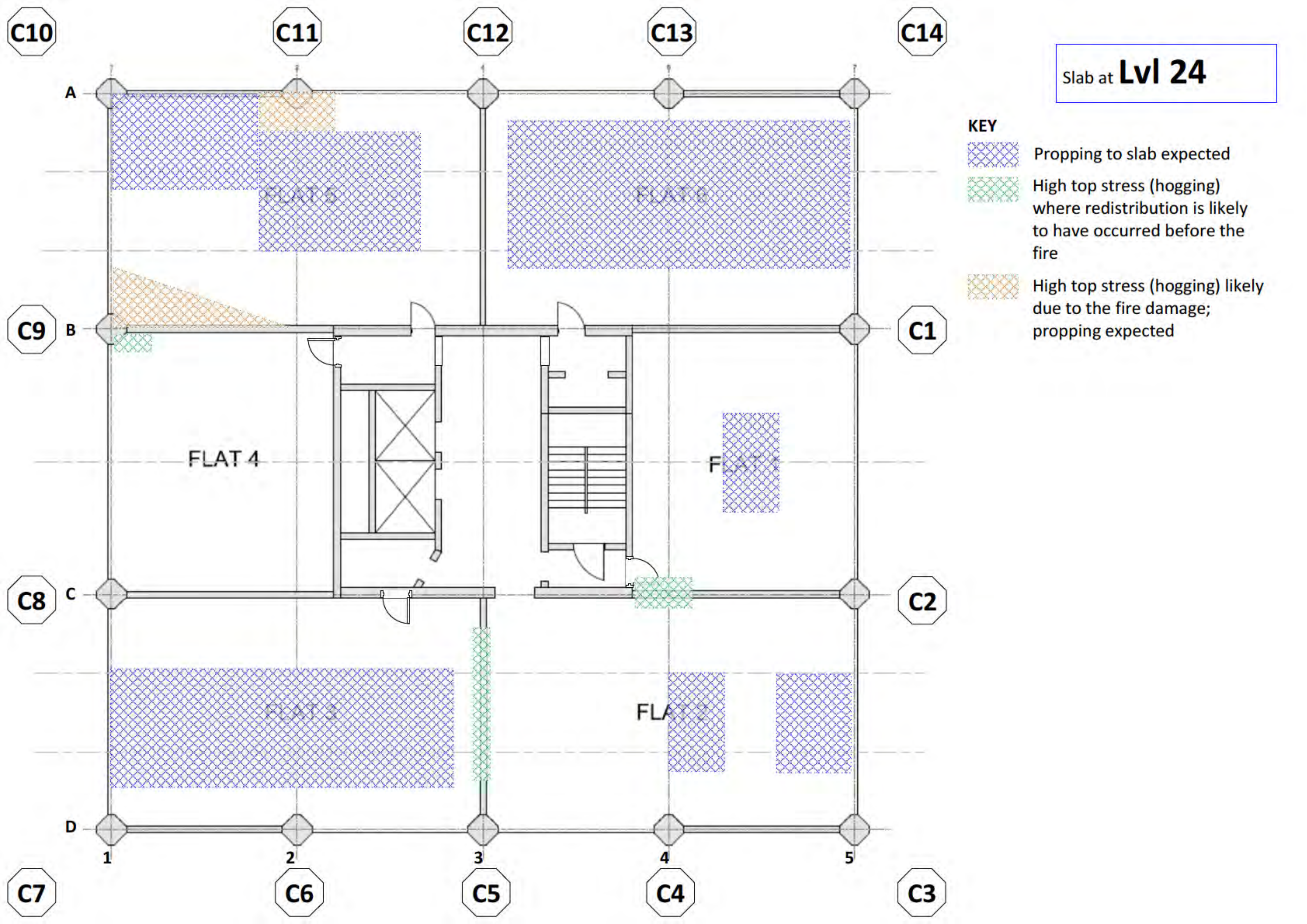
- Propping to slab expected
- High top stress (hogging) where redistribution is likely to have occurred before the fire
- High top stress (hogging) likely due to the fire damage; propping expected

Slab at **Lvl 23**



KEY

- Propping to slab expected
- High top stress (hogging) where redistribution is likely to have occurred before the fire
- High top stress (hogging) likely due to the fire damage; propping expected



Slab at Lvl 24
KEY
Propping to slab expected
High top stress (hogging) where redistribution is likely to have occurred before the fire
High top stress (hogging) likely due to the fire damage; propping expected
C10
C11
C12
C13
C14
C9
C1
C8
C2
C7
C6
C5
C4
C3
A
B
C
D
1
2
3
4
5
FLAT 4
FLAT 3
FLAT 2
FLAT 1

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