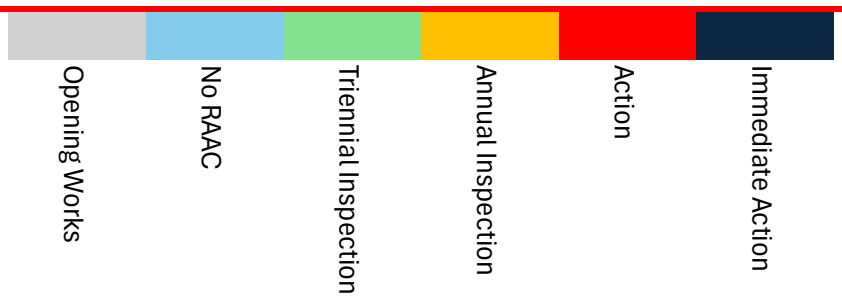
Detailed RAAC Inspection Report

Project Name:	NHS RAAC Inspections
Project Number:	UK70098755
Inspection Date:	21 & 28 August 24
Engineers:	#020, #016, #013, #002,
Checker:	#002
Approver:	#002
Issue date:	28/10/2024

NHS Board:	Ayrshire & Arran
Site Code:	B114H
Site Name:	University Hospital Crosshouse
Block Number:	03
Block Name:	Lister Centre
Discovery Report:	WSP-RP03-A111H-3-University Hospital Crosshouse_Lister Centre
Structural Engineers:	#020, #016, #013, #002
NHS Estates:	Fraser McNeil

General Appraisal:	
Bearing Appraisal:	
Comments:	Planks with holes often have minor spalls, and are sometimes amber, but many openings merit a red rating and therefore **remedial details have been recommended.** Many cut planks have 50-55 folded plate straps as additional support. IStructE guidance views this as a risk because transverse bars may not be present over the strap, neverthless if deflection is not excessive, the longitudindal bars are currently sufficient, and if present, the transverse bars are yet to be mobilised. **Providing mitigations are in place** amber is satisfactory. This conclusion, of course, assumes an absence of distress and damage. Some planks are cracked and in these locations **we have recommended carrying plant and suspened services from the primary frame and not the RAAC.** This implies alterations should be made. Statistical analysis shows a 25% probability of bearings < 45 mm wide. **Enhanced bearings are therefore recomended**, although top and bottom rebar were found in each location investigated, which helps to mitigate brittle behaviour. We have also **recomended the implementation of a written management and mitigation strategy** to ensure that the existing loads are not increased, the planks remain dry, and no unauthorised penetrations are made. Without this some amber locations would become red, and some red may become black. The internal leaf of the cavity cladding is made of RAAC, but this is not included within the roof appraisal.

Key



Introduction

This report has been prepared to record the findings of an appraisal of the roof structure at the noted address, which is made of RAAC planks. The appraisal takes into account both visual inspection and intrusive investigation. The building facade is of cavity construction. The outer leaf is made of conventional pre-cast concrete, however the inside leaf is made of RAAC. The facade is not included in this report.

A risk based approach was used to identify where the structure should be viewed. This began with a point cloud survey of the roof, which was subsequently overlaid with a plan of the floor below. Openings where then made in the ceilings from which to view locations where penetrations in the roof were identified as being present, and where plant is located above.

Several locations were also identified to intrusively investigate the plank bearings from above. These were generally chosen for practical reasons on site. The intrusive work involved removing roof finishes so that the width of bearings could be measured, and so that suitably placed reinforcement could be identified by locally cutting the planks.

In some locations, limited access was available due to servicing of the building, the placement of partitions, and due to the constraints of the building being live. This means that we may not have been able to collect a full data set at each location, for instance spans and plank depths. We have inferred that these remain relatively consistent by aggregating our observations across the site. For similar reasons, in some cases we only viewed openings from one or two sides.

For each location viewed from within the ceiling void, the RAAC has been placed in a risk category based on tables 3 and 4 of the IStructE guidance. That said, it has been necessary to apply judgement to some locations, as there are sometimes factors present that do not appear in the standard tables. Where appropriate we have also given weight to the reason damage or distress is evident and whether it is likely to re-occur.

A risk category, based on table 2 of the guidance, has been given to the plank bearings, albeit for the highest category we have adopted different colours and terminology to improve their clarity. We have used "red" when action is required and "black" when action is to be taken immediately. We have also provided a mitigated risk category based on the presence of factors that address potential causes of failure, or reduce the likely consequences of failure.

For practical reasons, we have not exposed reinforcement at every location, but have inferred our findings to be representative, based on the external appearance of what we see. If their manufacture and installation are similar, adjacent planks subjected to the same conditions, ought to behave in a similar manner. If they are dissimilar we ought to see differences in behaviour or condition. We have also performed a statistical assessment, using standard deviation and T-distribution, to estimate an upper and lower bound for bearing widths across the site. We based this on a confidence limit of 95%, which is considered normal for engineering calculations.

Where appropriate we have made recommendations for repair or enhancement, and have referred to standard details that have been prepared on behalf of NHSScotland Assure.

We have not given a specific duration for acting on "red" items, but our expectation is that a "reasonably practicable" time frame should apply. In practise this means, taking into account relevant factors. For instance, design and planning, re-routing services, decanting patients, complying with infection control processes, procuring remedials etc. This does not permit an indefinite period of time, but it does recognise the challenges of a healthcare environment and is intended to offer some flexibility. Key to this flexibility is a management strategy that is used to control spaces that contain RAAC. This should be a written document that provides mitigations against issues known to affect RAAC. For example, water ingress, overloading & unauthorised alterations. Health Boards are responsible for preparing this, although guidance has been provided via NHSScotland Assure.

Thus, our approach is risk based and evidence led. It is intended to provide a pragmatic model for applying the principles set down within the IStructE's guidance, while recognising the challenge of working within a healthcare environment. It relies on the active management of spaces by the Health Board and for this reason, over the longer term, Health Boards should plan to phase out RAAC within their estate.

Notwithstanding the above, Health boards may choose to place less reliance on active management by implementing a more extensive programme of enhancements, especially at the support bearings. The operational disruption this will cause will need to be managed in the short term.

This report is limited in scope to RAAC. It not intended to be an appraisal of the whole structure, nor is it intended to report on structural matters unrelated to RAAC. Should these services be required by the Health Board then a separate board should be commissioned.

Our report reflects the building and its condition at the time of inspection, however if RAAC becomes wet or is overloaded it will become distressed, and its capacity will reduce. For this reason, the building fabric should continue to be managed and monitored after the works are complete. This must include maintenance of the rainwater goods and roof coverings, plus control of the load applied to the RAAC. Robust processes should also be in place for assessing and approving alterations. These requirements, and other relevant issues, should be written down in a management and maintenance strategy to be implemented by the Health Board.

The reader may not assume that locations not expressly described in this report are free from defects, damage and distress. Nor can it be guaranteed that RAAC is not present in locations that were not viewed.

Disclaimer

Location Plan

Panel Condition Location Plan

Location Plan

Bearing Condition Location Plan

Panel Condition

Location	General Condition														Repair Detail		Comments
	Cracking			Spalling				Alterations									
	Perpendicular [1]	Parallel [2]	Distance from Support [Edg]/[Mid]	Stress [3]	Modification [4]	Rebar Visible [R]/[NR]	Penetration [5]	Approx. Size [mm] [Dxxx]	Edge Modification [6]	Folded PLT [7]	Suspended Services [8]	Wet [9]	Deflection [10]	Risk Rating	Drawing No.	Detail No.	
1																	No penetration - removed.
2																	No penetration - removed.
3																	No penetration - removed.
4	No	No	<500mm	No	No	No	Yes	130	No	Yes	Yes	No	No				Penetration framed, 90x90x10, 290x350 spacing. Steel trusses with sloped back to back angles at plank bearing.
6	No	Yes	<500mm	Yes	No	No	Yes	150	No	Yes	Yes	No	No		S-00005	09	Penetration is through precast, both precast and RAAC are on folded plt straps. At steel truss with 150mm flange. Folded strap circa 40mm. Steel angle running length of cut raac panel.
7	Yes	Yes	<500mm	No	No	No	No		No	No	No	No	No		S-00005	08	No penetration found. Large crack running down one plank with some cracking visible. Steel trusses with sloped back to back angles at plank bearing.
8	No	Yes	<500mm	No	No	No	Yes	120	No	Yes	Yes	No	No		S-00005	09	Penetration is through precast, both precast and RAAC are on folded plt straps. Crack due to suspended services.
9	No	No	>500mm	No	Yes	Yes	Yes	330 sq	No	No	Yes	No	No		S-00005 S-00002	09 R1	Penetration (vent) without framing observed. Planks affected with spalling to the soffit.
10	No	No	<500mm	No	No	No	Yes	C 150	No	Yes	Yes	No	No				Penetration framed,with steel angles. Trusses as before.
11	No	No	<500mm	No	Yes	Yes	Yes	C 200 d	No	Yes	No	No	No				Hole framed with angles. Adjacent plank has a single longitudinal crack.
12	No	Yes	<500mm	No	Yes	Yes	Yes	C 200 d	No	No	Yes	No	No				Hairline crack that is diagonal, bridges two planks.
13																	No penetration - removed.
14	No	Yes	<500mm	No	Yes	Yes	Yes	C 150	No	Yes	Yes	No	No				Penetration supported by steel angles, longitudinal crack is hairline.
16																	No penetration - removed.
17	No	No	<500mm	No	Yes	No	Yes	200	No	Yes	Yes	No	No		S-00005	09	Spall repaired. Penetration is through precast, both precasts and RAAC are on folded plt straps. Truss flange width 150mm, finger gap available.
18	Yes	Yes	>500mm	No	Yes	Yes	Yes	200x200 + 180x250	No	Yes	Yes	Yes	No				Steel angles used around penetrations, 90x90x10. Framed out, with 400 spacing and 370 spacing respectively. Appears to have historic wetness.
19	No	No	<500mm	Yes	Yes	No	Yes	300dia	No	Yes	Yes	No	No		S-00005	09	Penetration is through precast, both precasts and RAAC are on folded plt straps.
20	No	No	<500mm	Yes	Yes	Yes	Yes	300dia	No	No	Yes	No	No		S-00005 S-00002	09 R1	Flange 170mm wide with planks sitting on inverted T.
21	No	Yes	>500mm	No	Yes	Yes	Yes	120 pipe, approx 150 hole	No	Yes	Yes	No	No				Boxed out 90X90X10 angles, 340mm spacing between boxing.
22	No	Yes	<500mm	No	No	Yes	Yes	200x300 hole, 150x250duct	No	Yes	Yes	No	No				Boxed out 90X90X10 angles, 400mm spacing between boxing. Trusses as before.
	No	No	>500mm	No	Yes	Yes	Yes	200	No	Yes	Yes	No	No				Boxed out 90X90X10 angles, 490x400 spacing between boxing. 165 x 105 UB and truss.
24	No	Yes	<500mm	Yes	Yes	Yes	Yes	330x330	No	No	Yes	No	No		S-00005 S-00002	09 R1	Plate covering actual opening so cannot determine the size. Duct is 330x330 sq. Trusses as before.
25	No	Yes	>500mm	Yes	Yes	Yes	Yes	120dia	No	No	Yes	No	Yes		S-00005	09	No straps around penetration. plank with pen doesnt seem to be deflected as much as the ones closer to interior of building, probably due to edge support on building perimeter. 10 mm difference in deflection between planks.
26	No	No	>500mm	No	Yes	No	Yes	150dia	No	Yes	Yes	No	No				315x315 plate around hole. framed by steel angles, approx 100mm flange.
27	No	No	>500mm	No	Yes	Yes	Yes	200dia, 400dia hole	No	Yes	Yes	No	No				Framed by steel angles, approx 90mm flange.
28	No	No	<500mm	No	Yes	Yes	Yes	200x300 duct, 350x450 hole	No	Yes	Yes	No	No				Change in orientation for planks (corner of building. Pentration cut into two planks at edges. Framing 100x100x10, 600 x500 spacing. Trusses as before in one direction for penetration.
29	No	No	>500mm	No	Yes	Yes	Yes	120 pipe, approx 175 hole	No	Yes	No	No	No		S-00005	08	Boxed out 90X90X10 angles, approx. 300mm square. Trusses as before. Parallel and perpendicular cracks found in nearby plank.
30	No	No	<500mm	No	Yes	No	Yes	1100x1200 skylight	No	Yes	Yes	No	No				Angle on one side, truss on other side. 90x90x10 angles framing the skylight. Trusses as before.
31	No	No	<500mm	No	Yes	Yes	Yes	550x500 square peno,	No	Yes	Yes	No	No				Penetration goes through 2 planks. 100x100x10 angles framing penetration. Trusses as before.
32	No	No	<500mm	No	Yes	Yes	Yes	200dia pipe, 300dia hole.	No	Yes	Yes	No	No				Framed by 90x90x10 steel angles. Trusses as before.
33	No	No	<500mm	No	Yes	Yes	Yes	300dia pipe, 350dia hole	No	Yes	Yes	No	No				Framed by 90x90x10 steel angles.

Panel Condition

Location	General Condition														Repair Detail		Comments
	Cracking			Spalling				Alterations									
	Perpendicular [1]	Parallel [2]	Distance from Support [Edg]/[Mid]	Stress [3]	Modification [4]	Rebar Visible [R]/[NR]	Penetration [5]	Approx. Size [mm] [Dxxx]	Edge Modification [6]	Folded PLT [7]	Suspended Services [8]	Wet [9]	Deflection [10]	Risk Rating	Drawing No.	Detail No.	
34	No	No	<500mm	No	Yes	Yes	Yes	150dia pipe, 300dia hole	No	Yes	Yes	No	No				Framed by 90x90x10 steel angles. Trusses as before.
35	No	No	<500mm	No	Yes	No	Yes	300d pipe	No	Yes	Yes	No	No		S-00005	09	Angle along long edge of plank, 90 flange. Penetration is through precast, both precasts and RAAC are on folded plt straps.
36	No	No	<500mm	No	Yes	Yes	Yes	300d pipe, 350 square hole	No	Yes	No	No	No				Angles framing penetraition, 100x100. Trusses as before.
37	No	Yes	>500mm	No	Yes	Yes	Yes	150diapipe, 200 hole	No	Yes	Yes	No	No				Angles framing penetraition, 100x100. Trusses as before.
38	No	No	<500mm	No	Yes	No	Yes	150d pipe, 250 hole	No	Yes	Yes	No	No		S-00005	09	Penetration is through precast, both precasts and RAAC are on folded plt straps.
39	No	Yes	<500mm	No	Yes	Yes	Yes	500sqaure duct, same hole	No	Yes	Yes	No	No				Vent cuts through 2 planks. Angles framing penetration, 100x100. Trusses as before.
40	Yes	Yes	<500mm	No	Yes	No	Yes	120dia pipe, plate covering	No	Yes	Yes	No	No				Angles framing penetraition, 100x100. Trusses as before.
41	No	No	<500mm	No	Yes	Yes	Yes	300dia pipe, 400dia hole	No	Yes	Yes	No	No		S-00002	R1	Area of RAAC around penetration is potentially loose. Concrete repair may be required. Angles framing penetration, 100x100. Trusses as before. Framing angles supported by truss and blockwork wall.
42	No	No	<500mm	No	Yes	No	Yes	300dia pipe,	No	Yes	Yes	No	No		S-00005	09	Penetration is through precast, both precast and RAAC are on folded plt straps, approx 2 x 50mm each.
43	No	Yes	>500mm	No	Yes	Yes	Yes	150dia pipe, 200dia hole.	No	Yes	Yes	No	No				Angles framing penetraition, 100x100. Trusses as before. Crack around services fixing.
44	No	Yes	<500mm	No	No	No	Yes	120dia pipe, cover plate	Yes	Yes	Yes	No	Yes		S-00005	08	Steel cover plate around penetration. Steel angle along edge of modified plank. Angles framing penetration, 100x100. Large crack ~2-3mm, 25mm depth, running parallel with span along full length.
45	No	No	<500mm	No	Yes	No	Yes	120dia pipe. plate covering	No	Yes	Yes	No	No				Spalling has been repaired. Angles framing penetration, 100x100. Trusses as before. Cellular beam supporting framing.
46	No	No	<500mm	No	Yes	No	Yes	150dia pipe, 250x250square hole	No	Yes	Yes	No	No		S-00005 S-00002	09 R1	Visibility impaired due to suspended services, but appears to be penetration is through precast, both precast and RAAC are on folded plt straps. Minor spalling at the strap.
47	No	No	<500mm	No	Yes	No	Yes	C 460	No	Yes	No	No	No				Hole filled and edges of opening repaired. Steel angles used to frame the hole.
48	No	No	>500mm	No	Yes	Yes	Yes	C 460 sq	No	Yes	Yes	No	No				Ventilation unit suspended from slab, but hole trimmed with steel angles.
49	Yes	Yes	<500mm	No	No	No	Yes	C 150 diam	No	Yes	Yes	Yes	No		S-00005	09	Rain water pipe in a precast plank, both RAAC and precast on 50 folded plt straps. Longitudinal crack remote from strap, small local crack at strap.
50	No	No	>500mm	No	Yes	Yes	Yes	150d pipe, 200 hole	No	No	Yes	No	Yes		S-00005 S-00002	09 R1	No framing around penetration, sagging visible. Significant spalling, repair required. Raised marking in perpendiculer direction, continuous over 5 planks. Penetration between two planks.
51	No	Yes	<500mm	No	Yes	Yes	Yes	200x200 hole	No	No	Yes	No	Yes		S-00005 S-00002	09 R1	Several smaller service pipes coming through penetration. Angle running the length of the adjacent plank. Possible debris falling, concrete repair required.
52	No	No	>500mm	No	Yes	Yes	Yes	300d pipe, 400 square hole	No	No	Yes	No	Yes		S-00005 S-00002	09 R1	Rebar is visible 500mm beyond penetration. Concrete repair required. The adjacent planks is affected with spalling. Minor sagging visible at midspan. Plant above.
53	No	Yes	<500mm	No	No	No	Yes	1100 square	No	Yes	Yes	No	No		S-00005	08	Skylight, parallel cracks in two adjacent planks. Framed by truss and steel angles, 100x100.
54	No	No	<500mm	No	Yes	No	Yes	1200 square	No	Yes	No	No	No				Angles framing penetration, 100x100. Small holes drilled in nearby planks, 20mm diameter. Trusses as before.
55	Yes	Yes	<500mm	No	No	No	Yes	80dia, thick cables	No	No	Yes	No	Yes		S-00005	08	3 planks with identical cracking, panels adjacent to penetration are deflected, plant above.
56	No	No	<500mm	No	Yes	Yes	Yes	200dia pipe, 300sq hole.	No	No	Yes	No	No		S-00005 S-00002	09 R1	Penetration has no framing.
57	No	No	<500mm	No	No	No	Yes	approx 500sq pipe in 500hole	No	Yes	Yes	No	No				Truss on one side of penetration, steel angles 100x100 on other. Trusses as before.
58	No	No	<500mm	No	No	No	Yes	400dia pipe	No	No	Yes	No	No		S-00005	09	Steel plate covering hole for pipe, may cut through 2 planks.
59	No	No	<500mm	No	Yes	No	Yes	200d pipe	No	No	Yes	Yes	Yes		S-00005 S-00002	09 R1	Limited visibilty, possibly rebar showing. Sagging around penetration, difference in planks observed.
60	No	No	<500mm	No	No	No	Yes	1200x1200	No	Yes	Yes	No	No				Skylight, framed by truss and angles (100x100).
61	No	No	<500mm	No	Yes	Yes	Yes	C 250 sq	No	No	Yes	Yes	No		S-00005 S-00002	09 R1	Gap between adjacent planks is circa 10mm, plank has moved during modifications. Some evidence of historic water.

Panel Condition

Location	General Condition														Repair Detail		Comments
	Cracking			Spalling					Alterations								
	Perpendicular [1]	Parallel [2]	Distance from Support [Edg]/[Mid]	Stress [3]	Modification [4]	Rebar Visible [R]/[NR]	Penetration [5]	Approx. Size [mm] [Dxxx]	Edge Modification [6]	Folded PLT [7]	Suspended Services [8]	Wet [9]	Deflection [10]	Risk Rating	Drawing No.	Detail No.	
62	No	Yes	<500mm	No	No	No	No		No	No	Yes	No	No		S-00005	08	Hairline cracks, longitudinal, possibly low cover. Below AHU on top side.
63	No	Yes	<500mm	No	Yes	Yes	Yes	150x150	No	No	Yes	No	No		S-00005 S-00002	09 R1	3 planks with parallel cracks. Not currently wet but historic water ingress. Penetration framed by straps/angles.
64	Yes	Yes	<500mm	No	Yes	No	Yes		No	Yes	No	Yes	No		S-00005	09	Pipe placed in pc unit that replaces RAAC, both of which are carried on folded plt straps. There is some cracking adjacent to the strap. At the other end of the RAAC there is a minor spall, likely damage, near the support.
65	No	Yes	>500mm	No	Yes	Yes	Yes	C 300 sq	No	No	No	Yes	No		S-00005 S-00002	09 R1	
66	No	No	>500mm	No	Yes	Yes	Yes	C 300 sq	No	No	No	No	No		S-00005 S-00002	09 R1	
67	No	Yes	<500mm	No	Yes	Yes	Yes	C 250 sq	Yes	No	No	No	No		S-00005 S-00002	09 R1	End plank which appears to have been trimmed to fit gap, but supported on an edge angle. Some minor cracking on soffit.
68	Yes	No	>500mm	Yes	Yes	No	Yes		No	Yes	Yes	No	No		S-00005	09	Cracking & minor spalling in location of service fixings. Penetration in precast, both precast & RAAC on folded plt straps. Minor spall at folded straps.
69	Yes	No	>500mm	No	Yes	No	Yes		No	Yes	Yes	No	No		S-00005	09	Limited visibility due to services. Penetration is through precast, both precasts and RAAC are on folded plt straps. Cracking is near service fixings.
70	No	No	<500mm	No	Yes	No	Yes	200d pipe	No	Yes	Yes	No	No		S-00005	09	Limited visibilty due to services. Penetration is through precast, both precasts and RAAC are on folded plt straps. 2x 50mm straps.
71	No	No	<500mm	No	Yes	Yes	Yes	C 350x250	No	No	Yes	Yes	No				Major unsupported penetration near the plank end.

Bearing Condition

Location Key:
1a1: location on the roof; position along the length of the support; position either side of the support

Location	Bearing Condition					Repair Detail	
	Bearing Width	Transverse bar in end zone	Risk Rating	Mitigations	Mititgated Risk Rating	Drawing No.	Detail No.
1a1	53			Free from cracks top and bottom; dry; top and bottom rebar proven at 1b1; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
1a2	42			Free from cracks top and bottom; dry; top and bottom rebar proven at 1b1; bar in longitudinal joints; bearing marginally less than 45; **actively managed**		S-00004	06/07
1b1	53	yes		Free from cracks top and bottom; dry; top and bottom rebar proven; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
1b2	42			longitudinal hairline crack in top at corner; dry; top and bottom rebar proven at 1b1; bar in longitudinal joints; bearing marginally less than 45; **actively managed**		S-00004	06/07
1c1	53			Free from cracks top and bottom; dry; top and bottom rebar proven at 1b1; bar in longitudinal joints; bearing marginally less than 45; **actively managed**		S-00004	06/07
1c2	42			Longitudinal hairline crack in top at corner; dry; top and bottom rebar proven at 1b1; bar in longitudinal joints; bearing marginally less than 45; **actively managed**		S-00004	06/07
2a1	42			Longitudinal hairline crack in top; dry; top and bottom rebar proven at 2b1; bar in longitudinal joints; bearing marginally less than 45; **actively managed**		S-00004	06/07
2a2	63			no cracks [though full plank width not visible]; dry; top and bottom rebar proven at 2b1; bar in longitudinal joints; bearing marginally less than 45; **actively managed**		S-00004	06/07
2b1	42	yes		perpendicular hairline crack in top; dry; top and bottom rebar proven; bar in longitudinal joints; bearing marginally less than 45; **actively managed**		S-00004	06/07
2b2	64			Longitudinal hairline cracks in top; dry; top and bottom rebar proven at 2b1; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
2c1	42			longitudinal and diagonal hairline cracks in top near side edge; dry; top and bottom rebar proven 2b1; bar in longitudinal joints; bearing marginally less than 45; **actively managed**		S-00004	06/07
2c2	55			longitudinal hairline cracks top and bot; dry; top and bottom rebar proven 2b1; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
2d1	42			longitudinal hairline cracks in top; dry; top and bottom rebar proven 2b1; bar in longitudinal joints; bearing marginally less than 45; **actively managed**		S-00004	06/07
2d2	63			longitudinal hairline cracks in top; dry; top and bottom rebar proven 2b1; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
2e1	42			no cracks [though full plank width not visible]; dry; top and bottom rebar proven 2b1; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
2e2	59			no cracks [though full plank width not visible]; dry; top and bottom rebar proven 2b1; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07

Bearing Condition

Location Key:
1a1: location on the roof; position along the length of the support; position either side of the support

Location	Bearing Condition					Repair Detail	
	Bearing Width	Transverse bar in end zone	Risk Rating	Mitigations	Mititgated Risk Rating	Drawing No.	Detail No.
3a1	50			diagonal hairline crack in top [though full plank width not visible]; dry; top and bottom rebar proven 3b1; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
3a2	45			no cracks [though full plank width not visible]; dry; top and bottom rebar proven 3b1; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
3b1	50	yes		longitudinal hairline crack; dry; top and bottom rebar proven; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
3b2	47			free from cracks top and bottom; dry; top and bottom rebar proven at 3b1; bar in longitudinal joints; bearing > 45; actively managed		S-00004	06/07
3c1	50			diagonal hairline crack in top; dry; top and bottom rebar proven at 3b1; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
3c2	51			free from cracks top and bottom; dry; top and bottom rebar proven at 3b1; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
3d1	50			free from cracks top and bottom [though full plank width not visible]; dry; top and bottom rebar proven at 3b1; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
3d2	48			free from cracks top and bottom [though full plank width not visible]; dry; top and bottom rebar proven at 3b1; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
4a1	43			free from cracks top and bottom [though full plank width not visible]; dry; top and bottom rebar proven at 4c2; bar in longitudinal joints; bearing marginally less than 45; **actively managed**		S-00004	06/07
4a2	52			free from cracks top and bottom [though full plank width not visible]; dry; top and bottom rebar proven at 4c2; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
4b1	43			top of slab damaged in corners during installation & repaired with hard cemenet, damage not full depth; dry; top and bottom rebar proven at 4c2; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
4b2	57	yes		free from cracks on top and bot, but not full depth; dry; top and bottom rebar proven at 4c2; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07
4c1	43			top edge of slab damaged during installation & repaired with hard cement, damage not full depth; dry; top and bottom rebar proven at 4c2; bar in longitudinal joints; bearing marginally less than 45; **actively managed**		S-00004	06/07
4c2	52			diagonal hairline crack; dry; top and bottom rebar proven; bar in longitudinal joints; bearing marginally less than 45; **actively managed**		S-00004	06/07
4d1	43			free from cracks top and bottom [though full plank width not visible]; dry; top and bottom rebar proven; bar in longitudinal joints; bearing marginally less than 45; actively managed		S-00004	06/07
4d2	55			free from cracks top and bottom [though full plank width not visible]; dry; top and bottom rebar proven; bar in longitudinal joints; bearing > 45; **actively managed**		S-00004	06/07

Conclusions

Panel Condition

In summary, the evidence suggests a history of cutting holes in the existing roof planks post construction. Sometimes they have been formed in a controlled manner and others times they have not. There has also been an uncontrolled accumulation of services suspended directly from the RAAC, rather than from the primary structure. Together these factors have resulted in the distress and, damage we have documented, and the associated remedial work we have recommended.

Our observations from the ceiling void fall into several broad categories:

1. Openings which have been trimmed back to primary structure
2. Openings where planks have suplementary support from adjacent planks using folded metal plates in the joints
3. Small openings without supplementary support
4. Large openinings without supplementary support
5. Panels with cracks and / or spalls

Within the first four categories the panels are generally dry and have not deflected excessively, but there is often minor spalling, which is generally associated with the formation of the hole.

Remedial works have been recomended for planks assigned a red category, which generally have a large opening without supplementary support, either from trimmer joists or folded metal straps [4], although sometimes cracks and spalls have also led to this category [5]. Typical details have been referenced for strengthening.

Planks with openings have generally been given an amber status if they are supported from adjacent planks by folded metal straps, rather than trimmer joists back to the primary structure [2]. This is, of course, based on the adjacent planks not being distressed. Such arrangements have adopted the contemporary detailing recomended by the original manufacturers.

That said, table 2 of the IStructE guidance views cut planks with supplementary support from folded plate straps as a risk because the straps are normally less than 75 wide, and because transverse bars may not be present over the bearing. Nonetheless, if a plank end is removed the tolerance issue, associated with placement of the longitudinal reinforcement in the plank end, is effectively removed. This means that the longitudinal bars can provide mitigation against the potential for brittle shear failure.

The potential absence of the transverse bar, due to cutting, is only relevant if the anchorage of the longitudinal bars is not sufficient. If this were the case, then we would expect to see signifcant deflections due to slippage of the longitunidal bars. In the absence of such deflections we may infer that the extant bond stress is sufficient for the loads currently being supported. In addition, the potential for failure has become more ductile and less brittle.

It follows that, providing the plank has been seated correctly, the load on the plank is not increased and its condition is maintained, the existing straps can provide satisfactory support. In respect of loading, it is also worth noting that by cutting a plank, its span will be shorter and it is therefore working less hard than its neighbours. Where these conditions have not been met supplementary support is recommended.

In the absence of other factors, some small openings, without supplementary support, are given an amber rating too [3].

Openings trimmed back to primary structure are generally green, unless there is evidence of significant distress or damage [1].

Cracks were observed on the soffit of some planks [5]. In some cases these are associated with service penetrations, but this is not always the case. Since the span to depth ratio, where measured, is not unreasonable, and is compatible with contemporary load span charts, we might infer that cracks remote from openenings are the result of the load that is being carried, albeit excessive deflection was frequently not observed. It is also worth noting that in many cases the cracks were parallel, rather than perpendicualr to the span. This could imply a 'shaddow effect' from the autoclave process has played a role in their formation. That said, we often found suspended services and / or rooftop plant corresponding to the crack locations. This could indicate there being an alternative, or at least additional explanation, for instance, insufficient distribution reinforcement to spread load from local fixings across the width of a plank. For this reason, we recomend that suspended services be re-supported from the primary structure instead of the RAAC planks and that rooftop plant be relocated. If the latter is not viable then it is recomended that the load be spread more widely, preferrably back to the primary structure i.e. steel beams or loadbearing walls.

For avoidance of doubt, the above appraisal is explicitily based on there being a written plan for actively managing the RAAC in-situ. This should specifically include preventing the existing load on the roof from being increased, keeping the planks dry, avoiding increased deflection, and preventing unauthorised alterations. It should also include a robust plan for monitoring the performance in-situ so that preventative action may be taken before a given plank changes risk category.

If the above plan is not in place then all RAAC in the building should be brought into strict alignment with the IStructE's recomendations. In practise this means that some amber locations will change category and structural enhancements will be required. References to strengthening details have been provided for this purpose.

Bearing Condition

Where inspected, the plank bearings were sometimes found to be marginally less than 45 mm wide, which was the contemporary requirement, and in every case they were found to be less than 75 mm, which is the IStructE requirement. A statistical analysis of the floor plate, using standard deviation and T-distribution, shows that the probability of bearings being less than 45 mm is 25%. The normative value for structural calculations is 5%.

In each location that was inspected, reinforcement was found in the bottom and top of the plank, and the appearance of adjacent planks was the same. Longitudinal reinforcement was also found in the recessed joints between planks. These bars were located over the supports, but extended only 320 beyond the centre line.

There were also some local areas of distress evident on the top edge of some plank ends. This seems to be associated with the installation process, likely when leverage was applied during placement. More remote from the edge there are hairline cracks in the top of some planks.

Self-evidently, although reinforcement has been found to be present at the bearings, which helps to mitgate the potential for a brittle failure, the existing bearing widths do not comply with either the contemporary or modern requirement. For this reason, remedial works are recomended.

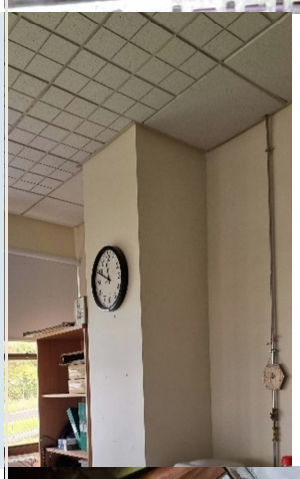
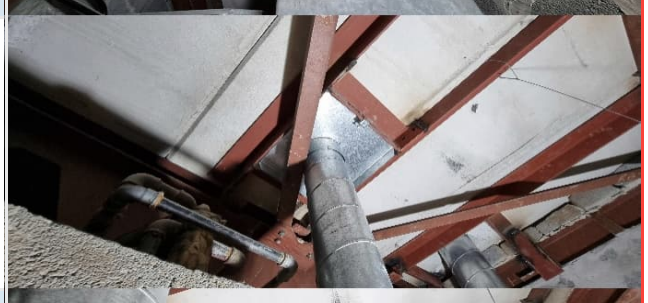
It is reasonable to ask why the roof has performed satisfactorily for a long time, despite the bearing widths being found to be inadequate. There are several reasons why this might be. Firstly, the planks may not have reached their design load, and secondly, where observed the non-conformance is small.

Another factor, could be the toughness of the original tar finish that remains in-situ below the single ply membrane. While you would not want to place structural reliance on roof finishes, the tar was bonded firmly to the RAAC and was found to be exceedingy difficult to remove during the opening works. Indeed, it had to be pre-weakended with saw cuts and even then proved exceedingly resiliant.

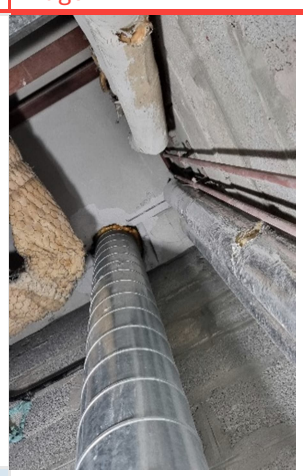
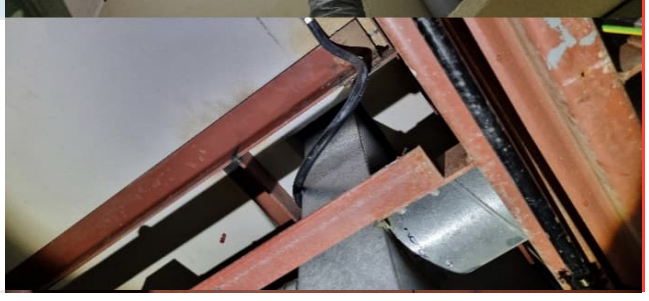
Nevertheless, since none of the measured bearings met the modern requirement, and our statistical assessment infers that a reasonable portion will fail to meet the original specification, there is no option but to recomend enhancements in line with the IStructE's guidance. Until this work is complete we also recomend that mitigations be put in place to manage the condition of the RAAC so that it becomes no worse than when the inspection took place.

This should include ensuring no new load is added to the roof, keeping the planks dry, and ensuring no unauthorised penetrations are made. The processes for achieving this should be contained in a written document and conveyed to staff responsible for implementing the plan. If the plan is not in place then the red locations will move up a category.

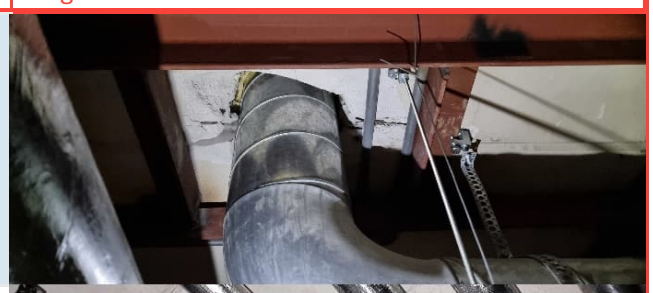
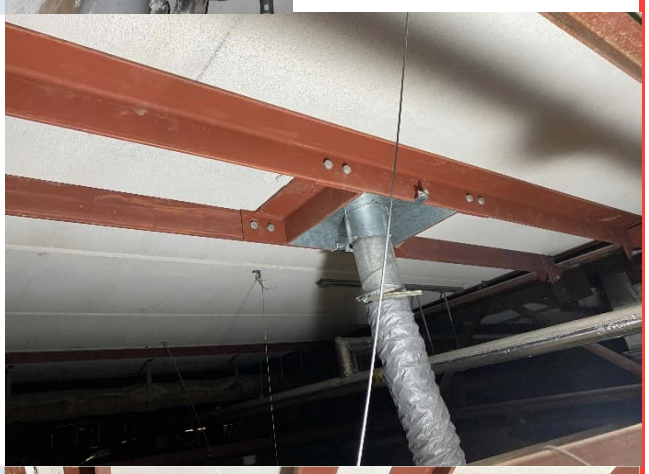
Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L02	GRY			
L03	GRY			
L04	GRN.Edg.NR.5.D130.7.8			
L05	GRY			
L06	RED.2.Edg.3.NR.5.D150.7.8	S-00005	09	
L07	AMB.1.2.Edg.NR	S-00005	08	
L08	AMB.2.Edg.NR.5.D120.7.8	S-00005	09	
L09	RED.2.Mid.4.R.5.D120 pipe, approx 150 hole.7.8	S-00005 S-00002	09 R1	
L10	GRN.Edg.NR.5.DC 150.7.8			
L11	GRN.Edg.4.R.5.DC 200 d.7			

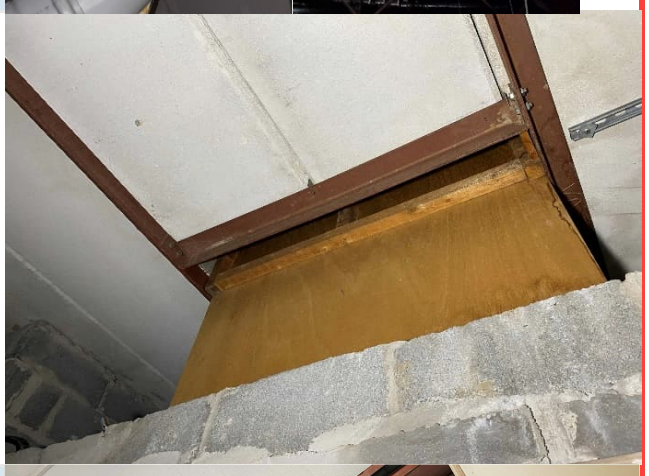
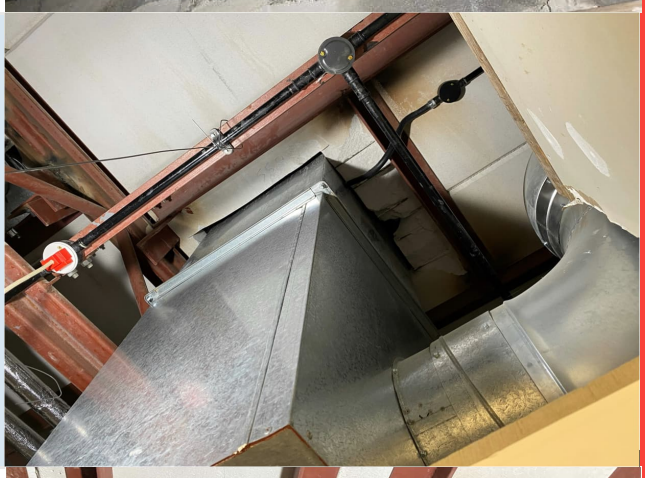
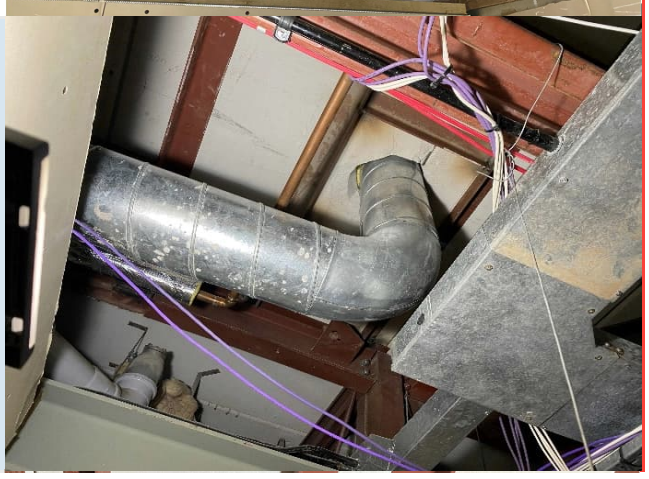
Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L12	AMB.2.Edg.4.R.5.DC 200 d.8			
L13	GRY			
L14	GRN.2.Edg.4.R.5.DC 150.7.8			
L15	GRY			
L16	GRY			
L17	AMB.Edg.4.NR.5.D200.7.8	S-00005	09	
L18	GRN.1.2.Mid.4.R.5.D200x200 + 180x250.7.8.9			
L19	AMB.Edg.3.4.NR.5.D300dia.7.8	S-00005	09	
L20	RED.Edg.3.4.R.5.D300dia.8	S-00005 S-00002	09 R1	
L21	GRN.2.Mid.4.R.5.D120 pipe, approx 150 hole.7.8			
L22	GRN.2.Edg.R.5.D200x300 hole, 150x250duct.7.8			

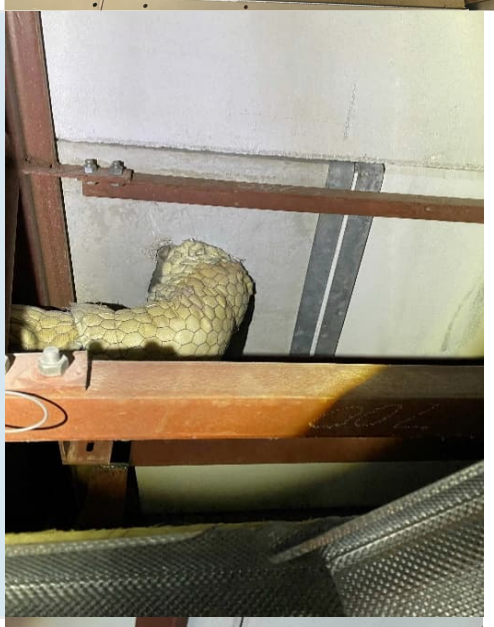
Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L23	GRN.Mid.4.R.5.D200.7.8			
L24	RED.2.Edg.3.4.R.5.D330x330.8	S-00005 S-00002	09 R1	
L25	AMB.2.Mid.3.4.R.5.D120dia.8.10	S-00005	09	
L26	GRN.Mid.4.NR.5.D150dia.7.8			
L27	GRN.Mid.4.R.5.D200dia, 400dia hole.7.8			
L28	GRN.Edg.4.R.5.D200x300 duct, 350x450 hole.7.8			

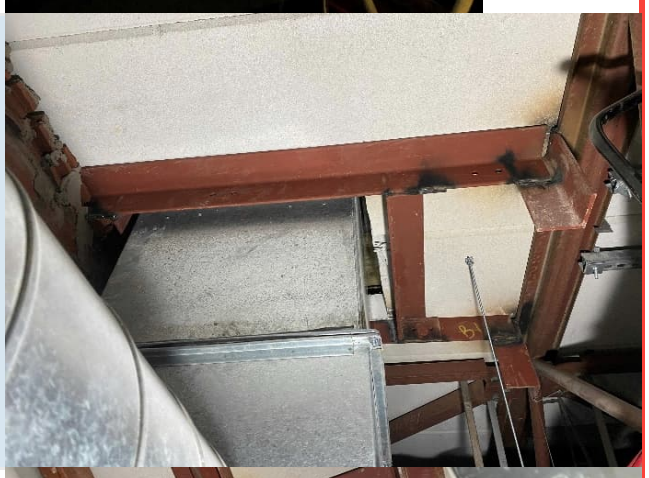
Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L29	RED.Mid.4.R.5.D120 pipe, approx 175 hole.7	S-00005	08	
L30	GRN.Edg.4.NR.5.D1100x1200 skylight.7.8			
L31	GRN.Edg.4.R.5.D550x500 square peno,.7.8			
L32	GRN.Edg.4.R.5.D200dia pipe, 300dia hole..7.8			
L33	GRN.Edg.4.R.5.D300dia pipe, 350dia hole.7.8			

Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L34	GRN.Edg.4.R.5.D150dia pipe, 300dia hole.7.8			
L35	AMB.Edg.4.NR.5.D300d pipe.7.8	S-00005	09	
L36	GRN.Edg.4.R.5.D300d pipe,350 square hole.7			
L37	GRN.2.Mid.4.R.5.D150diapipe, 200 hole.7.8			

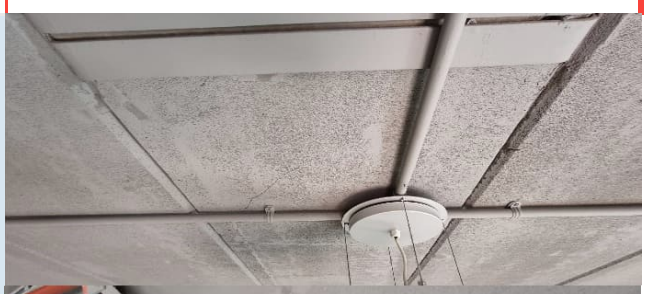
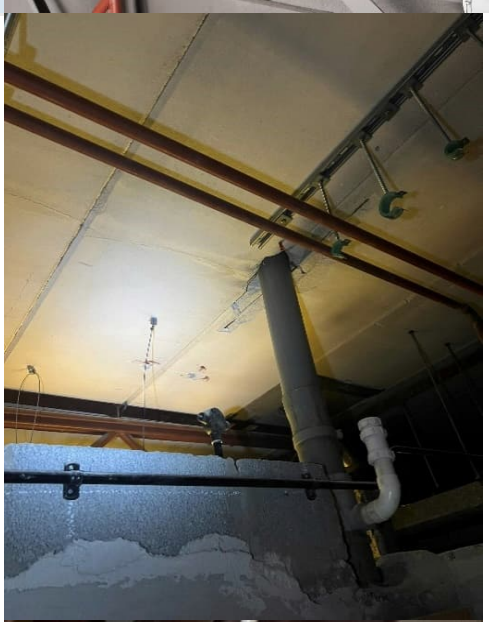
Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L38	AMB.Edg.4.NR.5.D150d pipe, 250 hole.7.8	S-00005	09	
L39	GRN.1.2.Edg.4.R.5.D500sqaure duct, same hole.7.8			
L40	GRN.1.2.Edg.4.NR.5.D120dia pipe, plate covering.7.8			
L41	RED.Edg.4.R.5.D300dia pipe, 400dia hole.7.8	S-00002	R1	
L42	AMB.Edg.4.NR.5.D300dia pipe, .7.8	S-00005	09	

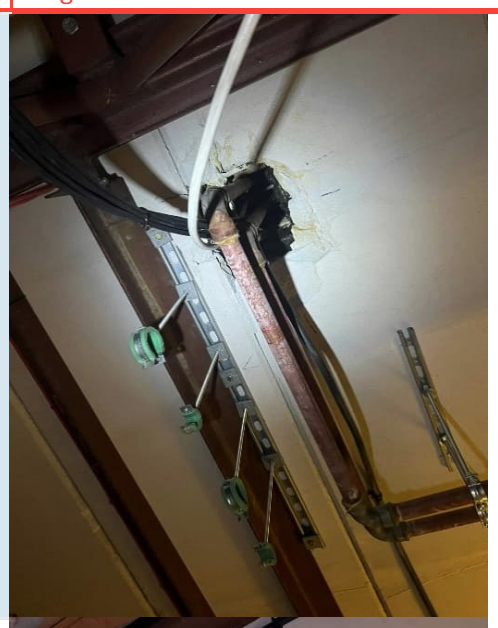
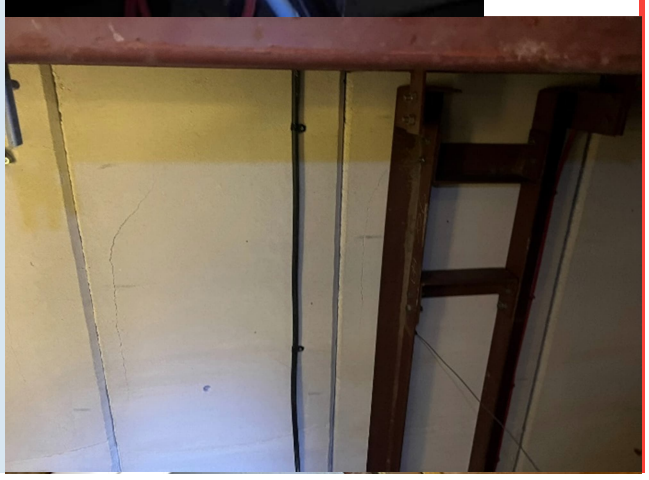
Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L43	GRN.2.Mid.4.R.5.D150dia pipe, 200dia hole..7.8			
L44	RED.2.Edg.NR.5.D120dia pipe, cover plate.6.7.8.10	S-00005	08	 
L45	GRN.Edg.4.NR.5.D120dia pipe. plate covering.7.8			

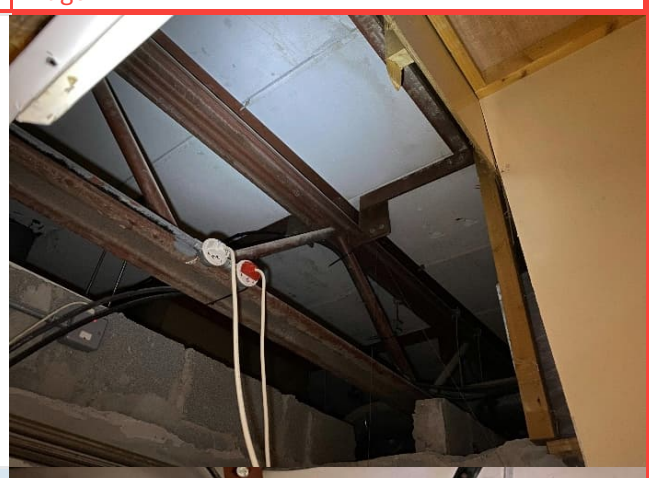
Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L46	RED.Edg.4.NR.5.D150dia pipe, 250x250square hole.7.8	S-00005 S-00002	09 R1	
L47	GRN.Edg.4.NR.5.DC 460.7			
L48	GRN.Mid.4.R.5.DC 460 sq.7.8			
L49	AMB.1.2.Edg.NR.5.DC 150 diam.7.8.9	S-00005	09	 
L50	RED.Mid.4.R.5.D150d pipe, 200 hole.8.10	S-00005 S-00002	09 R1	

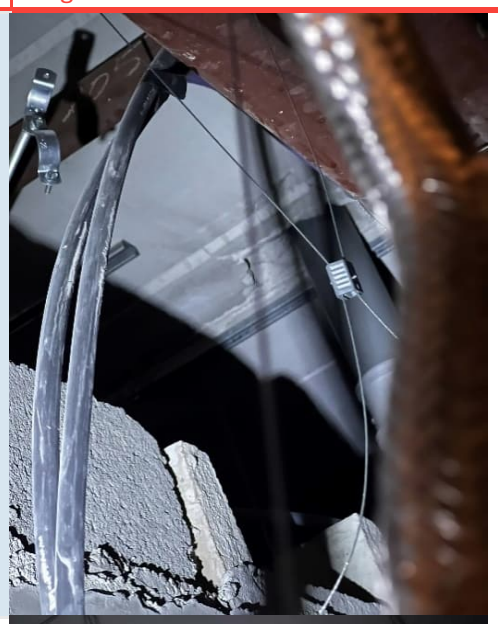
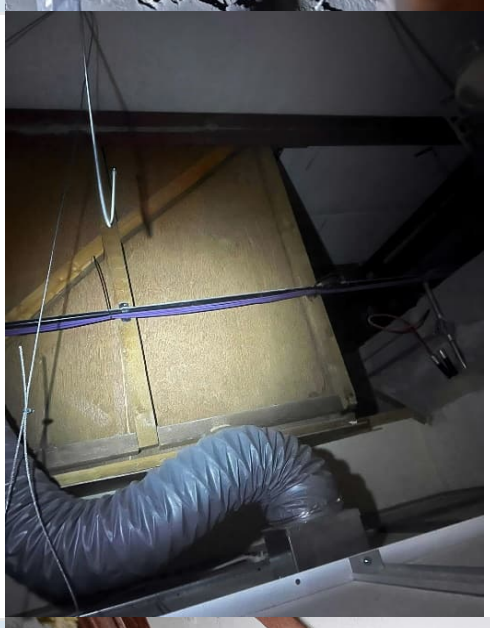
Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L51	RED.2.Edg.4.R.5.D200x200 hole.8.10	S-00005 S-00002	09 R1	
L52	RED.Mid.4.R.5.D300d pipe, 400 square hole.8.10	S-00005 S-00002	09 R1	
L53	AMB.2.Edg.NR.5.D1100 square.7.8	S-00005	08	 

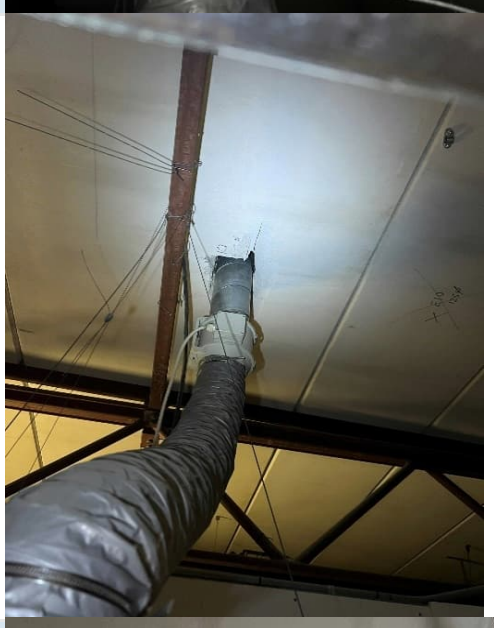
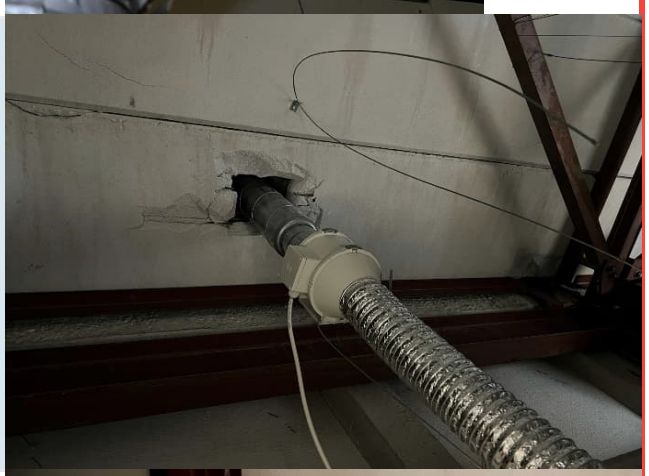
Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L54	GRN.Edg.4.NR.5.D1200 square.7			
L55	RED.1.2.Edg.NR.5.D80dia, thick cables.8.10	S-00005	08	
L56	RED.Edg.4.R.5.D200dia pipe, 300sq hole..8	S-00005 S-00002	09 R1	
L57	GRN.Edg.NR.5.Dapprox 500sq pipe in 500hole.7.8			
L58	RED.Edg.NR.5.D400dia pipe.8	S-00005	09	

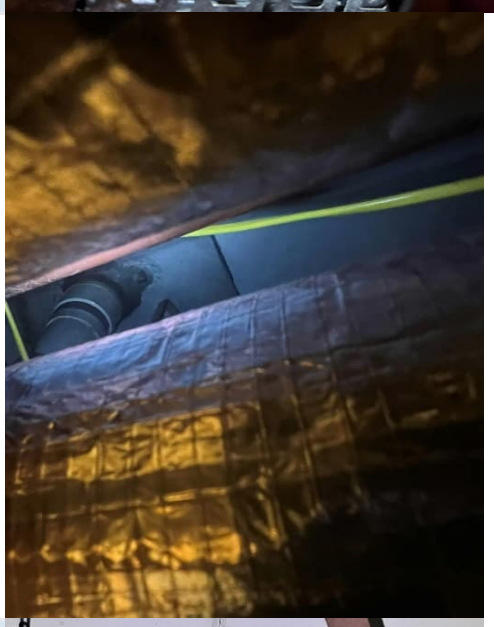
Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L59	RED.Edg.4.NR.5.D200d pipe.8.9.10	S-00005 S-00002	09 R1	
L60	GRN.Edg.NR.5.D1200x1200.7.8			
L61	RED.Edg.4.R.5.DC 250 sq.8.9	S-00005 S-00002	09 R1	
L62	AMB.2.Edg.NR.8	S-00005	08	
L63	RED.2.Edg.4.R.5.D150x150.8	S-00005 S-00002	09 R1	
L64	RED.1.2.Edg.4.NR.5.7.9	S-00005	09	

Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L65	RED.2.Mid.4.R.5.DC 300 sq.9	S-00005 S-00002	09 R1	
L66	RED.Mid.4.R.5.DC 300 sq	S-00005 S-00002	09 R1	
L67	RED.2.Edg.4.R.5.DC 250 sq.6	S-00005 S-00002	09 R1	
L68	RED.1.Mid.3.4.NR.5.7.8	S-00005	09	

Panel Summary

Location	General Condition Code	Repair Detail		Image
		Drawing No.	Detail No.	
L69	RED.1.Mid.4.NR.5.7.8	S-00005	09	
L70	AMB.Edg.4.NR.5.D200d pipe.7.8	S-00005	09	
L71	GRN.Edg.4.R.5.DC 350x250 .8.9