Batchelor's Row, Christ Church Oxford

Structural Inspection of Roof Soffit

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Job Number:	29414

Date	Revision	Notes/Amendments/Issue Purpose
April 2021	1	Information
June 2021	2	Review of records & beam capacity assessment added

Note:

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1 Introduction

Price & Myers visited Batchelor's Row, Christ Church, Oxford on behalf of Christ Church on 15th March 2021. The purpose of the inspection was to assess the condition of the soffit to the roof of Batchelor Row following concerns raised as to its condition by Sidley Chartered Surveyors.

The roof soffit is exposed and visible from within the majority of the rooms within Batchelor's Row, the exceptions are the bathrooms where a suspended ceiling severely restricted visibility.

In addition to the visual inspection a level survey was carried out by James Brennan Associates, this was converted to contour maps which are discussed later within this report.

2 Description of Existing Structure

Batchelor's Row occupies the top floor of Tom Gate, a wing of Christ Church which faces onto St Aldates. The top floor is a later addition to the seventeenth century building, the form of structure suggesting construction sometime between 1960 to 1980. Batchelor's Row is a linear floor running north-south and predominantly consists of bedrooms located either side of a central corridor, shared bathroom facilities are located toward the centre of the floor. Access is via stairs at the southern end and towards the northern end of Batchelor's Row. Beyond the northern staircase is a computer suite.

The façade to Batchelor's Row is set back from the main façade of Tom Gate, this creates a gutter-line behind the stone parapet of Tom Gate. The façade consists of rendered masonry with rendered reinforced concrete buttress piers corresponding to beam lines within the roof.

The roof structure consists of reinforced autoclaved aerated concrete (RAAC) panels spanning between beams. Within the bedrooms the RAAC panels span north-south between beam lines. The roof within the bedrooms falls from the corridor to the external wall, the soffit of the panels is exposed and so the fall evident within each room Within the corridor the RAAC panels span east-west across the width of the corridor, alternate bays within the corridor contain large roof lights which are surrounded by reinforced concrete slabs rather than RAAC panels. The roof beams are finished in concrete and span between the exterior buttress column and an internal column concealed within the corridor walls. Internal walls to the corridor are typically masonry, however some division walls are a mix of masonry & studwork and contain a roof beam concealed at the head of the wall, rather than being loadbearing itself. The roof is finished lead.

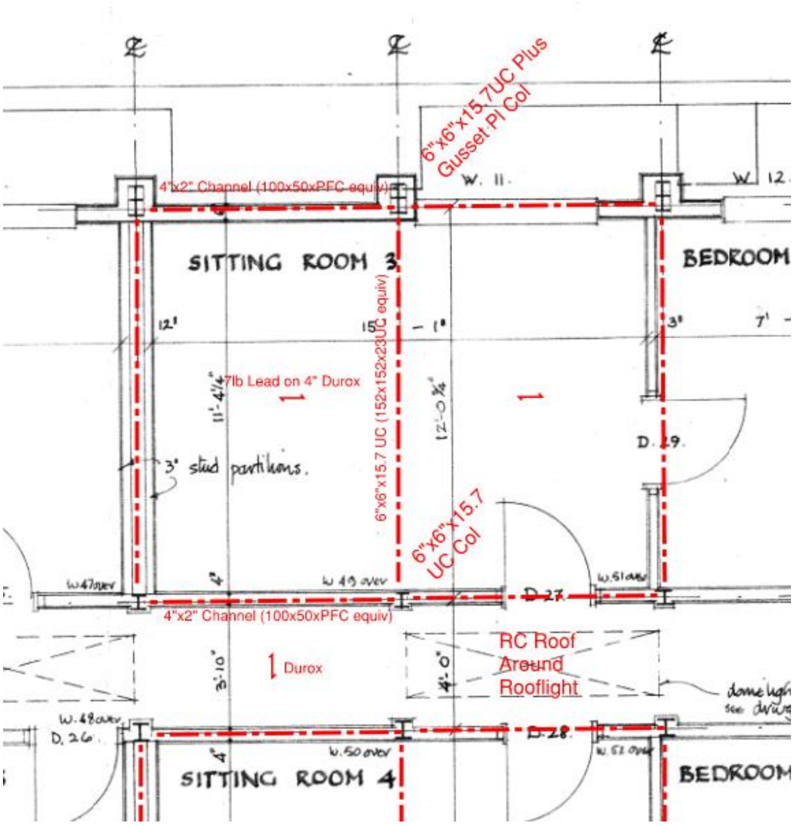


Figure 1 – Extract of Original Architect's Plan with Structure Overmarked

Record drawings show roof structure to consist of 7lb leadwork on 4" Durox (lightweight precast RAAC panels). The downstand beams spanning across rooms are shown as 6"x6"x15.7lb/ft UC sections, encased in concrete. These are supported on the equivalent section columns concealed within the corridor wall and a tapered column consisting of a 6"x6"x15.7lb/ft UC with a tapered gusset plate within the external walls. From the cross sections it appears that this tapered column transfers to via an RC corbel element to the original perimeter wall. There are no details of the reinforcement used. 4"x2" Channel sections run between columns perpendicular to the main beams, these act as tie beams, also supporting the corridor roof structure which spans the width of the corridor.

The James Brennan Associates survey floor plan is appended, refer to Appendix A.

RAAC Panels

Of particular concern are the reinforced autoclaved aerated concrete panels (RAAC). RAAC is a form of roof, wall and floor construction developed in the 1950s and used between then and the late 1970s. Panels have a similar appearance to conventional pre-cast concrete panels however the concrete contains no coarse aggregate, and was made in factories using fine aggregate, chemicals to create gas bubbles, and heat to cure the compound. It is relatively weak with a low capacity for developing bond with embedded reinforcement.

In the 1980s there were several failures of RAAC roof planks installed during the mid-1960s, research revealed a number of problems with the panels installed; incorrect cover to the tension steel, high span-to depth ratio, insufficient provision of crossbars for providing anchorage for the longitudinal steel, failure in performance of roof membrane and local corrosion of embedded steel.

The following indicators can suggest problems with RAAC panels in service;

- Creep deflections
- Corrosion of embedded reinforcement leading to cracking and spalling
- Cracking, thought to be associated with moisture and temperature related movement
- Panels tending to act independently, rather than as a single structural entity.

3 Observations

Deflection

In order to assess the deflection of the panels James Brennan Associates carried out a survey of the RAAC plank soffit. For the longer span panels, generally within bedrooms, these were converted to contour maps in order to estimate relative deflection, see Figures 2 & 3. Estimated values of deflections derived, Table 1 summarises these.

The panels within corridors are short spanning and therefore deflections are modest and so were not subject to contour analysis.

The Standing Committee on Structural Safety (SCOSS) indicate that deflections exceeding span/100 are of concern, not only because this is suggestive of panel failure but also that increased deflection can lead to excessive ponding on flat roofs which can further increase loading. Batchelor's Row roof falls are sufficient for ponding not to be a concern.

Table 1 shows that the majority of panels, (151 of 192 panels) have a deflection greater than span/200. Of the remainder most have a deflection limit of span/140 to span/145, still significantly below the limit of concern. However 3 panels, panels 19/3-5 have a deflection limit of span/108 and these warranted closer visual inspection.

Upon visual inspection there was no discernible difference in condition between those panels showing a higher degree of deflection and those showing more typical deflection. Therefore it is proposed that all panels should be considered in the same manner within the bedrooms.

The next step was to carry out a visual inspection of all panels for signs of excessive cracking, water ingress & spalling.

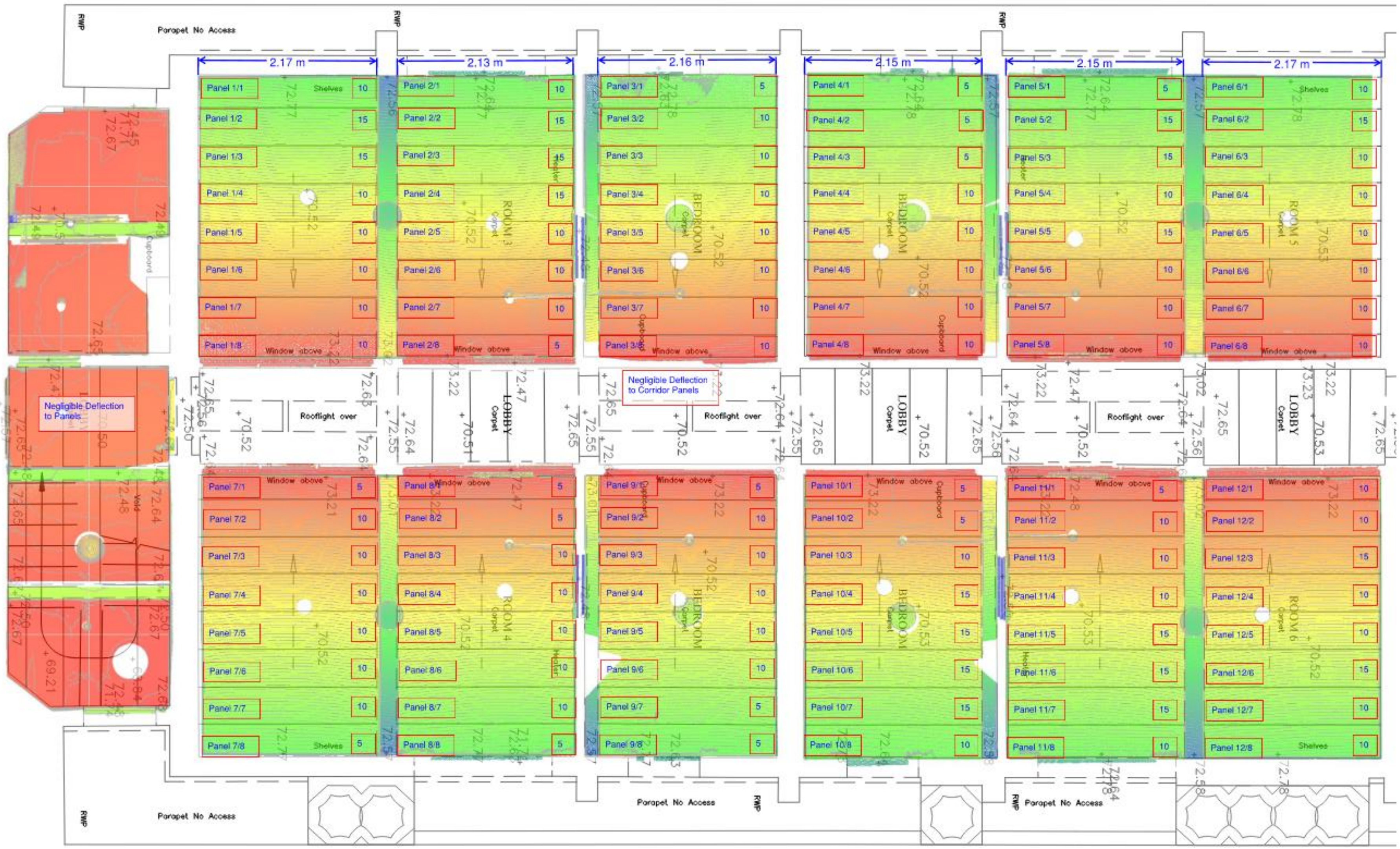


Figure 2 – Batchelor's Row – South – Roof Soffit Contours (James Brennan Assoc)

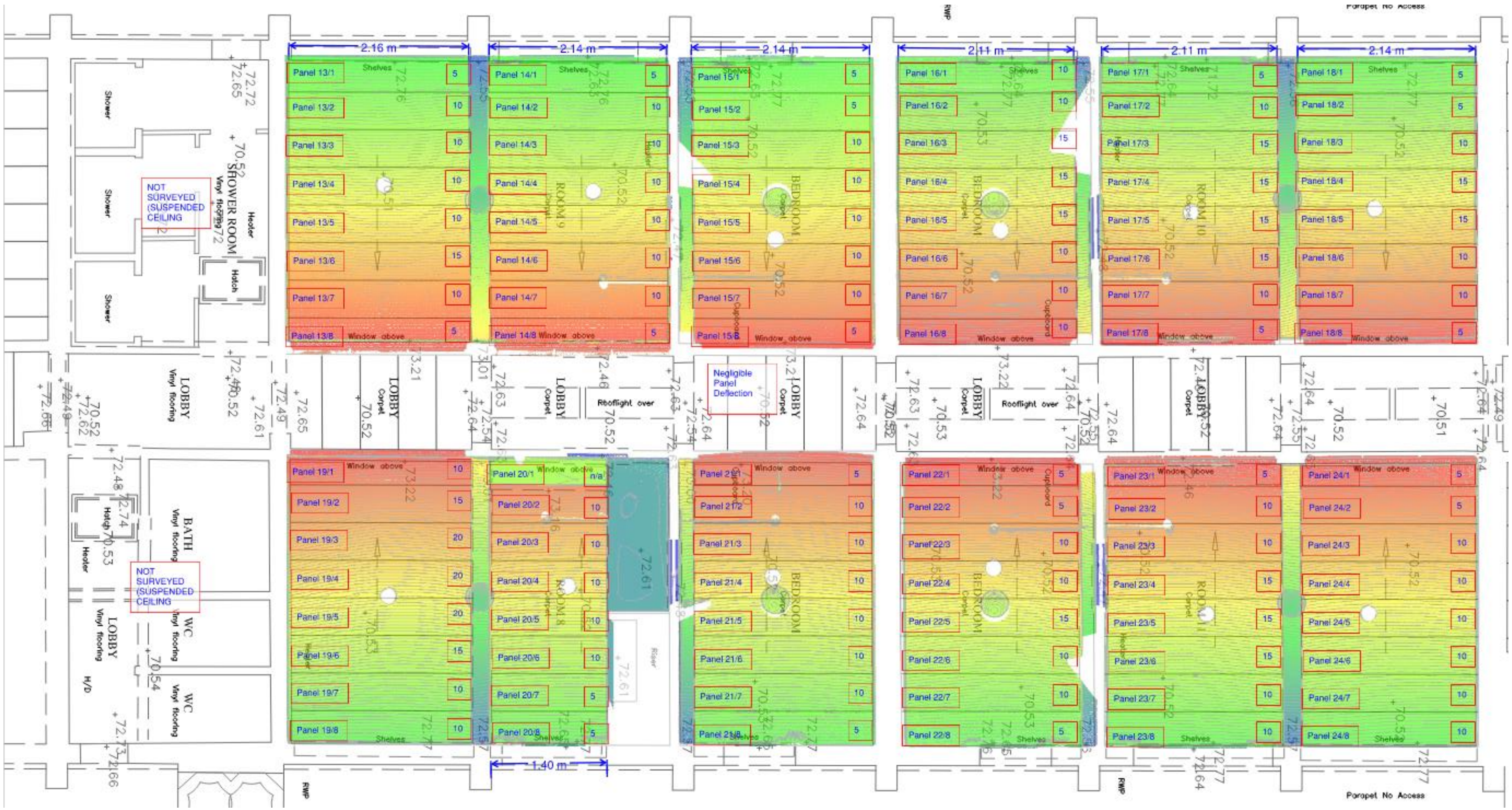


Figure 3 – Batchelor's Row – North – Roof Soffit Contours (James Brennan Assoc)

Panel No	Span (mm)	Est deflection (mm)	Span/defl
1/1	2170	10	217
1/2	2170	15	145
1/3	2170	15	145
1/4	2170	10	217
1/5	2170	10	217
1/6	2170	10	217
1/7	2170	10	217
1/8	2170	10	217
2/1	2130	10	213
2/2	2130	15	142
2/3	2130	15	142
2/4	2130	15	142
2/5	2130	10	213
2/6	2130	10	213
2/7	2130	10	213
2/8	2130	5	426
3/1	2160	5	432
3/2	2160	10	216
3/3	2160	10	216
3/4	2160	10	216
3/5	2160	10	216
3/6	2160	10	216
3/7	2160	10	216
3/8	2160	10	216
4/1	2150	5	430
4/2	2150	5	430
4/3	2150	5	430
4/4	2150	10	215
4/5	2150	10	215
4/6	2150	10	215
4/7	2150	10	215
4/8	2150	10	215

Panel No	Span (mm)	Est deflection (mm)	Span/defl
5/1	2150	5	430
5/2	2150	15	143
5/3	2150	15	143
5/4	2150	10	215
5/5	2150	15	143
5/6	2150	10	215
5/7	2150	10	215
5/8	2150	10	215
6/1	2170	10	217
6/2	2170	15	145
6/3	2170	10	217
6/4	2170	10	217
6/5	2170	10	217
6/6	2170	10	217
6/7	2170	10	217
6/8	2170	10	217
7/1	2170	5	434
7/2	2170	10	217
7/3	2170	10	217
7/4	2170	10	217
7/5	2170	10	217
7/6	2170	10	217
7/7	2170	10	217
7/8	2170	5	434
8/1	2130	5	426
8/2	2130	5	426
8/3	2130	10	213
8/4	2130	10	213
8/5	2130	10	213
8/6	2130	10	213
8/7	2130	10	213
8/8	2130	5	426

Panel No	Span (mm)	Est deflection (mm)	Span/defl
9/1	2160	5	432
9/2	2160	10	216
9/3	2160	10	216
9/4	2160	10	216
9/5	2160	10	216
9/6	2160	10	216
9/7	2160	5	432
9/8	2160	5	432
10/1	2150	5	430
10/2	2150	5	430
10/3	2150	10	215
10/4	2150	15	143
10/5	2150	15	143
10/6	2150	15	143
10/7	2150	15	143
10/8	2150	10	215
11/1	2150	5	430
11/2	2150	10	215
11/3	2150	10	215
11/4	2150	10	215
11/5	2150	15	143
11/6	2150	15	143
11/7	2150	15	143
11/8	2150	10	215
12/1	2170	10	217
12/2	2170	10	217
12/3	2170	15	145
12/4	2170	10	217
12/5	2170	10	217
12/6	2170	15	145
12/7	2170	10	217
12/8	2170	10	217

Panel No	Span (mm)	Est deflection (mm)	Span/defl
13/1	2160	5	432
13/2	2160	10	216
13/3	2160	10	216
13/4	2160	10	216
13/5	2160	10	216
13/6	2160	15	144
13/7	2160	10	216
13/8	2160	5	432
14/1	2140	5	428
14/2	2140	10	214
14/3	2140	10	214
14/4	2140	10	214
14/5	2140	10	214
14/6	2140	10	214
14/7	2140	10	214
14/8	2140	5	428
15/1	2140	5	428
15/2	2140	5	428
15/3	2140	10	214
15/4	2140	10	214
15/5	2140	10	214
15/6	2140	10	214
15/7	2140	10	214
15/8	2140	5	428
16/1	2110	10	211
16/2	2110	10	211
16/3	2110	15	141
16/4	2110	15	141
16/5	2110	15	141
16/6	2110	10	211
16/7	2110	10	211
16/8	2110	10	211

Panel No	Span (mm)	Est deflection (mm)	Span/defl
17/1	2110	5	422
17/2	2110	10	211
17/3	2110	15	141
17/4	2110	15	141
17/5	2110	15	141
17/6	2110	15	141
17/7	2110	10	211
17/8	2110	5	422
18/1	2140	5	428
18/2	2140	5	428
18/3	2140	10	214
18/4	2140	15	143
18/5	2140	15	143
18/6	2140	10	214
18/7	2140	10	214
18/8	2140	5	428
19/1	2160	10	216
19/2	2160	15	144
19/3	2160	20	108
19/4	2160	20	108
19/5	2160	20	108
19/6	2160	15	144
19/7	2160	10	216
19/8	2160	10	216
20/1	1400	N/A	N/A
20/2	1400	10	140
20/3	1400	10	140
20/4	1400	10	140
20/5	1400	10	140
20/6	1400	10	140
20/7	1400	5	280
20/8	1400	5	280

Panel No	Span (mm)	Est deflection (mm)	Span/defl
21/1	2140	5	428
21/2	2140	10	214
21/3	2140	10	214
21/4	2140	10	214
21/5	2140	10	214
21/6	2140	10	214
21/7	2140	10	214
21/8	2140	5	428
22/1	2110	5	422
22/2	2110	5	422
22/3	2110	10	211
22/4	2110	10	211
22/5	2110	10	211
22/6	2110	10	211
22/7	2110	10	211
22/8	2110	5	422
23/1	2110	5	422
23/2	2110	10	211
23/3	2110	10	211
23/4	2110	15	141
23/5	2110	15	141
23/6	2110	15	141
23/7	2110	10	211
23/8	2110	10	211
24/1	2140	5	428
24/2	2140	5	428
24/3	2140	10	214
24/4	2140	10	214
24/5	2140	10	214
24/6	2140	10	214
24/7	2140	10	214
24/8	2140	10	214

Legend:

- S/D ratio: >200.
- S/D ratio: 125 - 200.
- S/D ratio: 100-125
- S/D ratio: <100

Table 1 - Summary of Panel Deflections – Estimated from James Brennan Contour Map

Cracking & Corrosion

A visual inspection of the accessible panels; those to the bedrooms, corridor and computer suite, was carried out on 15th March 2021.

Corridors

The corridor roof soffit is broken into bays, which correspond the beam lines which run across the width of the building at approximately 2.15m centres. Alternate bays comprise linear rooflights spanning the length of the bay with a solid, assumed RC, infill either side. Intermediate bays comprise of RAAC panels spanning across the width of the corridor on to corridor wall lines. An extract from the James Brennan Associates survey below shows a typical section of corridor roof soffit. Photograph 1 shows a view from the southern end of the corridor.

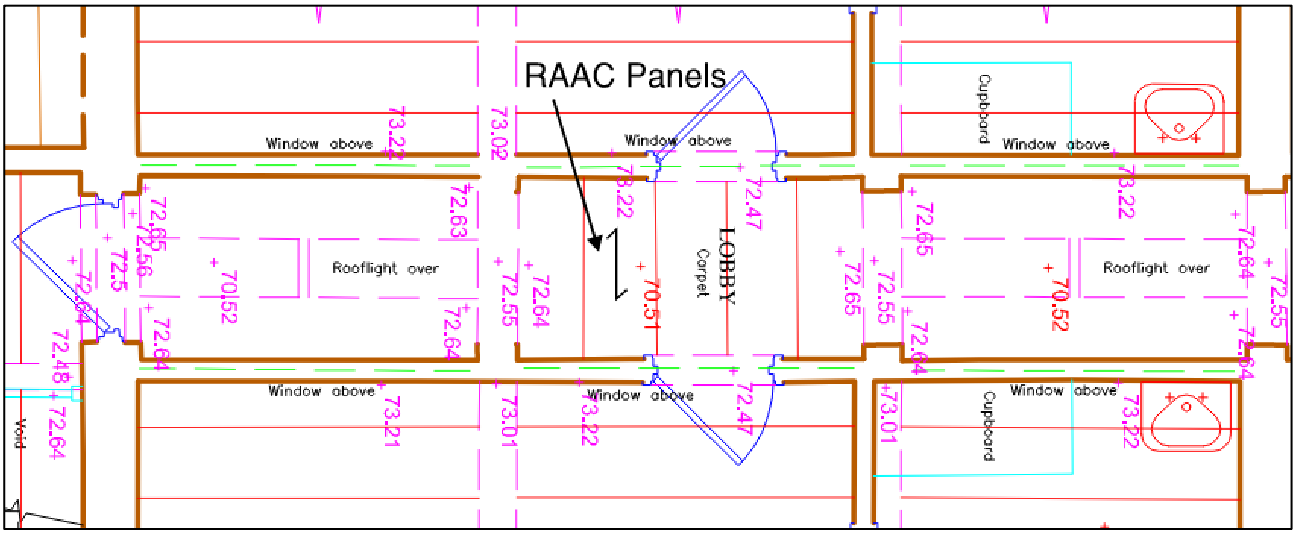


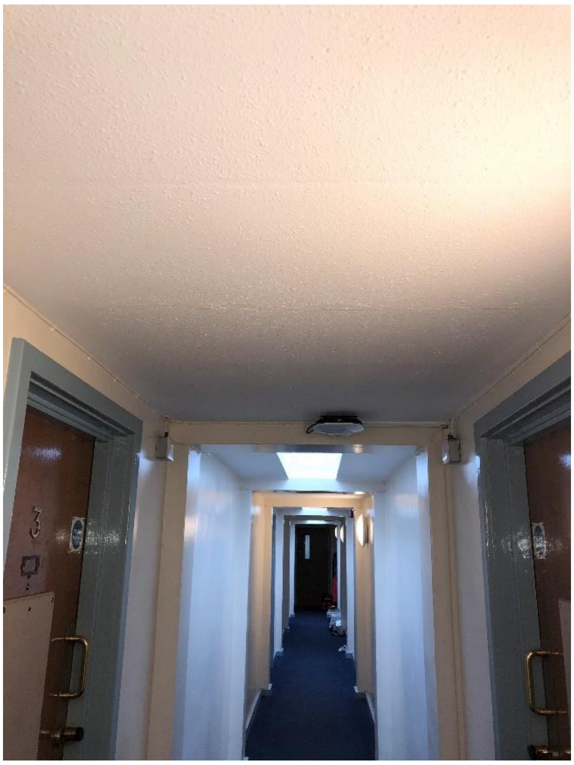
Figure 4- Corridor Soffit Arrangement (James Brennan Associates)

Typically the corridor bays containing rooflights appear to be in good condition. An exception is the first bay when entering the corridor from the south. There is evidence of water ingress resulting in spalling plasterwork, most severely on the right side but also at the ends, see Photograph 2.

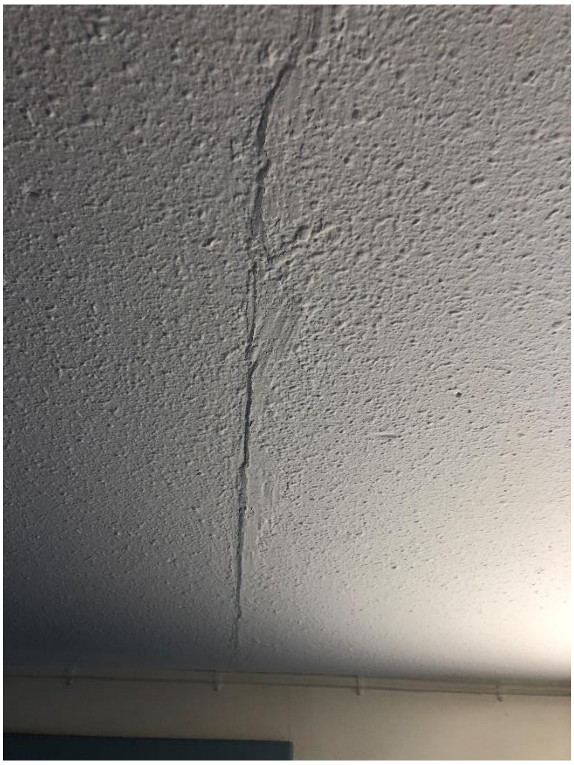
The intermediate bays formed using RAAC panels have a textured painted finish. There is little evidence of cracking within panels. There is very slight to slight cracking along the joint between adjacent panels, see Photograph 4. Joints are filled with a cement based mortar or plaster. The cracking is not thought to be significant, although over time there is a risk the joint fill will de-bond and fail resulting in spalling. There is a slight vertical misalignment between some panels however it is not known if this has been present since installation. The stepping in itself is not of concern given the apparent reasonable condition of the panels. There is no evidence of insufficient bearing or movement at bearing positions.

Photograph 1- Corridor from South

Photograph 2- Spalling plasterwork 1st Bay



Photograph 3- RAAC Corridor Bay



Photograph 4- Typical Joint Between RAAC Corridor Panels

Bedrooms

Bedrooms either side of the central corridor typically contain three bays of RAAC panels, spanning between party walls with two intermediate beams which run from the external wall to corridor wall, a typical panel arrangement is shown below in the extract of James Brennan Associates survey, Figure 5.

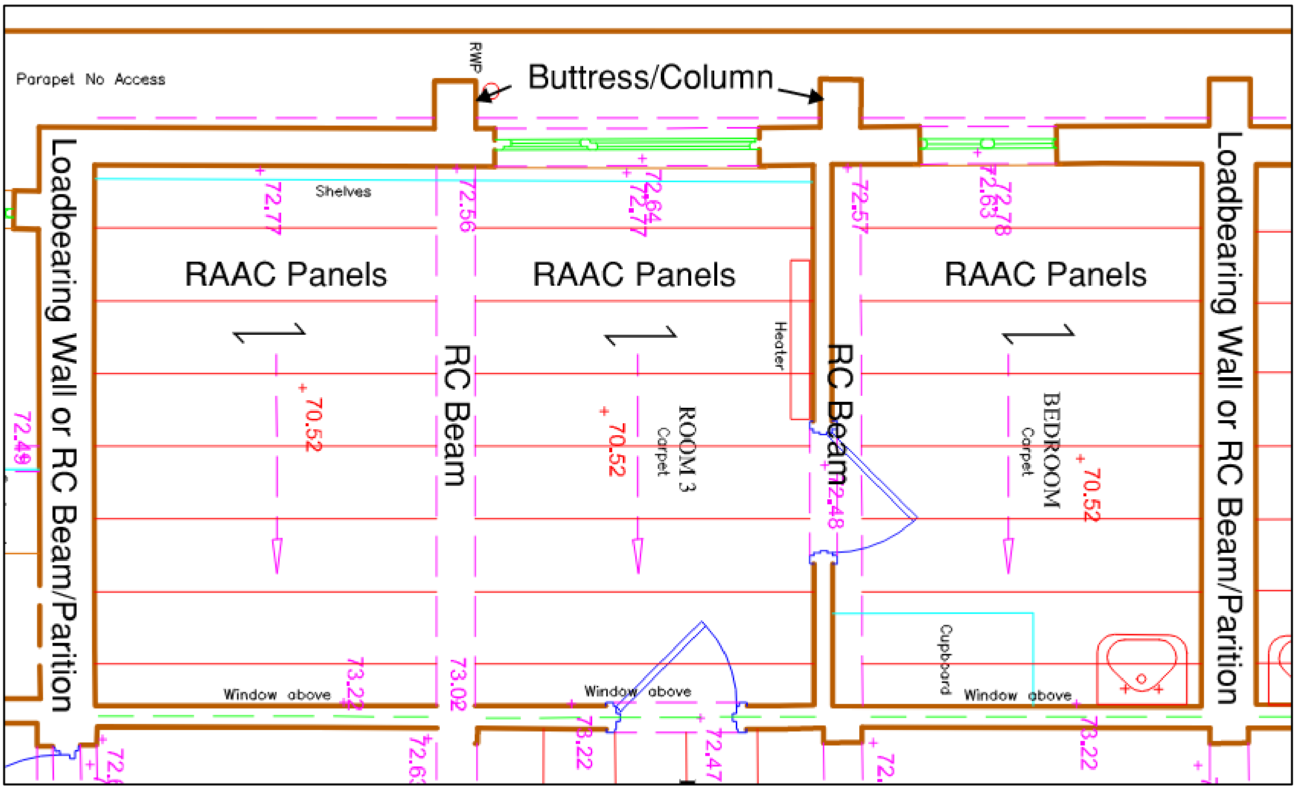


Figure 5- Typical Roof Structure Arrangement for Bedrooms (James Brennan Associates)

The bedrooms typically display similar conditions, outlined below, exceptions are noted separately.

Many RAAC panels show fine cracks running perpendicular to span, these are usually reasonably well/evenly spaced along the panel's span, typically 4 to 6 cracks per panel. As the soffit of each panel is the tensile face of the panel it is unsurprising to see signs of this type of cracking, indeed most concrete beam and slab structures will crack in this way and it does not infer failure of the member.

The joints between panels have been filled with a plaster fillet. In many cases the joint is pronounced suggesting remedial repairs. In many cases there is a slight step between adjacent panels. The condition of these joints is variable, in some places the mortar is showing signs of de-bonding and in a few instances has failed

The bearing points of all panels appeared sound and there was no evidence of bearing failure or cracking around bearing positions. There was no sign of panels slippage on bearings. This suggests the panels have adequate bearing and sufficient reinforcement at the support, although this has not been verified by intrusive survey.

There was no significant staining of the soffit, which would have been suggestive of water ingress and corrosion of embedded reinforcement.


Photograph 5- Typical RAAC Bay Bedroom (Room 3)

The supporting beams appear to be structurally sound and in good condition throughout.

It is not clear whether walls between rooms and gable end walls are loadbearing, there is evidence in the form of horizontal cracking which suggests there is an RC beam along the top of each wall. This pattern is repeated in the external wall, see Photograph 6. This cracking is not of structural concern as it is expressing a joint between two elements. Whether intended or not the wall may be offering support to the beam, however given the age of the building loads appear to have reach equilibrium.

In corridor and external walls there are vertical and horizontal cracks which appear to coincide with junctions between solid RC/masonry elements & boarded sections of wall.

In addition to the typical condition described above the following exceptional observations are made;

Room 3 – Failed joint between panels in bedroom, see Photograph 7.

Room 5 – Vertical crack to external wall to right of right-hand window and adjacent buttress column showing cracking in finishes. Further investigation into the condition of the column recommended, see Photograph 8.

Room 7b- Horizontal crack below window this may be associated with leaking pipework as there appears to be a riser box out on the corridor side.

Room 8 – This room shows the most significant deflection on the contour mapping, however visually the room does not show exceptional cracking or joint failure.

Room 9 - Cracking to render to the external buttress column, this appears to have previous been repaired unsuccessfully.

Room 10 – More significant recent loss of plaster from panel joints, however the panels condition is typical.

Photograph 6- Horizontal Crack to Perimeter Wall (Room 3)

Photograph 7- Failed Joint (Room 3)

Photograph 8- Cracking to Rendered Finish to RC Column (Room 5) Photograph 9- Horizontal Crack to Perimeter Wall (Room 7b)

Northern Stair Lobby & Computer Suite

The RAAC panel soffit at the stop of the stairs has been repaired, the plastered finish has been partially removed and a directly applied textured paint finish applied. It is assumed it was a failure of the plastered finish which resulted in the repair, the RAAC panels appear to be sound.

The store at the top of the stairs has a secondary steel frame and RAAC panels appear to be in sound condition.

The configuration of the RAAC panels within the GCR/Computer Suite are similar to those in the bedrooms, spanning onto RC beams, however there is also a ridge beam forming an apex to the soffit running down the length of the room. The condition of the panels in this area are similar to those of the bedrooms. However the flank walls contain several cracks which is suggestive of local failure of the masonry, see Photograph 10.

There is a severe crack in the corner of the wall adjacent the store off the half landing to the stairs, This may be a junction between the older and newer part of the building and it is not thought to be linked to the RAAC panels but may warrant further investigation, see Photograph 11.


Photograph 10- Cracking in Gable Wall Computer Suite


Photograph 11- Cracking in Corner of Half Landing North Stair

4 Conclusions

The RAAC panels do not generally show evidence of failure when inspected from below. Whilst the panels generally appear to be in reasonable condition they should be continued to be regularly monitored, we would suggest a visual inspection to check for changes in condition takes place annually. If leaks are detected these should be remedied promptly. When next a major refurbishment of the roof finishes is planned it would be prudent to inspect the top surface of the RAAC panels.

The jointing between the RAAC panels is a concern and a regime of regular inspection and repair could be implemented to reduce risk of failure which may risk injury of occupants. Alternatively a boarded soffit could be installed to encapsulate the RAAC soffit. The disadvantage of this is the RAAC panels are no longer visible for inspection unless an easily demountable ceiling is installed.

It is understood that the college would like to install PV panels upon the roof. Such an installation is viable provided that no additional load is placed upon the RAAC panels either during installation or afterwards. Therefore installation should be from a scaffold deck which spans over the roof. PV panels should be supported on a sub-frame which spans onto beam lines.

An initial capacity check of a typical roof beam (see Appendix B) indicates that the roof beams have sufficient capacity to support a PV installation and a new ceiling, this analysis assumes;

- Existing roof build up as records 7lb lead on felt on RAAC panels.
- PV panels supported on a secondary frame between beams – total weight 80kg/m^2
- Plasterboard ceiling supported on SFS light gauge steel spanning between beams – total weight 40kg/m^2.

Once more details of the proposed PV panel installation & ceiling works are available a more detailed analysis of the existing structure should be carried out.

The render to a number of external buttress columns has failed, it is not possible without partial removal to determine if the column itself has corroded, we recommend localised removal of the failed render to allow closer inspection.

Horizontal cracking to some walls indicative of a joint line between either masonry and studwork or masonry and a beam line could be cosmetically repaired. The joint may be strengthened with Expamet or similar to help prevent further cracking, however this cracking is not of concern structurally.

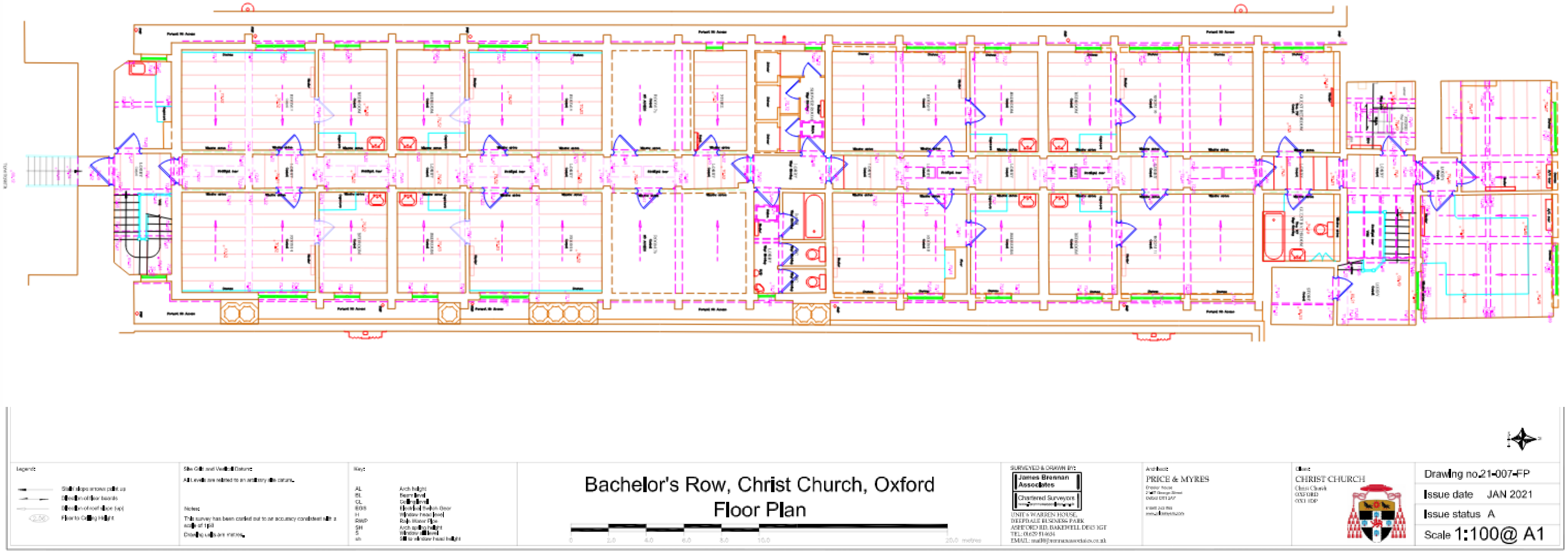
Localised Issues

Localised water ingress at the southern end of the corridor should be investigated and remedied to prevent further damage to finishes and ultimately the structure.

The damage to plasterwork in Room 7b, may be due to leaking pipework which should be investigated and rectified, although this is below the soffit level and so poses no risk to the RAAC panels.

Cracking to the gable wall within the computer suite. Although the most severe crack is beneath the bearing to the ridge beam it is unlikely to be due to compressive failure as loads are relatively low. The cause of cracking is not evident, localised removal of plasterwork may reveal the cause to be poorly bonded brickwork which could be re-pointed. Helical bar may be required to locally strengthen.

Appendix A
Survey Plans


Bachelor's Row, Christ Church, Oxford
Floor Plan
James Brennan Associates
Chartered Surveyors
PRICE & MYRES
CHRIST CHURCH
Drawing no.21-007-FP
Issue date JAN 2021
Issue status A
Scale 1:100@ A1

Appendix B
Beam Capacity Assessment

PRICE& MYERS

Job No. 29414	Page Calc 01	Rev 1
Date June 2021	Eng IRF	Chd
Job Batchelor's Row - Chistchurch		

Load Assessment of Existing Roof Beams

Assessment of roof beams to assess their ability to support the existing loads and proposed additional loads from a new PV installation and grillage to provide protective support the the roof panels.

Existing beams 6"x6"x15.7lb/ft UC - equivalent to 152x152x23 UC

Beam Span 11' 6" = 3.51m
Roof span = 2.5m

Existing Loads

Lead, plus felt = 0.40kN/m2
Durox= 1.8kN/m2
Beam SWt incl encasement = 1.5kN/m

Live load = 0.75kN/m2

Total load on beam
Ws= 2.2x2.5+1.5+ 0.75X2.5= 7+2kN/m = 9kN/m
Wu= 1.4x7+1.6x2 = 13kN/m

Mu= 13x3.51^2/8 = 20kNm,

Mb= 45.1kNm, assuming full restraint by roof slab.

Defl= 5/384x 9x3.51x3510^3/205x1250x10^4 = 7mm = span/500

Additional loads

PV panels plus supporting structure = 0.8kN/m2 (est)
Secondary support structure = 0.25kN/m2
Ceiling = 0.15kN/m2

Total load on beam
Ws= 9+1.2x2.5 = 12kN/m
Wu= 1.4x10+1.6x2 = 17.2kN/m

Mu= 17.2x3.51^2/8 = 27kNm

Defl= 5/384x 12x3.51x3510^3/205x1250x10^4 = 9mm = span/390

The roof beams are within acceptable limits with the additional load allowance