SOUTHAMPTON
CITY COUNCIL

Medium Rise Housing Blocks

Structural Investigation of Cantilever Balconies

Project No RP200058

Date: August 2017

Quality Management

Job No	RP200058 (& CS/087894)		
Project	Medium Rise Housing Blocks		
Location			
Title	Structural Investigation of Cantilever Balconies		
Document Ref		**Issue / Revision**	0
File reference	G:\PROPERTY\Housing\RP200058-Cantilever Balconies Supports\Structures General\Reports\Medium Rise Housing Block Balcony Report.docx		
Date	August 2017		
Prepared by 1	D Harrison	Signature (for file)	
Checked by	C Bainvridge	Signature (for file)	
Authorised by	D Harrison	Signature (for file)	

Revision Status / History

Rev	Date	Issue / Purpose / Comment	Prepared	Checked	Authorised
0	Auh 2017	Information	DH	CB	DH

SOUTHAMPTON
CITY COUNCIL

Contents

Appendices

1. Introduction

Southampton City Council (SCC) owns a number of medium rise blocks of flats in various locations around the city. These buildings all have reinforced concrete cantilevered balconies at one or more floor levels that provide access to the flats and maisonettes on the upper floors.

Following structural problems that were recently found with the balconies of many of the two storey walk-up blocks around the city, concerns were raised with respect to the balconies on the medium rise blocks, as these are of a similar form of construction.

This report describes structural engineering investigations into the strength of the cantilever balconies on these buildings.

It also considers the need for temporary propping and permanent repairs or support as appropriate.

The investigations were initially arranged and carried out by Capita Property on behalf of the SCC Housing Client. The resultant remedial and strengthening work on site is now being managed by SCC Capital Assets, who have now taken over the former role of Capita Property.

SOUTHAMPTON
CITY COUNCIL

2. History

SCC has a large number of two storey walk-up block of flats that have cantilevered balconies at 1st floor level. In 2010, five of these blocks at Bassett Green Court were being refurbished, and it was found that the concrete slabs were in poor condition. It was also found that the reinforcement provided in the slabs was insufficient to support the design loads required under current British standards and the Building Regulations. Consequently a scheme to provide additional support to the balconies with structural steelwork was designed and installed on these blocks.

The condition of the blocks at Bassett Green Court led to concern about the condition of the other two storey blocks around the city and subsequently investigations were carried out at most similar blocks city wide. These investigations found that most of the other blocks also had insufficient reinforcement, and a similar scheme to provide additional support with structural steelwork was designed and is currently being installed where required on the majority of these blocks.

As a result of the problems described above with the two storey blocks Capita recommended to the SCC Housing Client that similar investigations should be carried out on some of the similar medium rise, (3, 4, and 5 storey) blocks.

3. Investigations

It was agreed with SCC that investigations should be carried out aS described above, and Capita were appointed to manage the investigations as described below.

All of the relevant blocks were identified from SCC records, and it was found that there were 39 blocks.

The full list of blocks, along with their check status, is included in Appendix A.

The initially agreed extent of the investigation included three of the 10 blocks at Golden Grove and the three blocks at Ridding Close. It was initially thought that 10% of the blocks should be investigated in total.

However, following a review of the initial results, the investigation was then extended to include the remainder of the blocks at Golden Grove and several other blocks that were originally built by the same contractors as those at Golden Grove (G Wimpey & Co) and Ridding Close (H Stevens & Co).

The extent of the investigation was then further extended to include various other blocks city wide.

These investigations were carried out in May and June 2016 and this report describes the site investigations and design checks that were carried out.

It was agreed that the site work would be carried out by Bagnalls under their term contract with SCC for Concrete Repairs, and the laboratory testing would be carried out by ACS Testing, all as previously done on the two storey walk-up blocks.

4. Detailed Scope of Investigations

It was envisaged by SCC that the investigation would be limited to breaking out to check the reinforcement only, but Capita recommended that the scope should include concrete testing as previously done on the 2 storey walk-up blocks.

For each site, all blocks should be investigated, typically at 2 locations per balcony floor level, i.e. one at each end. If cantilever roofs are present, they should be allowed for in the budget, unless or until it is positively confirmed that they are timber, rather than concrete.

As previously, site investigations should include:

Reinforcement break outs for bar size and type, bar spacing, & cover to steel,
Making good with concrete repairs as necessary.

Consideration was given to taking concrete cores to be tested for strength, carbonation, and chlorides. However, as there had not been any history of problems with these aspects of the balconies on the two storey walk-up blocks, it was decided that no action was required on them.

SOUTHAMPTON
CITY COUNCIL

5. Results

The initial investigations were carried out at:

76 Golden Grove (Ground Floor)
84 Golden Grove (Ground Floor)
4 Ridding Close (Ground Floor)

From the design checks for all of these cases, all of the slabs failed in bending.

Following the above results it was agreed that the following blocks, built by the same contractors, should be investigated as the next priority:

Golden Grove -	the remaining 6 blocks	(Wimpey)
Ascupart Street -	1 block	(Wimpey)
James Street -	2 blocks	(Wimpey)
Portelet Road -	1 block	(Stevens)
Hurstbourne Place -	2 blocks	(Stevens)
Dart House, Neva road -	1 block	(Stevens)
Total	17 blocks.	

The design checks found that, in 15 of the 17 blocks that were tested, all of the balconies failed structurally in at least one location.

There was no clear pattern to the failures, and there were often significant variations within each block.

It was therefore concluded that it was highly likely that most of the remaining balconies would also fail the checks.

Sample results of the design checks are included in Appendix B.

The summary of results for Golden Grove covers 14 locations. It would be expected that all of the balconies on this group of blocks would be identical or very similar in thickness and have identical or very similar reinforcement in the slabs. However, this was not the case.

This table shows the variations in slab thickness, which range from 140 to 160 mm, and is a 15% variation. The cover to the reinforcement varied from 35 to 65 mm, which is a difference of 85%. Both of these aspects can be attributed to poor workmanship and lack of supervision during construction.

The table also show the variations in reinforcement, which ranges from 5.7 mm @ 150 mm centres (160 mm2/m) to 7.5 mm @ 140 mm centres (309 mm2/m), which is a difference of 93%. In addition, whilst in most locations the bars were of the square twisted high yield type, in two locations they were found to be of the plain round mild steel type.

This amount of variation in quantity and type indicates that there was little or no control over the reinforcement that was used in the slabs and further demonstrates the poor workmanship and lack of supervision during construction.

Finally the table shows the utilisation factor for the slabs taking account of their thickness, the cover to the steel, and the reinforcement provided. For the slab to be considered as satisfactory, this factor should not exceed 100%. The factor varied between 72% (Pass) and 174% (Fail).

Only 5 out of 14 locations at Golden Grove were found to be satisfactory, and therefore two out of three slabs failed.

City wide, 3 blocks at 2 sites passed, and 13 blocks at 5 sites failed. The remaining 23 blocks at 8 sites were not tested.

We consider that there is no logical explanation for these variations other than as described above.

The enormous variations described above, and the random nature of the results, are a cause for major concern with regard to the structural safety of the remainder of the balconies, both at this site and elsewhere in the city.

On the basis of these results it is concluded that there is a serious risk of a structural failure / collapse of many of the balconies across the city. The risk was such that it was recommended that all balconies of this type should be propped immediately as an emergency action whilst a scheme for providing additional structural support was prepared.

Full results are available on file if required.

Photographs of typical break-outs are included in appendix C.

6. Conclusions

The design checks found that, in 15 of the 17 blocks that were tested at various locations, all of the balconies failed structurally in at least one position.

There was no clear pattern to the failures, and there were often significant variations within each block.

It was therefore concluded that it was highly likely that most of the remaining balconies would also fail the checks and were therefore potentially structurally unsafe.

SOUTHAMPTON
CITY COUNCIL

7. Recommendations

No further investigations should be carried out, and it should be assumed that all blocks of this type require remedial work.

Temporary propping should be provided immediately to all of the balconies on all blocks of this type.

Refer to the e-mail in Appendix D for proposed details of the propping.

(NOTE: The recommended propping was installed to all blocks in summer 2016)

A scheme to provide additional permanent structural support should be designed and installed on all balconies on all blocks of this type as soon as possible.

SOUTHAMPTON
CITY COUNCIL

Appendix A

Summary of Investigation Results

Name	Number of Blocks	Number of Blocks Tested	Result
Ascupart Street	1	1	Pass
Benhams Road	2		Not Tested
Challis Court	2		Not Tested
Copse Road	1		Not Tested
Dart House	1	1	Pass
Golden Grove	10	7	**Fail**
Howards Grove	1	1	**Fail**
Hurstbourne Place	2	2	**Fail**
Irving Road	1	1	Not Tested
James Street	2	2	Pass
Portelet House	1	1	**Fail**
Ridding Close	3	1	**Fail**
Rowlands Walk	3		Not Tested
Threefields Lane	1		Not Tested
Vanguard Road	1		Not Tested
Vaudrey Close	6	2	**Fail**
Witts Hill	1		Not Tested
Total	**39 Blocks**	**17**	**2 Pass, 15 Fail**
	In 17 locations		**23 Not Tested**

SOUTHAMPTON
CITY COUNCIL

Appendix B

Summary of Design Check and Sample Calculations for Golden Grove

GOLDEN GROVE

Block	Floor Level	Flat No	Cantilever (mm)	Slab thickness (mm)	Cover (mm)	Main Bars	Area of Steel	Distribution Bars	Bar Type	Usage (%)	Pass/Fail
15-53	Ground	15	1320	145							Fail
15-53	Ground	25	1320	145	35	6.0mm @ 155mm	188	6.0mm @ 175mm	Sq Twist	129%	
15-53	First	27	1320	160							Pass
15-53	First	39	1320	160	30	7.6mm @ 210mm	226	7.6mm @ 200	Sq Twist	96%	
55-93	Ground	55	1320	150							Fail
55-93	Ground	63	1320	150	40	7.5mm @ 200mm	226	7.5mm @ 200mm	Sq Twist	109%	
55-93	First	67	1320	160							Fail
55-93	First	79	1320	160	40	7.5mm @ 190mm	226	7.5mm @ 200mm	Sq Twist	102%	
95-127	Ground	95	1310	160	60	7.3mm @ 200mm	226	7.3mm @ 200mm	Sq Twist	121%	Fail
95-127	Ground	103	1310	160							
95-127	First	107	1310	155	50	8.0mm @ 190mm	251	8.0mm @ 195mm	Round	171%	Fail
95-127	First	115	1310	155	40	8.0mm @ 175mm		8.0mm @ 195mm	Round		
129-161	Ground	129	1310	160	37	7.5mm @ 140mm	309	7.5mm @ 200mm	Sq Twist	72%	Pass
129-161	Ground	137	1310	160							
129-161	First	141	1310	160	65	7.5mm @ 70mm		7.5mm @ 200mm	Sq Twist		Fail
129-161	First	149	1310	160	47	7.5mm @ 185mm	220	7.5mm @ 200mm	Sq Twist	109%	
163-195	Ground	163	1320	155							Fail
163-195	Ground	171	1320	155	30	7.5mm @ 200mm	220	7.5mm @ 200mm	Sq Twist	100%	
163-195	First	175	1320	160	50	7.5mm @ 195mm	220	7.5mm @ 195mm	Sq Twist	100%	Fail
163-195	First	181	1320	160	40	7.5mm @ 210mm		7.5mm @ 200mm	Sq Twist		
197-235	Ground	197	1320	165	65	6.0mm @ 170mm	166	6.0mm @ 165mm	Sq Twist	174%	Fail
197-235	Ground	207	1320	165	45	6.0mm @ 155mm		6.0mm @ 165mm	Sq Twist		
197-235	First	211	1320	165	45	8.0mm @ 170mm	295	8.5mm @ 200mm	Sq Twist	81%	Pass
197-235	First	221	1320	165	40	8.0mm @ 170mm		8.0mm @ 200mm	Sq Twist		
237-275	Ground	237	1310	140	35	5.7mm @ 150mm	170	5.7mm @ 165mm	Sq Twist	144%	Fail
237-275	Ground	247	1310	140	30	5.7mm @ 155mm		5.7mm @ 165mm	Sq Twist		
237-275	First	251	1310	155	40	5.7mm @ 165mm	170	5.7mm @ 170mm	Sq Twist	139%	Fail
237-275	First	261	1310	155	35	5.7mm @ 155mm		5.7mm @ 165mm	Sq Twist		

Design Check for Existing RC Balcony Slabs

data
result

Design Codes

Original	CP 3 – Ch .V - Pt 1	Loadings
	CP 114	Concrete
Current	BS 6399 - Pt 1	Loadings
	BS 8110 - Pt 1	Concrete

Dimensions

Cantilever length L=	1350	mm			
Slab Thickness D =	150	mm			
Main Reinforcement =	R6.3-80	mm	Ast =	354	mm2/m
2ndy Rft =	R4–300	mm			
Top cover c =	40	mm	(Bottom 104 mm)		

For D =	150	slab,	& top cover c =	40	(NB single layer only)
Effective depth to reinforcement d =		d = D - c - 3 =		107	mm from underside
Adopt Lever Arm La =	0.9 x d =	0.9 x d =		96	mm

Materials

Concrete – from tests adopt — CP 114 - pcb = 7 N/mm^2 (1:2:4 mix)

BS 8110 - fcu = 30 N/mm^2 (RC30)

Reinforcement	CP 114			BS 8110		
R = round mild steel	pst =	140	N/mm^2	Fy =	250	N/mm^2
S = High Yield (Square)	pst =	230	N/mm^2	Fy =	420	N/mm^2

Loadings

			kN/m^2		
20	Asphalt	= A1 x 20 kN/m3 =	0.40		
0	Screed	= S1 x 24 kN/m3=	0.00		
150	RC slab	= D x 24 kN/m3 =	3.60		
	Live load	CP 3 =	2.00	(2.0 or 3.0)	No of Flats
	Live load	BS 6399 =	3.00	(1.50 or 3.0)	4

(NB BS 6399 Live load for access to not more than 4 flats = **1.5** kN/m2)

(NB BS 6399 Live load for access to more than 4 flats = **3.0** kN/m2) (= 2.0 for CP3 Ch 5 Pt 1)

TOTAL	Unfactored service load	CP 114 =	6.00	= W
TOTAL	Factored ultimate load	BS 8110 =	10.40	= W

Design

For CP 114 (service loads & stresses etc)

Cantilever bending moment	$M = W \times L^2/2$ =	**5.47**	**kNm**
Shear force	Q =W x L =	**8.10**	**kN**
Shear stress	q = Q / (b x la) =	**0.084**	**N/mm^2**

For slab depth = D =		150	eff depth = d =		107	& La=0.90 d	
Ast =	354	mm^2	Pst =	140	N/mm^2	La =	96 mm
Moment of resistance = MR = Ast x Pst x La				Mr =	**4.77**	**kNm**	**FAIL**
Allowable shear stress q =					**0.7**	**N/mm2**	**OK**
Deflection check: Maximum allowable span L = 12 x D =					**1800**	**mm**	**OK**

For BS 8110 (ultimate loads & stresses etc)

Cantilever bending moment	$M = W \times L^2/2$ =	**9.48**	**kNm**
Shear force	Q =W x L =	**14.04**	**kN**
Shear stress	q = Q / (b x d) =	**0.131**	**N/mm^2**

For slab depth = D =		150	eff depth = d =		107	& La=0.90 d	
Ast =	354	mm^2	Fy =	250	N/mm^2	La =	96 mm
Moment of resistance = MR = Ast x 0.95 x Fy x La =					**8.10**	**kNm**	**FAIL**
Allowable shear stress = Vc =					**0.48**	**N/mm^2**	**OK**
Deflection check: Maximum allowable span L = 7 x d x factor						Adopt factor = 2.0 maximum (T3.10 BS8110)	
				L =	1498	mm	**OK**

Handrails

Consider also additional moment due to handrail loads:

From CP 3 adopt horizontal load H = 0.36 kN/m at a height H = 1.1 m

For CP 114: Additional moment Ma = H x L = 0.36 x 1.1 = 0.40 kN/m (service)

From BS 6399 Pt 1 adopt horizontal load F = 0.74 kN/m at a height H = 1.1 m,
& a vertical load of V = 0.6 kN/m or 1.0 kN

For BS 8110: Additional moment Ma 1 = F x H x 1.6 = 0.74 x 1.1 x 1.6 = 1.30 kN/m (ultimate)
Ma 2 = V x L x 1.6 = 0.6 x. 1.35 x 1.6 = 1.30 kN/m (ultimate)

Propping

Where deflection has occurred or reinforcement is considered inadequate to allow the slab to act as a cantilever, consider propping the edge of the slab at Lb = 1.25 m from face of building.

For simplicity, check bending of balcony (conservatively) as a simply supported spanning slab

Check to current standards only, ie for BS 8110:

Spanning bending moment	$M = W \times Lb^2 /8$ =	**2.03**	**kNm**	ultimate

For the top reinforcement (NB single layer only, placed approximately centrally)

Effective depth to reinforcement = d2 = c+3 =	43	mm from top		la2 = 0.9x d2
Moment of resistance Mr = Ast x 0.95 x fy x la2 =	**3.25**	**kNm**	ultimate	**OK**

SUMMARY Slabs **FAIL**

Appendix C

Photographs

1 Typical Break-Out – 2-74 Golden Grove

2 Typical Break-Out – 2-74 Golden Grove

3 Typical Break Out - 39 Golden Grove

4 Typical break Out – 79 Golden Grove

5 Typical Break Out - 6 Golden Grove

Appendix D

E-Mail 27 May 2016 – Capita (DH) / SCC (N Tomblin)

Investigations were carried out on the ground floor balconies at these two sites and the initial findings are as follows:

76 Golden Grove (Ground Floor)

Reinforcement consisted of R 6.3 mm bars at 80 mm spacing (354 mm2/m) with 40 mm top cover.
Calculations indicate the moment of resistance to be 8.1 kNm (BS 8110)
Design moment = 9.48 kNm
The slab FAILS in bending

84 Golden Grove (Ground Floor)

Reinforcement consisted of R 6.3 mm bars at 300 mm spacing (94 mm2/m) with 25 mm top cover.
Calculations indicate the moment of resistance to be 2.45 kNm (BS 8110)
Design moment = 9.48 kNm
The slab FAILS in bending

4 Ridding Close (Ground Floor)

Reinforcement consisted of S 6.5 mm bars at 160 mm spacing (174 mm2/m) with 45 mm top cover.
Calculations indicate the moment of resistance to be 5.75 kNm (BS 8110)
Design moment = 9.17 kNm
The slab FAILS in bending

Comments

Although further testing was originally planned, work was halted at this point due to the obvious problems with these balconies.

The reinforcement appeared to be a long mesh, but not a structural mesh that is in use today.
The problem with these slabs is the minimal amount of reinforcement compared to the WUBs.
However in these slabs the steel was towards the top of the slab, i.e. where it should be in a cantilever.

At Golden Grove, the block in question has a full height screen to the balcony, but on the other type of block, it is only a half-height barrier.

The effect of the loads from the screen / barrier have not been directly included in the calculations (which was the same approach that we previously used for the WUBs). In all cases the additional vertical load from the screen or the cantilever moment from the barrier would make the situation worse.

In the worst case, 84 Golden Grove, it appears that the slab has insufficient reinforcement to support its self-weight.

There is clearly a massive variation at Golden Grove, and this needs further investigation on the first block We note that the calculations are based on limited information, but are sufficient to give rise to serious cause for concern.

Compared to the 2-storey Walk-Up Blocks, these slabs are slightly thicker, but are also wider.
In the WUBs the problem was a combination of inadequate steel and excessive top cover.

We recommend the following, which in view of the significant concern, should be carried out immediately:

The existing break-outs should remain open for the time being.
Further investigations (3 break-outs) should be carried out at the top level on the same block at Golden Grove, and also at ground floor.

As there are two types of blocks at Golden Grove, this should be repeated at ground floor and the top level in one of the other type of blocks.

At Ridding Close, we should look at the ground and top floors of one block (perhaps 3 each).
Further investigation may be required to these blocks depending on the results of the above.

Temporary propping should be installed on the 5 blocks at Golden Grove, and also on the single block at Ridding Close.

This propping may need to be extended depending on the results of the above.

Props should be installed at 3.0 m centres on the outer edge of the slabs in the usual manner.

Prop loads are D + L = 4.0 + 3.0 = 7.0 kN/m2
For props at 3.0 c/cs Load per floor = 7.0 x 3.0 x 1.35 / 2 = <u>14 kN</u> (service)
Add say 3.0 kN for the screen load, total = 17 kN/m
For 2 floors, load = <u>34 kN</u>
For 3 floor, load = <u>51 kN</u>

Hence single props will be OK for up to 2 floors, but for 3 floors, they should be placed in pairs.

This is subject to a check of my Acrow prop loading table which I do not have at present, however I believe a single prop can carry around 30 kN.

We then need to consider the other similar blocks city wide, starting with identifying these blocks, which is already under way.

The approach to these block will depend on the further work at Golden Grove and Ridding Close.

End.

SOUTHAMPTON
CITY COUNCIL

CAPITAL ASSETS
Southampton City Council
Civic Centre
Southampton
SO14 7LY