[redacted]
Cardiff County Council
County Hall
Atlantic Wharf
Cardiff
CF10 4UW

Our Ref: 70086249
9 December 2021
CONFIDENTIAL

Dear [redacted],

St David's Hall – Summary of Building Condition Surveys and Associated Costing

1 INTRODUCTION

WSP has been commissioned by Cardiff Council to coordinate and undertake building condition surveys of the St David's Hall property, in Cardiff's city centre. WSP has worked in conjunction with Rio Architects – looking at Building Fabric – and RPA Group – who have provided cost advice based on the condition survey report prepared. The team has undertaken a 'RAG' ('red, amber, green') assessment to identify and prioritise remediation requirements and costs.

2 SUMMARY OF SURVEYS AND REPORTS

The following surveys were undertaken, and reports prepared (which are appended to this letter). All surveys and reports were commissioned by Cardiff County Council.

PREPARED BY	DISCIPLINE	REPORT DATE	SCOPE
1 Building condition survey			
Commissioned to report on general condition reflecting the building's age, general deterioration.			
WSP	Building structures	19/02/2021 updated 18/05/2021	Internal and external structural elements. Includes commentary on roof coverings and cladding, noting these were subject to separate surveys. Follow-on surveys identified.
	Mechanical and electrical services	11/03/2021	Mechanical and electrical building services. Excludes passenger and goods lifts, escalators.
Rio Architects (under WSP)	Building fabric	02/03/2021	Internal and external building fabric, fixtures, finishes. Excludes roofing, noting this was subject to separate surveys.

1 Capital Quarter
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PREPARED BY	DISCIPLINE	REPORT DATE	SCOPE
2 External concrete cladding survey			
Commissioned due to reported falls of concrete fragments and visible defects.			
WSP	Building structures	13/03/2021	Visual inspection (by WSP), intrusive testing and localised repairs (by Restruct Ltd) of the concrete cladding panels and concrete façade elements to the SW-facing elevation (The Hayes).
		07/10/2021	Visual inspection (by WSP), intrusive testing and localised repairs (by Restruct Ltd) of the concrete cladding panels and concret façade elements to the NE-facing elevation (rear loading bay).
Note: NW-facing elevation not yet surveyed closely due to restricted access for access equipment (e.g. large rooflight over St David's Shopping Centre, width restrictions for MEWP apparatus). SE-facing elevation (over adjacent Miller & Carter premises) not accessible for close inspection.			
3 Concrete roof plank survey			
Commissioned as follow-on from [1] to consider more closely the condition of RAAC roof planks.			
WSP	Building structures	07/10/2021	Visual and deflection survey of RAAC roof planks (reinforced autoclaved aerated concrete), subject of recent construction safety alerts. Includes outline of steel framing remedial works. Recommends intrusive investigations and outlines future reinspection regime.
Note: Intrusive investigations to establish arrangement of steel reinforcement outstanding, arrangements being made to undertake this (in tandem with rope access specialist) in January 2022. *Ad-hoc visual inspections undertaken following recent high-winds events, arrangements for additional inspection 'call-outs' over winter months in place.*			
4 Lead-sheet mansard roof survey			
Commissioned due to noticeable defects affecting, primarily, the NW-facing roof slope.			
Taliesin Conservation	Lead sheet roofing	05/07/2021	Lead sheet roof covering to the mansard roof (steeply sloping sides of the main roof), including cost estimate for replacement options.
Note: We understand urgent consideration is being given to access arrangements and repairs to the worst of the defects noted.			

3 SUMMARY OF FINDINGS – RAG COST ANALYSIS

AREA	COST
Substructure	[redacted]
Structural frame	
Roof structure and coverings	
Upper floors	
Stairs	
External walls	
External windows and doors	
Internal walls and partitions	
Internal doors	
Wall finishes	
Floor finishes	
Ceiling finishes	
Furniture, fittings and equipment	
Sanitary fittings	
Mechanical installations	
Electrical installations	
Specialist installations	
Lifts and vertical transport installations	
Builders work in connection with M&E installations @ 1.5%	
External works	
Drainage works	
Statutory services	
Sub-total	
Main Contractor preliminaries @ 12%	
Sub-total	
Main Contractor OH&P @ 5%	
Sub-total	
Contingency @ 5%	
Sub-total	
Professional fees @ 12%	
Total Budget Cost Estimate	

The repair and refurbishment costs (report appended to this letter) have been prioritised as follows:

- Red ..... Essential
- Amber ..... Consequential
- Green ..... Future

The costs associated with each priority are as follows:

PRIORITY	RED	AMBER	GREEN	TOTAL
COST				[redacted]

We trust this summary provide the information you require. Please do not hesitate to contact us if you require additional detail of if you have any queries or comments.

Yours sincerely

[redacted]

[redacted] MEng (Hons)
Senior Structural Engineer | Property & Buildings

cc: [redacted] - Cardiff County Council
Enc.

REPORT 1
BUILDING CONDITION SURVEY

Cardiff County Council

ST DAVID'S HALL

Structural Condition Survey

70069626-S-1000
FEBRUARY 2021

Cardiff County Council

ST DAVID'S HALL

Structural Condition Survey

TYPE OF DOCUMENT (VERSION): CONFIDENTIAL
PROJECT NO.: 70069626
OUR REF. NO.: 70069626-S-1000
DATE: FEBRUARY 2021

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QUALITY CONTROL

ISSUE/REVISION	FIRST ISSUE	REVISION 1	REVISION 2
Remarks	First issue	Section 3.2.1 (page 8) and Section 4.2.1 (page 11) revised to suit additional information made available to us relating to RAAC roof planks	
Date	19 February 2021	18 May 2021	
Prepared by	[redacted]	[redacted]	
Signature	[redacted]	[redacted]	
Checked by	[redacted]	[redacted]	
Signature	[redacted]	[redacted]	
Authorised by	[redacted]	[redacted]	
Signature	[redacted]	[redacted]	
Project number	70069626	70069626	
Report number	S-1000	S-1000	
File reference	70069626-S-1000	70069626-S-1000	

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1 INTRODUCTION

1.1 THE SURVEY

- A visual structural condition survey was undertaken of St David's Hall, The Hayes, Cardiff. The interior and exterior of the building were surveyed as far as practicable and where safe to do so.
- The survey of structural elements was undertaken by [redacted] (Senior Structural Engineer, WSP's Cardiff Office) on the 28 January 2021. Complementary surveys of were also undertaken: the MEP installations were surveyed by WSP on the 28 January 2021; the architectural building fabric was surveyed by Rio Architects on the 27 January.
- Weather conditions during the structural condition survey were dry, overcast, moderate westerly winds, air temperature around 10-degrees Celsius.

1.2 AUTHORITY

- Authority to undertake the survey was provided by Cardiff County Council. Access was agreed and made available by Cardiff County Council and St David's Hall staff.

1.3 LIMITATIONS

- The survey was visual only, undertaken from:
  - safely accessible floors, stairways and walkways internally;
  - safely accessible external roofs and internal roof spaces;
  - safely accessible external ground areas, i.e. pedestrianised areas of Working Street, The Hayes and Hills Street, and the St David's Shopping Centre loading bay area to the rear of St David's Hall.
- The building was closed to the public, due to COVID-19 restrictions in place at the time; a small number of staff were working in the building, who assisted the surveyor with access and background information. Mains lighting was not available throughout the building; the surveyor utilised a handheld torch to inspect areas with limited lighting.
- No opening up works were undertaken. No finishes, fixtures or fittings were disturbed or removed. No material testing or other analysis has been undertaken, e.g. to determine composition, loadbearing capacity, etc.
- Measurements stated in this report are approximate and based on visual estimations only; no measuring equipment was used.
- This report shall be for the private and confidential use of the Cardiff County Council. It must not be reproduced in whole or part or relied upon by a third party without the express written authority of WSP.
- The report is not a specification and it must not be relied upon to prepare estimates.

2 SURVEY OBSERVATIONS

2.1 GENERAL DESCRIPTION OF THE BUILDING

- St David's Hall is a large concert hall building in Cardiff's city centre. It was constructed between 1977 to 1982, in tandem with the St David's Shopping Centre development which surrounds it on the north and east sides.
- The large auditorium at its centre is encircled by foyers, circulation space and 'back-of-house' accommodation over six floors. A large clear-span steel framed mansard roof covers the auditorium and much of the 'back-of-house' accommodation, with terraced flat roofs covering the remainder, primarily to the south side.

AERIAL IMAGE OF ST DAVID'S HALL - © 2021 GOOGLE

2.2 EXTERNAL OBSERVATIONS AND DEFECTS NOTED

2.2.1. ROOFS

a) The roof covering to the two main, flatter slopes of the mansard roof appears to be a bitumen-based material. Gutters to these two slopes (along the north-western and south-eastern edges) were holding water; *staff reported periodic unblocking of the outlets was required*. However, *there were no significant deflections or other obvious structural defects evident* from observations above the roof covering.

b) The steeply sloping faces of the mansard roof have a lead sheet covering. Access for observations was limited to the adjacent flat roofs, from ground level, and from the main roof slopes (i.e. viewing down the steeper slopes). *There were no obvious structural defects noted*; however, *the lead sheet covering to all slopes appears to be in poor condition, but particularly along the north-western and north-eastern faces where large tears, holes and lifting of the lead sheet was evident. Such materials could cause serious injury / damage to persons / property below if they became detached, but also increase the risk of water ingress*.

c) Holes were noted to isolated soffit panels of the mansard roof overhang. *Whilst not a structural defect, materials may cause injury / damage to persons / property below*. The panels prevent inspection of any structure that might exist behind them.

d) Smaller lead sheet roofs exist over the various structures projecting from the main façade and roof slopes (which are believed to accommodate lift shafts, stairwells, plant, etc.). These could not be inspected thoroughly. However, *there were no obvious structural defects noted*.

e) There are a number of flat roofs to areas below and around the mansard roof. Where accessible for inspection, these appear to have a liquid-applied or bitumen-based roof covering, or paving slabs to the roof terraces accessible to the public. *There were no obvious structural defects noted*.

f) Access to the roofs is provided via doorways, internal access corridors and cat ladders, and external cat ladders. A self-supporting counterweighted edge protection barrier is provided around the main slopes of the mansard roof. The publicly accessible roof terraces have fixed barriers; other flat roofs did not appear to have permanent roof edge protection, with only a small upstand around 300mm high provided along the edge. *There were no obvious structural defects affecting the roof edge protection*.

g) We understand the loading bay structure and canopy at the northeast corner of the building has a bitumen-based roof covering, together with metal sheet cladding covering to the roof soffits and walls. *Active water ingress was noted causing localised corrosion to the steel support framing;* however, *there were no significant structural defects noted*.

2.2.2. WALLS / FAÇADE

a) Observation of the external walls and façade was limited without elevated access. Observations were made from the pedestrianised area to the west and south, and loading bay areas to the north and east.

b) The building façades are generally comprised of:

North elevation:	+ Precast concrete cladding panels. + Buff-coloured brickwork masonry. + Glazed curtain walling. + Regularly spaced concrete framing elements (beams, columns) expressed externally. + Window cleaning apparatus is attached to some panels / columns.
East elevation:	+ Buff-coloured brickwork masonry. + Glazed curtain walling. + Pressed metal-sheet cladding. + Isolated concrete framing elements (beams, columns) expressed externally.

South elevation:	+ Mostly hidden from view by the adjoining building (Miller & Carter restaurant / office space). + Precast concrete cladding panels. + Buff-coloured brickwork masonry. + Regularly spaced concrete framing elements (columns) expressed externally.
West elevation:	+ Precast concrete cladding panels. + Glazed curtain walling. + Regularly spaced concrete framing elements (columns, walls) expressed externally.
Common to all elevations:	+ Ad-hoc louvred panels, presumably where required for building services, etc.

c) Selected façade types are described in more detail as follows:

Precast concrete panels:	+ Each panel measures approximately 3m wide, generally arranged singularly or in pairs (side-by-side) next to / between concrete frame elements which are expressed externally. Panel heights vary, to suit adjacent cladding, fenestration, storey heights, etc. + Vertical joints between abutting panels, other façade types and concrete frame elements are evident but could not be inspected closely. + Panel support fixings are not immediately obvious externally. Some metal studs / bolts are visible along the bottom edge of some panels. + *Some localised damage to concrete panels was evident*: (i) spalling / missing concrete along the bottom edge of some panels (no exposed reinforcing steel noted); (ii) minor cracking was noted to the face of one panel (only visible from observations through an adjacent window); and (iii) spalling / missing concrete and exposed reinforcing steel to the vertical edge of a single vertical panel (framing the window noted in (ii), over the main entrance area). *Concrete fragments could cause injury / damage to persons / property below if they become detached*.
Buff coloured brickwork panels:	+ The panels of masonry vary in size. The east elevation has large expanses of brickwork; elsewhere smaller panels exist abutting other façade elements. *There were no obvious structural defects noted from the distant observations made*.
Exposed concrete framing elements:	+ The side / end faces of selected concrete beams, column and walls are visible on all elevation. In such instances, the concrete appears to have a slightly textured finish with smooth finished 'margins' to the arrises. + *Some isolated areas of damaged concrete was noted*: (i) to a beam at the corner of the north- and east-facing elevation, with potential for exposed reinforcing steel; and (ii) to the side of the doorway leading to the 5th floor roof terrace (several reinforcing bars are exposed). *Concrete fragments could cause injury / damage to persons / property below if they become detached*.

2.2.3. FLOORS

a) The undersides of concrete floor slabs are visible externally where undercrofts are formed along the east elevation. *There were no obvious structural defects noted*.

b) The undersides of concrete floor slabs are visible externally where balconies / undercrofts are formed along the west elevation: the slabs in such areas are formed in 'waffle-slab' construction. The balconies were not accessible to allow closer inspection of these; however, *no obvious structural defects were noted from internal observations from windows or external ground level*.

2.2.4. OTHER EXTERNAL STRUCTURES

a) An elevated plant platform, constructed in galvanised steel, is mounted on top of a single storey building within the loading bay. *There were no obvious structural defects noted*.

2.3 INTERNAL OBSERVATIONS AND DEFECTS NOTED

- The building's internal accommodation is distributed over six floors, generally. Not all rooms / areas were inspected: based on the observations and the limited number of defects noted as the survey progressed, the surveyor became confident that the rooms / areas inspected offered a representative account of the building's structural condition.

2.3.2. ROOF

a) The two main slopes of the mansard roof appear to be formed with precast concrete planks spanning between the steel roof trusses. Not all panels could be inspected: observations could only be made from accessible gantries over the auditorium. However, based on the observations made, *no obvious structural defects or evidence of water ingress was noted*.

b) The steeply sloping sides of the mansard roof appear to be lined with woodwool slabs (planks of compressed cement-bound timber stands) supported on secondary galvanised steel framing. *Some evidence of water ingress was noted* (along the route taken to access the gantries over the auditorium). However, based on the limited observations made, *no obvious structural defects were noted*.

c) The mansard roof structure appears the be formed from large, regularly-spaced fabricated roof trusses. The trusses appear to be supported off concrete framing elements (beams, columns or concrete walls) around the perimeter of the auditorium, with additional support to the lower edges of the mansard. The trusses appear to support the suspended grid ceiling, stage rigging equipment, ventilation and electrical services, and the access gantries. The steelwork has a painted finish. Based on observations made from the access gantries, *no obvious structural defects were noted*.

2.3.3. STRUCTURAL FRAMING

a) A number of columns and beams are visible within the public circulation areas; this, together with the columns and beams visible externally, leads us to conclude that the building is a concrete framed structure.

b) Much of the framed structure within the public circulation areas is obscured by the suspended grid ceilings, which were not disturbed during the survey. Only the columns in the circulation space, together with beams and walls forming balconies and stairwells were visible. As noted externally, a slightly textured surface is evident with smooth finished 'margins to arrises, etc. *No obvious structural defect were noted* to the visible structure.

c) Much of the structure within the auditorium is obscured by suspended grid ceilings, wooden panelling or similar decorative finishes, which were not disturbed during the survey. However, the main side faces of a number of the cantilever beams forming the tiered seating were visible. *No obvious structural defect were noted* to the visible structure.

d) Structural elements within the 'back-of-house' areas are identifiable, primarily columns / concrete walls, particularly where these elements continue beyond the curtain walling to the exterior. *No obvious structural defect were noted* to the visible structure.

e) The 'back-of-house' stairwells and staircases have an exposed concrete finish. *No obvious structural defects were noted*.

2.3.4. WALLS

a) The internal walls are assumed to be non-loadbearing and appear to be of brickwork or concrete blockwork construction. Whilst they are not considered structural elements, *no obvious defects were noted*.

2.3.5. FLOORS

a) Not all floor structures were visible. The floors are predominantly of concrete construction.

b) Suspended timber / timber-boarded metal-framed floors are anticipated within the auditorium, particularly the stage which we understand can be raised and lowered to suit performances. Such floors are outside the scope of this survey, although *no obvious structural defects were noted*.

c) We believe the floor to the 'green room' (third floor level, east elevation) is a suspended floor, based on the hollow sound when walked over. The floor structure was not accessible to view but *no obvious structural defects of excessive deflections were noted*.

d) Carpet or other floor coverings obscure floor slabs within the public areas (foyers, bars, etc.); suspended ceilings obscure their undersides, generally. However, the undersides of the 'waffle slab' floors above the main staircases and circulation areas were visible, which appear to be of a high-quality finish with *no obvious structural defects noted*.

e) Carpet or other floor coverings obscure floor slabs within the 'back-of-house' areas from view. Some floors in the 'service areas' (plant rooms, storage and loading areas) appear to have exposed concrete or a screed finish, sometimes painted. There were no obvious structural defects noted. The underside of the floor slabs were visible in some 'back-of-house' areas where suspended ceiling tiles had been removed: the slabs appear to be of solid concrete construction and *no obvious structural defects were noted*.

3 DISCUSSION

3.1 EXTERNAL ELEMENTS

3.1.1. ROOFS

a) Blocked gutter outlets could lead to water ingress and consequential damage to structural elements over time. We understand the outlets are fitted with cowls and screens to prevent large objects entering the internal drainage pipes, however these are not always effective. Staff expressed difficulty in clearing the blockages and removing waste materials, due to the restrictive nature of the cat ladder access and limited means of manoeuvring waste material and cleaning equipment.

b) Lead sheet covering:

- A number of spare lead sheet roof panels were stored near a roof access doorway. They appear to comprise: (i) lead sheet, oversized to allow forming the 'rolls' to the adjacent panels; (ii) a backing board (plywood or similar) to which the lead appeared to be bonded. It wasn't clear how the panel assembly is attached to the roof structure. Refer to the additional discussion in item 3.2.1.a).
- *The poor condition of the lead sheet covering to the mansard roof could cause serious injury / damage to persons / property below. The tearing observed to a number of panels could lead to large pieces of lead falling to the ground if further deterioration occurs*. The poor condition also increases the likelihood of water ingress and consequential damage. *We understand Cardiff Council are making arrangements for a surveyor to assess the condition of the lead roof*.

c) Similarly, *potentially loose fragments of soffit panel (to the underside of the mansard roof) could cause serious injury / damage to persons / property below*. The holes could also permit access to birds and other pests.

d) The corrosion noted to the steel framing supporting the loading bay canopy will continue to deteriorate and could lead to more significant structural defects if not addressed.

3.1.2. WALLS / FAÇADE

a) Precast concrete panels:

- We have reviewed a report made available to us (by Over Arup & Partners, November 1997) which includes diagrams of the precast panels. The concrete panels are shown to have an upside-down L-shape cross section, with the horizontal portion secured to the top of an adjacent concrete edge beam. The height of the panels vary. Bolts along the bottom edge allow the panels to be installed plumb (by adjusting the extension of the bolt from the rear panel).
- This report also describes failure and detachment of concrete along the bottom edge of two panels, which were subsequently replaced.
- The spalling concrete noted during the survey is likely to be a consequence of inadequate 'cover' to the reinforcing steel (the thickness of concrete around the steel which limits its corrosion) and / or carbonation of the concrete (where absorption of CO_2 from the atmosphere gradually reduces the alkalinity of the concrete (thereby reducing the chemical protection offered to the steel against corrosion). It isn't clear if the spalling along the bottom edge of the panels is also influenced by the possible corrosion of the bolt fasteners, water ingress behind panels, etc.

- Loosened concrete increases the risk of water ingress into the concrete and subsequent corrosion of the reinforcing steel, which could lead to more significant structural defects.
- *Potentially loose fragments of concrete could cause serious injury / damage to persons / property below*.
- *We understand that Cardiff Council have made arrangements to undertake a thorough survey of the concrete panels along the west elevation (where the risk of injury to the public is greatest, using elevated access equipment), to ascertain the condition of the panels, extents of the defects, potential for further defects, and implement localised repairs to existing defects where possible*.

b) Exposed concrete framing elements:

- Many of the points raised above (3.1.2.a)) apply.

3.1.3. FLOORS

a) *No obvious structural defects were noted internally*.

3.2 INTERNAL ELEMENTS

3.2.1. ROOFS

18/05/2021
REVISION 1

a) Review of record drawings made available to us by Cardiff Council, since our January survey, make reference to '250mm Siporex slabs' forming the two flatter slopes of the roof over the auditorium. Internet searches suggest these slabs are RAAC (Reinforced Autoclaved Aerated Concrete) – a lightweight form of concrete used primarily for roofs between the mid-60s and mid-80s.

Concerns have been raised recently (by the Local Government Association[1] in late-2018 and by SCOSS[2] (Standing Committee on Structural Safety) in mid-2019) following the sudden collapse of a flat roof constructed using RAAC. The relevant SCOSS Alert identifies the following risk indicators (*with our commentary*), adding that most RAAC planks that exist today have likely exceeded their intended design life:

- cracking and disruption of the planks near the supports;	*no obvious evidence, noting that not all areas could be inspected in detail;*
- short bearings (40mm or less) or reinforcement not extending to the bearing;	*could not be confirmed by visual observation; we understand inadequate bearing is the primary failure mechanism;*
- excessive deflections (exceeding span/200), sometimes leading to ponding of rainwater and thus potentially leading to increased loading;	*could not be confirmed by visual observation alone, noting no obvious significant deflection noted where viewed; the generous roof pitch would seem to limit scope for ponding;*
- replacement roof coverings where the loading has increased, or the thermal characteristics differ (e.g. a black surface finish where the original did not);	*we note (confirmed by information made available following our survey) that the roof covering has been replaced (from a grey finish to the present darker red finish);*
- the roof is leaking or has leaked in the past.	*no obvious evidence, although we note the blocked drainage outlet issue.*

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/971528/RAAC-Guidance.pdf
[2] https://www.cross-safety.org/sites/default/files/2019-05/failure-reinforced-autoclaved-aerated-concrete-planks.pdf

b) It is not clear how the external lead sheet panels are attached to the framing. The slabs appear to be slotted in between pairs of galvanised steel rails (channel or angle-iron sections are considered likely): it seems reasonable to conclude that the rails are structural, are attached to the structural steel roof trusses, and the external lead panels are attached to the rails.

c) Woodwool slabs have limited strength and are therefore considered non-structural. If exposed to water they swell and lose their integrity. It is unclear how easily individual woodwool slabs can be removed and replaced due to the apparent slotted-in assembly.

d) Water ingress through the roof covering has the potential to cause consequential damage to structural elements.

3.2.2. STRUCTURAL FRAMING

a) *No obvious structural defects were noted internally*.

3.2.3. WALLS

a) The majority of internal walls are considered to be non-structural: these appear to be constructed in blockwork or brickwork masonry.

b) Structural walls internally appear to be constructed in reinforced concrete, typically around stairwells, and are assumed to contribute to the lateral stability of the building. *There were no obvious structural defects noted*.

3.2.4. FLOORS

a) *No obvious structural defects were noted internally*.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 EXTERNAL ELEMENTS

4.1.1. ROOFS

a) *The flat and mansard roof structures appear to be in good condition, structurally*.

b) *Localised repairs should be implemented to address the corrosion of the loading bay canopy, likely requiring reapplication of protective paint, once the cause of water ingress has been investigated and addressed.*

c) *The efficacy of the roof drainage should be reviewed by a specialist to advise on improvements to reduce blockages, which will reduce the risk of water ingress*. *Consideration should be given to the access required for maintenance of the roof and drainage*.

d) *The condition of the lead roof and other external roof panels should be reviewed by a specialist to advise on suitable repairs and improvements to reduce the risk of water ingress and injury / damage to persons / property below*.

4.1.2. WALLS / FAÇADE

a) Precast concrete panels:

- Notwithstanding the specific defects noted in this report, *the concrete panels appear to be in good condition, based on the survey observations*.
- The planned survey of the concrete panels should confirm the extents and severity of defects noted and may identify additional defects not noted during this survey. *Suitable repairs, or other measures, should then be implemented to address concrete defects and reduce the risk of injury / damage to persons / property below*.
- Such repairs typically comprise removal of loose / defective concrete and application of a concrete repair mortar to include a corrosion inhibitor applied to the reinforcing steel. However, the practicalities of such repairs, when considering limited access to the rear of the panels, should be established during the concrete panel survey.

b) Brickwork masonry:

- *The brickwork masonry cladding appears to be in good condition*. *No obvious structural defects were noted*.

c) Exposed concrete framing elements:

- Notwithstanding the specific defects noted in this report, *the exposed concrete framing elements appear to be in good condition, based on the survey observations*.
- *Suitable repairs should be implemented to address concrete defects and reduce the risk of injury / damage to persons / property below*.
- Such repairs typically comprise removal of loose / defective concrete and application of a concrete repair mortar to include a corrosion inhibitor applied to the reinforcing steel.

4.1.3. FLOORS

a) *The exposed undersides of floor slabs, visible externally, appear to be in good condition*. *There were no obvious structural defects noted*.

4.2 INTERNAL ELEMENTS

4.2.1. ROOFS

a) *The flat and mansard roofs appear to be in good condition, structurally. There were no obvious structural defects noted.*

18/05/2021
REVISION 1

b) *In light of the recent SCOSS Alert (see section 3.2.1) the condition and robustness of the RAAC roof planks should be established and a risk assessment undertaken. This may require:*

- *a thorough visual inspection to identify cracking and evidence of corrosion of the reinforcement;*
- *a level survey to establish whether plank deflections are within acceptable limits;*
- *assessment using non-intrusive techniques, possibly verified by localised intrusive inspection, to establish the adequacy and robustness of the bearing offered to the planks and position and arrangement of reinforcement.*

Access onto the roof should be controlled and limited as far as practicable until the condition and robustness is established.

The assessment may determine the need for strengthening or other remedial works, e.g. to enhance the robustness at the bearings. The design life of RAAC planks has likely been exceeded, and this should be borne in mind when considering implementation of the recommendations of the assessment.

c) *The condition of the lead roof and other roof panels should be reviewed by a specialist to advise on suitable repairs and improvements to reduce the risk of water ingress and injury / damage to persons / property below.*

4.2.2. STRUCTURAL FRAMING

a) *The concrete frame of the building appears to be in good condition. There were no obvious structural defects noted.*

4.2.3. WALLS

a) *The internal walls appear to be in good condition. There were no obvious structural defects noted.*

4.2.4. FLOORS

a) *The floors appear to be in good condition. There were no obvious structural defects noted.*

APPENDIX A

SURVEY PHOTOGRAPHS

1 Capital Quarter
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wsp.com

Cardiff County Council

ST DAVID'S HALL

Building Services Condition Report

MARCH 2021

CONFIDENTIAL

Cardiff County Council

ST DAVID'S HALL

Building Services Condition Report

TYPE OF DOCUMENT (VERSION) CONFIDENTIAL

PROJECT NO. 70069626

DATE: MARCH 2021

Cardiff County Council

ST DAVID'S HALL

Building Services Condition Report

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QUALITY CONTROL

Issue/revision	First issue	Revision 1	Revision 2	Revision 3
Remarks	Initial Issue			
Date	11/03/2021			
Prepared by	[redacted]			
Signature				
Checked by	[redacted]			
Signature				
Authorised by	[redacted]			
Signature				
Project number	70069626			
Report number	9626-WSP-XX-RP-000-000			

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EXECUTIVE SUMMARY

WSP have been commissioned by Cardiff County Council to carry out a site inspection and review of the Building Services at the existing St David's Hall.

St David's Hall was construction started in 1977 & opened in 1982. Since its construction date it has primarily been used as a performing arts and conference venue.

Refurbishment work has been undertaken to various areas of the building during the lifespan of the building. At the time of our survey refurbishment works were being undertaken to the BMS systems and associated valving arrangements.

The findings of this report are based on record information made available at the time and a visual survey only, all observations and recommendations have been made based on this fact. The survey was undertaken in the morning of 28/01/2021 by [redacted] and [redacted].

In general, the services are in a condition as expected for their age. The cold water system storage is an area of concern due to legionella risk and condition of the cold water tanks. The remaining systems have been well maintained and repaired as required. Based on the CIBSE Guide M, all services are at the end of their economic life and should be considered for replacement.

EXISTING INFORMATION

Limited existing “as installed” drawings and Operating & Maintenance Manuals were available at the time of the survey. There were a comprehensive set of record information for the testing and cleaning of the mechanical and electrical systems.

Kitchen extract systems had been cleaned but noted that the ductwork was in poor condition. The rest of the system was noted as being acceptable.

Boilers were serviced and tested and noted in average condition for their age.

Gas safety certificates were available for the kitchen and boilers.

Comfort cooling systems were serviced and noted in average to poor condition depending on the system and its age.

Legionella risk assessments had been carried out. These had noted a number of potential issues mostly due to the condition of the water storage tanks.

The Asbestos survey noted the presence of asbestos in the AHU gaskets.

ASSESSMENT / OBSERVATIONS / FINDINGS

MECHANICAL SERVICES

CONDITION OF EXISTING MECHANICAL EQUIPMENT/SYSTEMS

The existing equipment at St David's Hall is generally of good condition, having been serviced, repaired and maintained as required during its life. However, much of the infrastructure dates to the original installation, which at 40 years old, is nearing the end of its economic life.

The mechanical plant components generally are in good condition, with many of the individual plant components undergoing replacement. During the survey it was noted that work was currently being undertaken to replace the BMS system and associated valving for the mechanical systems.

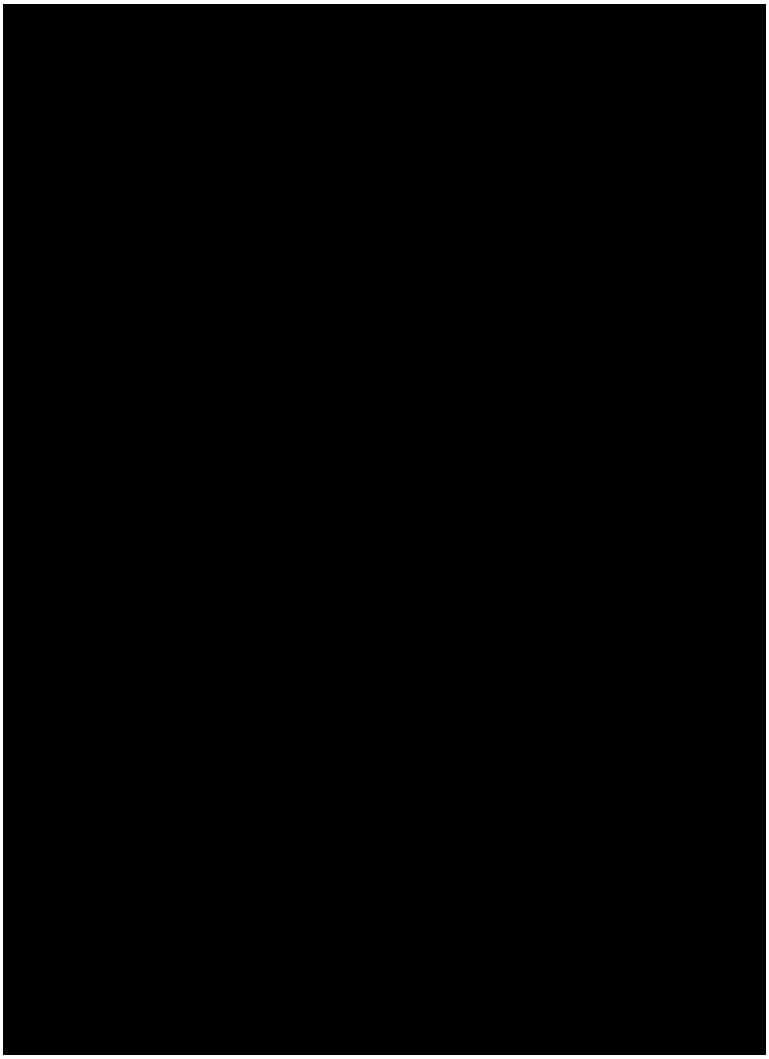
INCOMING SERVICES

The condition of the gas services visible during the inspection seemed to be good, recent work had been carried out to install an automatic shut off valve. This had required the replacement of several sections of pipe due to the original installation being caste through walls. The gas meters were in good condition with sufficient ventilation to the space.

The incoming water main feeds storage tanks and is then distributed to the rest of the building. The tanks and pipework are in poor condition with evidence of leaks and corrosion. As noted in the existing information section, these have been identified as a Legionella risk. Speaking to the engineer responsible for the site, they were aware of the issue and assessments had been undertaken to consider the replacement of these systems, however at the time of the report, no work had been agreed or started.

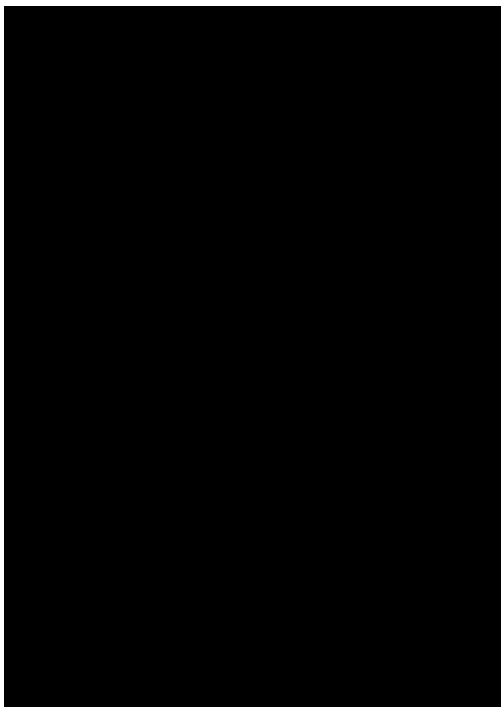
HEATING SYSTEMS

The heating system consists of two 900kW boiler, these supply the LTHW system which heats the building through a combination of VT circuit supplying radiators and CT circuit supplying the air handling systems. Both boilers date from 1980, however the burners have been replaced since that time. The plantroom also contains a CHP unit, however this is redundant and not connected to the rest of the system.



The pumps serving the LTHW system ranged in age, from original installation to very recent. All had recent inverter drives fitted to them. One of the pumps was showing signs of a leak from the shaft seal. We were informed a new seal was on order.

The radiators and pipework serving the building date to the original installation and their condition is as expected for their age. Modifications and repairs have been carried out to the installation to suit building use. Controls in the form of TRV's have been added to the radiators.

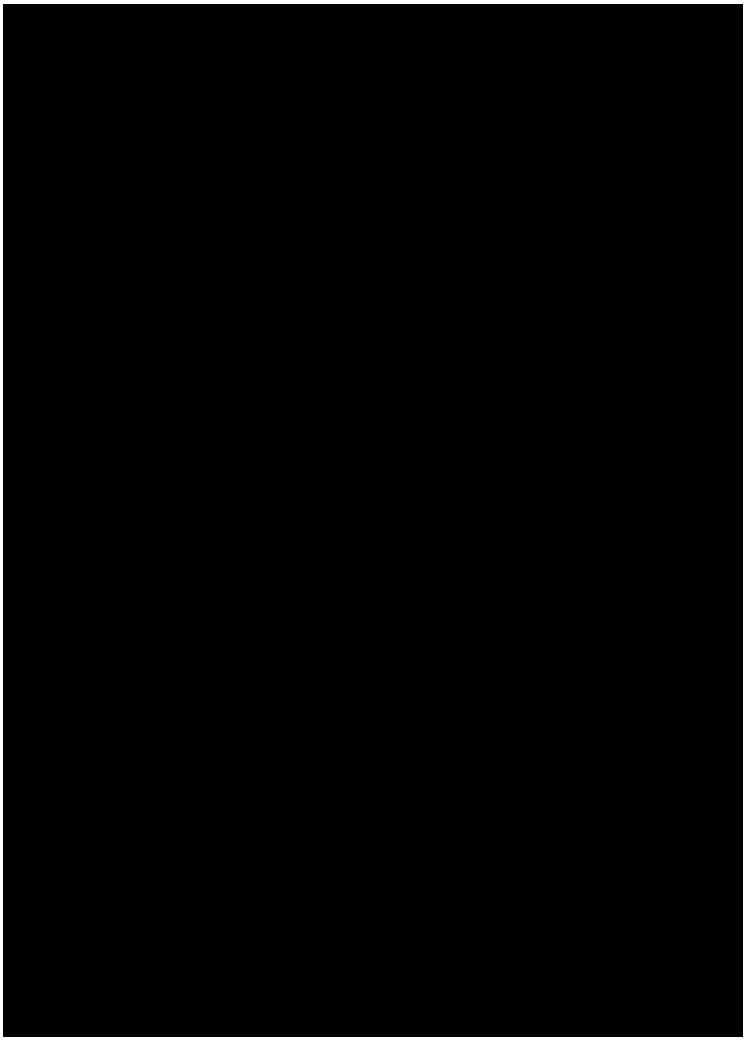


COOLING SYSTEMS

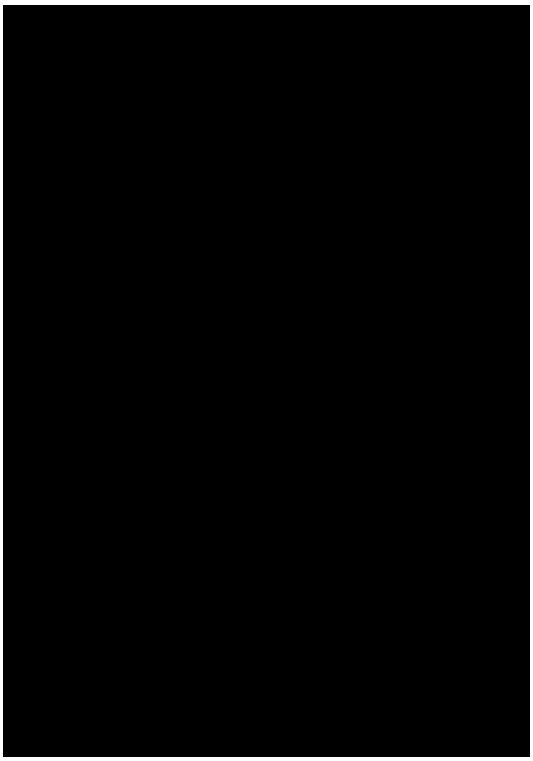
The building is served by a chilled water system serving the air handling units and multiple local DX units serving specific areas. The DX units vary in condition and use a variety of refrigerants from R22, R407C and R410A.

The chilled water system consists of two heat rejection cooling towers and two water chillers sized at approx. 200kW. However only one of these systems was in operation. One of the water chillers dating from 1996 has been disconnected and the pipework capped off.

Of the two roof mounted cooling towers, one has been decommissioned and is not operational. The remaining cooling tower had scaffolding surrounding it due to recent service work. Its condition is as expected due to its age, showing signs of corrosion and damage to lagging.



The chilled water pumps had recent inverter drives installed and appeared in good condition.



VENTILATION SYSTEMS

The building is served by a number of AHU's throughout the building. All off the AHUs date to the original install. Most do not include heat recover. The main auditorium AHU was originally fitted with humidification, however this has been decommissioned and is not operational. LTHW & CHW valves serving the AHUs have been replaced with new units as part of the BMS works.

The building is fitted with stair pressurisation fans, these are arranged in run and standby configuration. One of the fans was noted as non operational during the visit.

Kitchen ventilation system was suitable for a commercial kitchen. Gas interlocks were installed and had been tested.

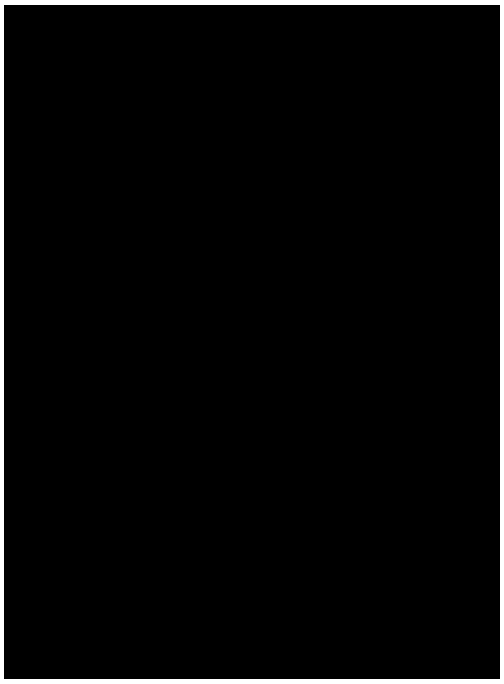
DISTRIBUTION SYSTEMS

Pipework and ductwork visible during our survey were of generally good condition, however systems located in inaccessible areas (e.g. within risers) could not be accessed during the survey but are anticipated to be in a satisfactory condition.

All systems are at the end of the economic lifespan based on the CIBSE Guide M for Maintenance Engineering and Management. Although kitchen ductwork has been cleaned, the remaining ventilation ductwork systems have not been cleaned to the best knowledge of the site engineer. Access for duct cleaning is limited.

DOMESTIC WATER SERVICES

As noted earlier, the water storage tanks and booster system are in poor condition and need replacement. The Legionella assessment also noted poor temperature control of the hot water system. The hot water system is served via a plate heat exchanger from the LTHW system.



DRAINAGE SYSTEMS

The majority of drainage systems were not accessible during the survey due to the building fabric. Those that were visible appear in acceptable condition, no leaks were noted, however they are at the end of their expected life.

BMS & CONTROL SYSTEMS

The BMS system was undergoing replacement at the time of the site visit and was non operational. Once the work is complete, the new system should provide better energy use and monitoring of systems.

ELECTRICAL SERVICES

CONDITION OF EXISTING ELECTRICAL SERVICES

The existing electrical installation/equipment at St Davids Hall is generally of good condition, having been serviced, repaired and maintained as required during its life. However, much of the infrastructure dates to the original installation, which at 40 years old and is nearing the end of its design/economic life.

The electrical installation components generally are in good condition, with a number of items replaced.

INCOMING ELECTRICAL SERVICES

The site is served via 11/0.4kV Transformers located within a HV switchroom in the rear service yard at First floor level. It is understood the transformers are owned and operated by Western Power distribution. It is understood the site is metered at HV. This should be clarified with WPD.

MAIN LV SWITCHGEAR

LV supplies emanate from the substation and terminate in the main LV switchgear located on the 2nd floor located within a dedicated LV Switchroom off the stair core. The switchgear is of Ottermill manufacture, consists of Main switches, changeover equipment, simple metering and outgoing fuseswitches. It is consistent with the age of the building. The LV Switchboard is split for essential/non-essential operation. Visually it is in good condition and has been well maintained. However, spares are becoming difficult to obtain for this style/manufacture of switchboard.

160 kVAr power factor correction cabinet is situated adjacent to the main LV switchboard.is located adjacent to the switchboard. It was unclear if this is operational and should be verified.

From the main switchboard outgoing SWA submain cables are routed though floor ducts and the building fabric to feed local switchboards/distribution boards, rising mains and plant items.

A number of the ways/boards around the building have individual electrical meters for monitoring of connection of third-party broadcasters. The functionality of these should be verified.

Limited schematic drawings of the interconnection of the building LV infrastructure is available. This should be investigated and schematic drawings produced for future maintenance.

The MCB distribution boards for the power and lighting have generally reached the end of their economic design lives as indicated in CIBSE Guide M Appendix 12. They do not meet the requirements of the latest version of BS7671 and consideration should be given to their replacement.

Electrical Installation condition reports have been maintained and any C1/C2 items have been resolved.

STANDBY GENERATOR

A 420 kVA diesel standby generator is situated on the third floor to the rear of the building. It provides power to the building essential services. It is consistent with the age of the building and has been well maintained with the expected

LIGHTING

Lighting throughout is generally in good condition, it is a mixture of fluorescent lighting and filament lighting with lamps and diffusers changed as necessary.

The lighting has exceeded its economic design life and is inefficient. Controls are manual and do not lend themselves to efficient operation of the building.

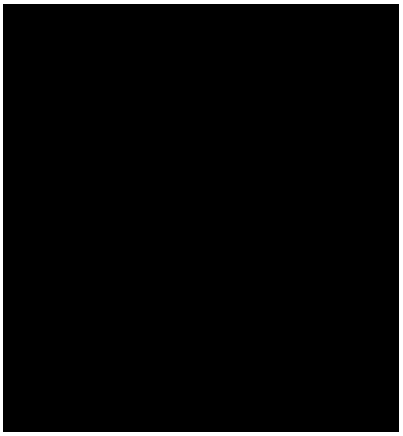
NB. The main hall lighting was not surveyed and should be assessed by a specialist in Theatre lighting.

EMERGENCY LIGHTING

The emergency lighting throughout is fed via 2 No. central battery systems on a 110 Volt system. The batteries and static inverters have recently been updated/renewed. The static inverters state 240V but we understand on site modification has been undertaken.

The emergency luminaires are a combination of standalone and combined luminaires. These have reached the end of their economic design lives, failing components have been replaced. The diffusers are aged and will contribute to light loss. Spare parts for these will become increasingly difficult to obtain.

Exit signage is old, is of a superseded design, does not comply with current standards and should be replaced.



SMALL POWER

The small power accessories are of various ages and have been changed throughout the life of the building as repairs/modifications have become necessary.

An attempt has been made to provide RCD protection as required by BS7671 to socket outlets. However these are to BS 7288 and do not provide the required additional protection as described in BS7671.

Consideration should be given to upgrading accessories. Small power cable systems are at the end of their design lives but meet the requirements of BS7671 with regards to insulation resistance etc.

FIRE DETECTION AND ALARM SYSTEM

An analogue addressable fire detection and alarm system is installed throughout. The fire alarm system has been renewed since the original building construction. However the system has a number of faults indicated on the main control panel. It has or is approaching the end of it's design life.

There is a Redcare link adjacent to the Fire alarm panel which also indicates a dualcom system is installed. Clarification should be sought as to which is currently enabled.

Where observed the installation of the fire alarm cables is poor and does not meet the current requirements of BS 5839-1 or BS7671.

Consideration should be given to replacing the entire system.

TELECOMMUNCIATIONS

The voice data systems are ad-hoc throughout the building and need updating.

There appears to be an internal PBX system in use within the building. The functionality of this needs to be verified and it's operations checked to ensure it meets the building users needs and requirements.

LIGHTNING PROTECTION SYSTEM

A structural lightning protection system is installed to BS6651. This appears well maintained. Consideration should be made to updating it to BSE EN 62305.

No transient overvoltage protection was evident.

INTRUDER ALARM SYSTEM

An intruder alarm system is installed on site maintained by Messrs Tremorfa. It appears to be based on Honeywell Galaxy system.

It appears to be functional. The operation of it should be verified to ensure it meets the building users requirements.

CCTV

A CCTV system is installed on site and appears to be functional with the recording/control equipment relatively new. The operation of it should be verified to ensure it meets the building users requirements.

EMERGENCY VOICE COMMUNICATION SYSTEM

An emergency voice communications system is installed on site with the stairwells. We were informed that this is not functional. As such this will need repair or replacement if one is required by the building fire strategy.

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Cardiff County Council

ST DAVIDS HALL

Architectural Fabric Condition Report

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FEBRUARY 2021

CONFIDENTIAL

Cardiff County **Council**

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TYPE OF DOCUMENT (VERSION) CONFIDENTIAL

PROJECT NO. RIO NL 19 078

DATE: FEBRUARY 2021

Cardiff County **Council**

ST DAVIDS HALL

Architectural Fabric Condition Report

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QUALITY CONTROL

Issue/revision	First issue	Revision 1	Revision 2	Revision 3
Date	02nd March 21			
Prepared by	[redacted]			
Signature				
Checked by	[redacted]			
Signature				
Authorised by	[redacted]			
Signature				
Project number	Rio NL 19 078			
Report number	19 078-RIO-XX-XX-RP-A-06201			

EXECUTIVE SUMMARY

Rio Architects have been commissioned by Cardiff County Council via WSP to carry out a site inspection and a general condition review of the Architectural Fabric at the existing St David's Hall.

This report simply identifies the current condition of existing building fabric elements and did not include any intrusive works.

The findings of this report are based on record information made available at the time and a visual survey only and all observations have been made based on this fact. The survey was undertaken on 27th January 2021 by [redacted].

FORMAT OF SURVEY

[redacted] was accompanied by [redacted] – Building Services Manager. The majority of spaces in the building were accessed and a series of photographs of each floor level were taken for reference and to be read in conjunction with the fabric condition statements.

We understand that external elements such as the metal rolled roof and the external elements of concrete are subject to a detailed survey by a specialist sub contractor.

The report references F.O.H, which refers to ‘Front of House’ public areas, and B.O.H, which refers to ‘Back of House’ non public areas.

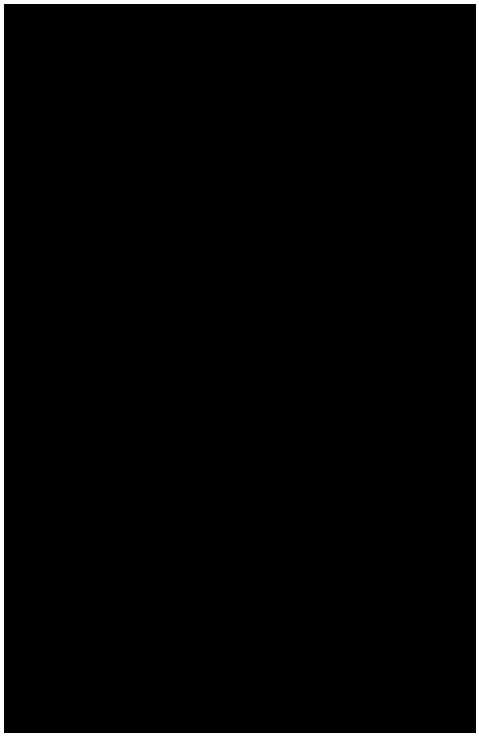
ASSESSMENT / OBSERVATIONS / FINDINGS

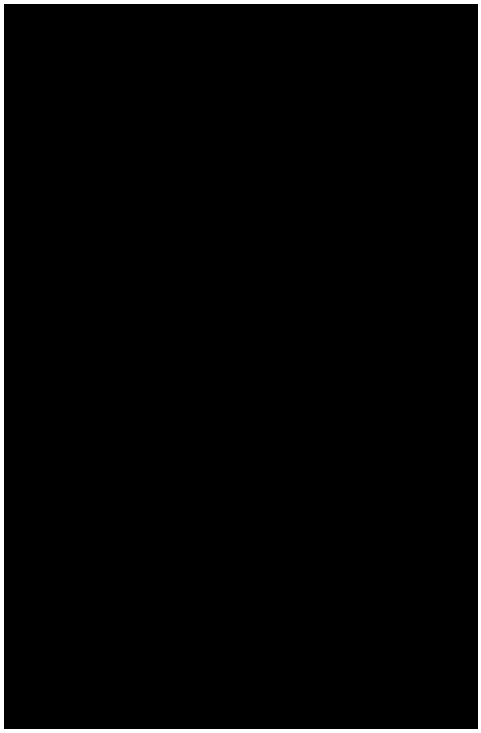
GROUND FLOOR

ENTRANCE DOORS

Parts of the entrance door threshold is damaged and will require repair to avoid any trip hazards.

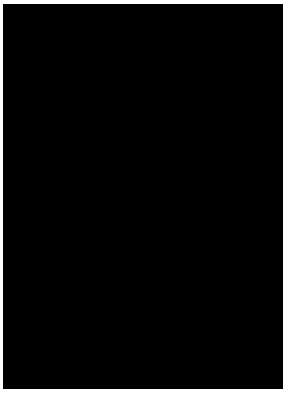
Aluminium glazed entrance doors appear to be in working order, however they are not automated. Disabled access is located away from the main entrance. A number of perimeter seals to the doors need attention.

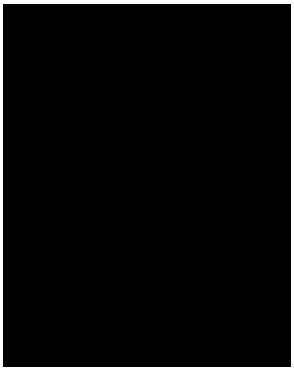




FOYER CEILING

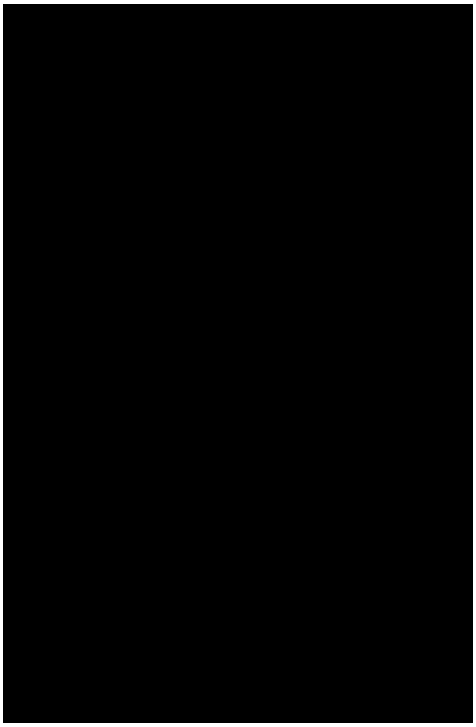
The foyer ceiling is an ‘open egg crate’ type ceiling which looks dated. There are a number of misplaced, damaged and missing portions to the ceiling.





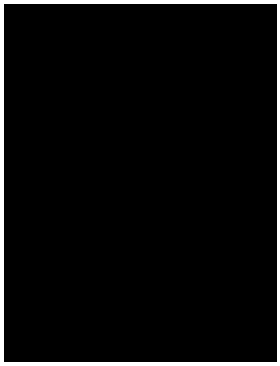
FOYER FLOOR FINISH

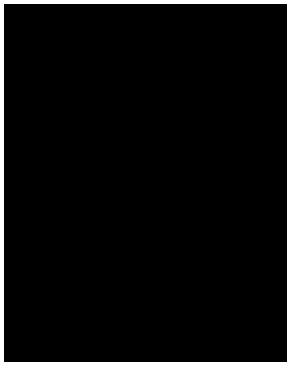
The foyer floor is a combination of hard tiling and carpet, with transition strips between the two finishes. The transition strip itself is dented and flattened. The carpet is dirty and dated. The entrance area has an inset matwell, the tuft of which is flattened.



FOYER F.O.H. DOORS

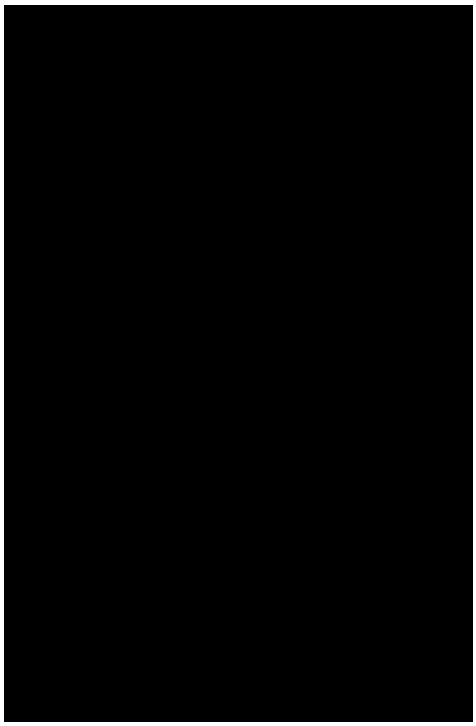
Foyer F.O.H. doors are generally of solid timber construction, with plastic coated ironmongery. Some doors are damaged, particularly at low level where a kick plate would normally be located and around handles.

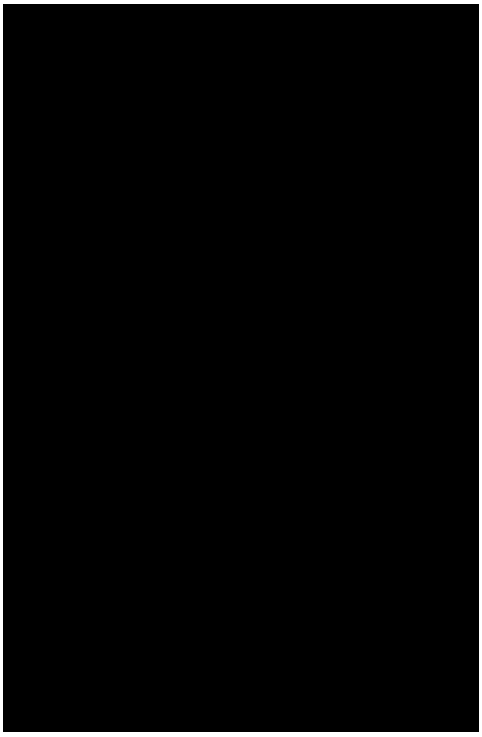




FOYER ENTRANCE STEPS

There are a number of steps just inside the main entrance doors. They are finished with small format hard tiling, with a contrasting nosing and inset LED light strip. An area of the LED light strip is not working.





FOYER B.O.H. DOORS

BOH doors are generally of solid timber construction, with plastic coated ironmongery.

Some doors and frames are damaged, particularly at low level where a kick plate would normally be located and around handles.

FOYER B.O.H. CEILINGS

The ticket office ceiling appears to be a textured finish board ceiling with inset grilles and access hatches. Access hatches are poorly fitted and not flush. The ceiling has areas of filled damage and is generally discoloured and of poor decoration.

TICKET OFFICE COUNTER

The ticket office counter is of stained timber construction, and has perspex screens mounted on it between the public and sales staff. The counter is dated in apprearance, and it is unknown if the timber is treated to deal with surface spread of flame.

B.O.H STAFF FACILITIES

The ticket office tea room is basic and dated.

B.O.H. stairs are basic, but functional. Areas of the contrasting nosing to treads are missing.

WC's are very basic and dated, with some signs of malfunction. Decoration is generally in poor condition, and plumbing pipework is generally exposed.

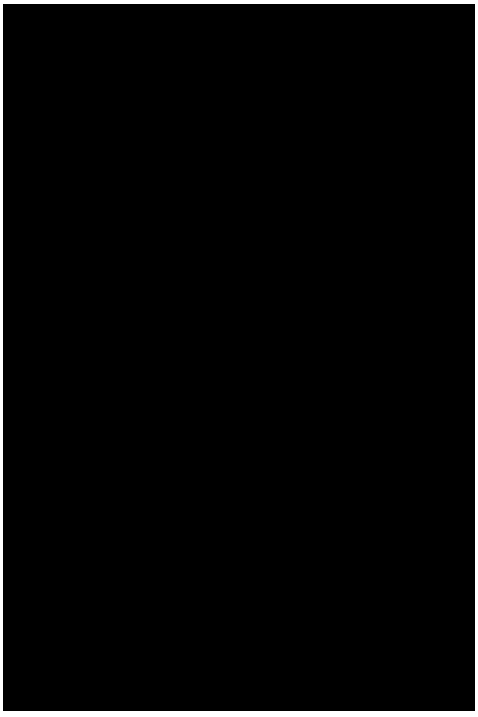
FIRST FLOOR

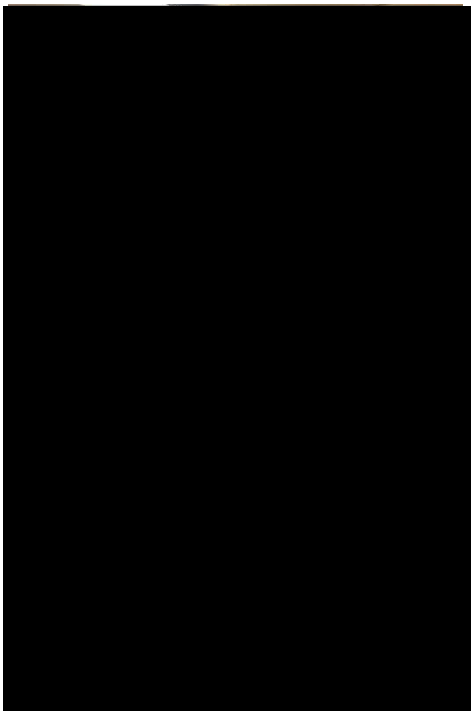
FUNCTION SPACE CEILING

The function space ceiling is an 'open egg crate' type ceiling which looks dated. There are a number of misplaced, damaged and missing portions to the ceiling. There are also messy cables looping across the space which are secured to the soffit.

FUNCTION SPACE KITCHEN

The function space kitchen is dated and it is not known if the facility would meet current environmental legislation. The textured floor finish is very dirty with multiple areas of spillage stains. The ceiling is a proprietary metal ceiling tile type, with various holes in it with damaged and dislodged tiles. Walls are partly tiled with ceramic tiles, and kitchen appliances are generally stainless steel.





FUNCTION SPACE BAR

The function space has a small bar facility which is timber fronted with a patterned bar front security grille. The timber plinth to the bar front is damaged in a number of locations. It is not known if the timber has been treated to deal with surface spread of flame.

FUNCTION SPACE ROOF TERRACE

The function room has an outside roof terrace. Access to the roof terrace is via number of internal timber steps and an external step. There is no disabled access to the roof terrace. The roof terrace shows signs of serious pigeon infestation, even though there are bird wires installed. The roof finish is of solid pavers with pointing with drainage to the edges. The surface is slippery and has a build up of moss.

FUNCTION SPACE WALLS

Function space walls are generally of a textured plaster finish, decoration of which is in a poor condition. Walls do not have skirtings which has caused localised wall decoration damage probably due to floor cleaning techniques.

FUNCTION SPACE F.O.H. WC'S

Function FOH space WC's are dated, with signs of malfunction and damaged tile grouting and missing elements of wall. The lay in grid ceiling is fitted poorly, we understand that a dislodged ceiling tile is the result of recent electrical works above the ceiling.

FUNCTION SPACE B.O.H. WC'S

Function space BOH WC's are dated, with very poor decoration and damaged linings / exposed insulated ductwork.

FUNCTION SPACE B.O.H. CIRCULATION

B.O.H. circulation has textured floors which are very dirty and stained, common blockwork walls which are showing signs of damage and exposed high level services distribution and exposed concrete soffits.

B.O.H. DOORS

B.O.H. doors have dated decoration and show signs of localised damage due to the nature of B.O.H circulation doors which are heavily trafficked. The appear to be generally functional with no apparent signs of damage that would affect functionality.

B.O.H. STORES

B.O.H. stores are generally undecorated or poorly decorated spaces with exposed common blockwork walls and exposed services and soffits.

F.O.H. DOORS

Foyer F.O.H. doors are generally of solid timber construction, with plastic coated ironmongery. The function space has a painted door. Some doors are damaged, particularly at low level where a kick plate would normally be located and around handles.

SECOND FLOOR

B.O.H. CIRCULATION SPACES

The B.O.H. circulation spaces are generally functional spaces, with exposed services and soffits, carpeted, vinyl or sealed concrete floors. Office areas have a lay in grid suspended ceiling. Doors are generally of solid timber construction, with plastic coated ironmongery. Some doors are damaged, particularly at low level where a kick plate would normally be located and around handles. Carpets are grubby and are damaged in a number of areas

B.O.H. DOORS

B.O.H. doors are a mixture of solid timber veneered and painted solid doors. They appear to be functional, however the decoration and finish is damaged in a number of areas which appears to be from wear and tear.

B.O.H. FLOORS

B.O.H. floors are generally of carpet, vinyl or sealed concrete floors. There are a number of areas of carpet which are very badly stained and damaged with patched, taped repairs.

B.O.H. OFFICES

B.O.H. offices are dated, with carpeted and vinyl floors and lay in grid suspended ceilings with surface mounted and inset luminaires. Walls are a mixture of painted blockwork and painted plastered walls. There are a number of damaged and dislodged ceiling tiles and areas showing signs of leaks above the suspended ceiling.

B.O.H. WC'S

B.O.H. WC's are dated with painted blockwork walls, tiled floors and lay in grid ceilings. The walls have redundant fixing locations where fittings have been moved or replaced.

B.O.H. STAIRS

B.O.H. stairs are sealed concrete, with painted and fair faced blockwork walls and painted soffits. The stairs have circular plastic-coated handrails. The leading edge of the stairs has a painted contrasting nosing, which has been partly worn away by foot traffic.

B.O.H. STORES

B.O.H. stores have sealed concrete floors, fairfaced blockwork walls, exposed services and exposed soffits. Doors are solid painted doors. Some fore rated soffit ductwork has been clad and is causing a headroom issue.

STAFF ENTRANCE STAIR

The staff entrance stair is exposed sealed concrete with a feature stone wall to one side and an external glazed screen to the other. It has a circular plastic-coated handrail. The leading edge of the stairs has a painted contrasting nosing, which has been partly worn away by foot traffic.

CLOAKROOM

The cloakroom has painted walls, a carpet floor, and a plastered ceiling with inset access panels and surface mounted luminaires. The coat hanging system is dated, and clearly causes a H&S headroom issue for operatives. The cloakroom has a decorative timber fascia and counter – it is unknown as to whether the timber has been treated for surface spread of flame.

F.O.H. DOORS

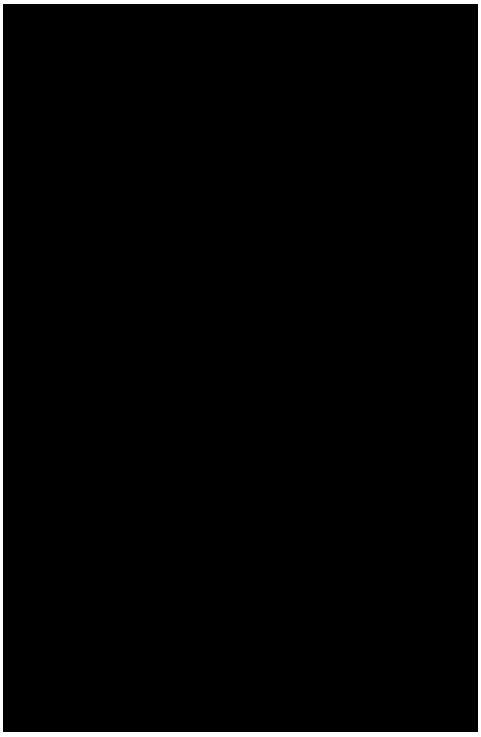
F.O.H. doors are generally of solid timber construction, with plastic coated ironmongery. Some doors are damaged, particularly at low level where a kick plate would normally be located and around handles.

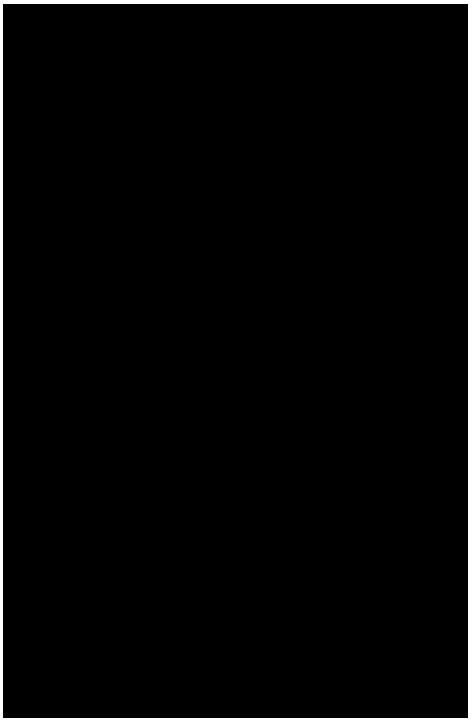
FOYER FLOORS

The foyer floor finish is predominantly carpet. The carpet is dated, dirty, and damaged in a number of areas, some of which have been repaired with tape

FUNCTION ROOM

The function room has a carpeted floor with a number of steps in it, exposed concrete walls, and a lay in grid ceiling with surface mounted luminaires and inset AC equipment. The external walls are showing some signs of damp ingress. The carpet is dated, dirty and damaged in some areas. There are some areas of decorative timber panelling and it is unknown if they have been treated for surface spread of flame.





F.O.H. WC'S

F.O.H. WC's have a vinyl floor, generally tiled walls and lay in grid suspended ceilings. The WC's are dated, there are a number of damaged areas of tiling, evidence of localised leaks and evidence of a leak above the ceiling. There are also a number of redundant fixing locations in tiled walls.

STAGE DOOR

The stage door area has a sealed concrete floor finish, with the office space carpeted. The walls are painted blockwork and brickwork walls. The office space has a lay in grid suspended ceiling. The office space has a timber faced reception counter. The access stairs are sealed concrete it has a circular plastic-coated handrail. The leading edge of the stairs has a painted contrasting nosing, which has been partly worn away by foot traffic. The delivery area of the stage door has evidence of a roof leak with streaking at high level. The concertina deliveries door is poorly fitted and not sealed.

THIRD FLOOR

BAR KITCHEN

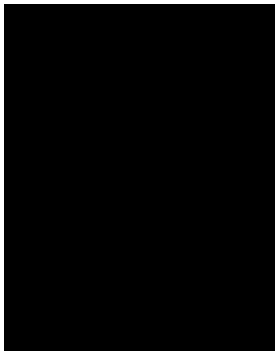
The bar kitchen is dated, although appears functional. The access door is of solid timber and has signs on kick and impact plates having been damaged and removed. The surface of the door is damaged as a result of this. The bar kitchen has a metal suspended ceiling, painted plastered walls, surface mounted electrics and a vinyl floor. Fittings are generally of stainless steel.

BEER STORE

The beer store has fairfaced exposed blockwork walls, exposed services and an exposed concrete soffit, with a sealed concrete floor. Doors are a mixture of solid timber veneered and paint grade and whilst they appear functional, their decoration is damaged locally.

B.O.H. CIRCULATION

B.O.H. circulation has carpeted floors, painted walls, partly exposed soffits with exposed services and some areas of lay in grid ceiling. Wall surfaces are dirty in places, there are areas of damaged ceiling, and carpets are grubby and damaged in certain locations.



B.O.H. DOORS

B.O.H. doors are generally of solid timber construction, with plastic coated ironmongery. Some doors are damaged, particularly at low level where a kick plate would normally be located and around handles. Doors with kick plates are badly scratched due to wear and tear.

B.O.H. WC'S AND SHOWERS

B.O.H. WC's and showers are dated, they have tiled walls and floors, timber cubicles and a lay in grid suspended ceiling. Plumbing pipework is exposed and there are redundant fixing locations in the tiled wall.

CHANGING ROOMS

Changing rooms have painted blockwork walls, lay in grid suspended ceilings and timber laminate flooring. Showers and WC's have tiled walls, and are dated. Various areas of laminate floor are damaged and have delaminated, there are a number of dislodged ceiling tiles and some areas of tiled wall are damaged. Vinyl floor to showers are showing signs of damage and ballooning at outlet positions.

CHANGING ROOM CORRIDORS

Changing room corridor has painted blockwork walls, exposed high level services and soffits, carpeted floors and solid timber veneered doors. The carpet is damaged in various locations.

EXTERNAL BALCONY

The external balcony has level access from internally. This is showing signs of water ingress as the surface of the balcony is paved up to the access door. The bottom of the access door is showing signs of decay and internal elements are showing signs of water damage. The balcony itself is showing signs of sitting water. There is a high level soffit above the balcony which is an ‘egg crate’ type which is showing signs of damage with certain elements missing.

F.O.H. WC’S

F.O.H. WC’s are dated. They have tiled walls and a mixture of tiled and vinyl floors, and a lay in grid suspended ceiling. Plumbing pipework is generally exposed. There are areas of repaired floor and wall tiling, and a number of redundant fixing positions on tiled walls. An area of flor tiling has been replaced with a concrete / resin type material.

F.O.H. DOORS

F.O.H. doors are generally of solid timber veneered construction, with plastic coated ironmongery. Some doors are damaged locally, particularly at low level where a kick plate would normally be located and around handles.

FOYER BAR

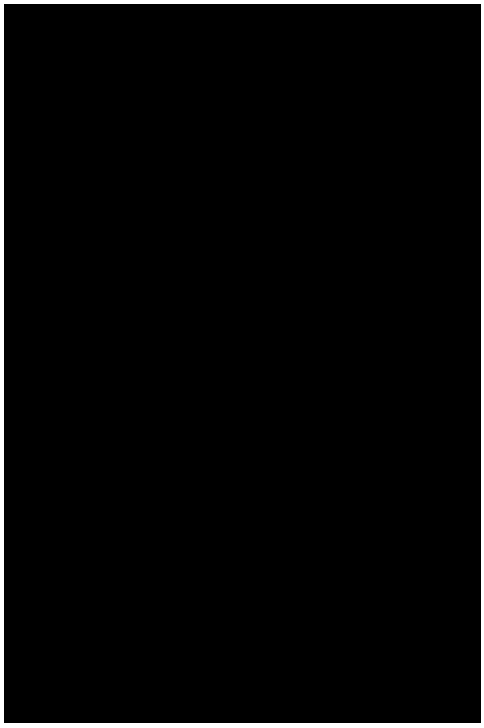
The foyer bar front appears to be in sound condition with no significant defects. It's appearance is dated, with bands of plastic laminate and rounded bullnose timber projections. The shutter was fixed down at the time of inspection so it is not known if there are any operational issues.

FOYER CARPET

The foyer carpet is dated and dirty. There are a number of damaged areas of carpet to the foyer which will cause a potential trip hazard.

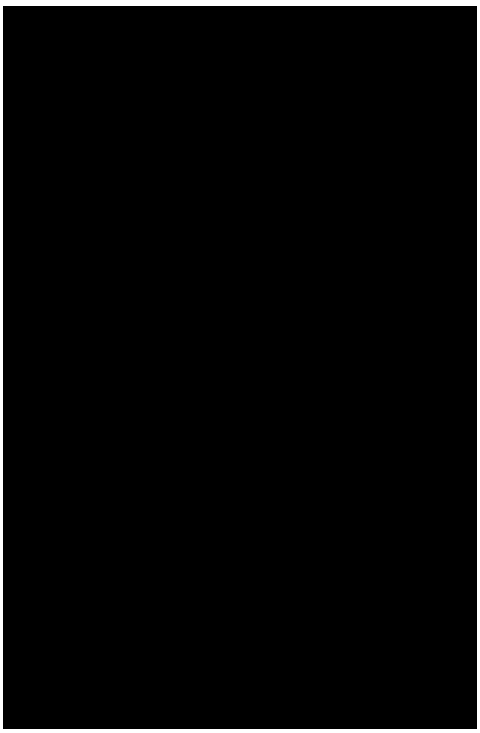
FOYER CIRCULATION

The foyer circulation is carpeted, with areas of exposed concrete wall and an exposed ‘egg crate’ type ceiling. There are areas of plastic coated handrailing to heavily trafficked areas. There are areas of damaged / m displaced egg crate ceiling. Concrete surfaces are generally dirty due to wear and tear. Signage is dated and power conduit is surface mounted to columns.



FOYER STAIRS

The foyer stairs carpeted with aluminium surface fixed nosing profiles. There are areas of exposed concrete wall. Concrete surfaces are generally dirty due to wear and tear. Stairs have wall and floor mounted circular plastic coated handrailing. Carpet is dirty and stained in some areas.



FUNCTION SPACE

The function space has a carpeted floor, wall papered walls and a lay in grid suspended ceiling. An access panel to the wall is dislodged. There is a solid timber glazed screen and doors are solid timber veneered with plastic coated ironmongery.

FUNCTION SPACE WC'S

The function space WC's have tiled walls with partly tiled and partly carpeted floors and a mixture of lay in grid and egg crate type suspended ceilings. Cubicle are laminate faced timber. The WC's are dated and plumbing is generally exposed.

GREEN ROOM

The green room has a carpeted floor, a lay in grid suspended ceiling and painted plastered walls. There is a large step and change in level to one side of the room adjacent external glazing. The room has a timber fronted bar area, it is not known if the timber is treated for surface spread of flame. Parts of the carpet has tape on it. There are no steps to the change in level in the room and the room does not have level access from adjacent spaces. Parts of the ceiling are stained adjacent AC grilles are stained. Doors are solid timber veneered with plastic coated ironmongery.

MULTI FUNCTION WC'S

The WC's to the Multi Function space are dated. The walls and floor are tiled, and plumbing is generally exposed. The ceiling is a lay in grid suspended ceiling. Lighting fluorescent tubes are exposed with no filters. The entrance doors are solid timber veneered with plastic coated ironmongery. The decoration to doors is damaged a little due to wear and tear.

AUDITORIUM

The floor to the auditorium is a wood block floor. It is in a poor state of repair and there are recurring issues of the wood blocks debonding from the substrate, and buckling up. The floor has to be repaired on a regular basis. It looks dirty and scratched and scuffed due to wear and tear. Auditorium seats are in a poor state of repair, upholstery is flat and damaged to many of the seats and the fabric has discoloured in many areas

TORING KITCHEN

The touring kitchen has painted blockwork walls, a vinyl floor and a lay in grid suspended ceiling. It has exposed pipework and drainage. Kitchen units and vinyl flooring are damaged, there are a number of dislodged ceiling tiles and the door and door frame show signs of impact damage.

FOURTH FLOOR

B.O.H. CIRCULATION

B.O.H. circulation has a carpeted floor, a lay in grid suspended ceiling and painted blockwork walls. Doors are solid timber paint grade doors, with plastic coated ironmongery. There are various areas of damaged and stained carpet, damaged ceiling tiles, damaged blockwork to walls and doors have damage to their decoration due to wear and tear.

B.O.H. DOORS

B.O.H. doors are solid timber paint grade doors, with plastic coated ironmongery. Many of the doors have damage to their decoration and there is a lot of ad hoc temporary signage applied to the faces of the doors.

CONTROL ROOM

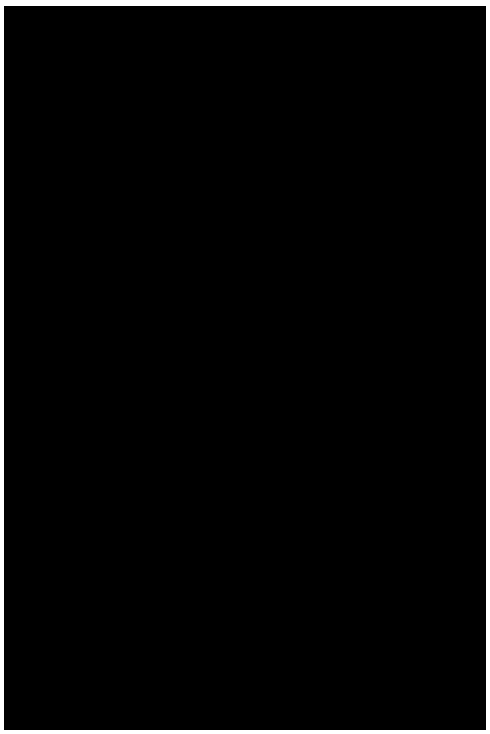
The control room has painted blockwork walls, a lay in grid suspended ceiling and part carpet part vinyl floor. There are a number of missing ceiling tiles and a hole in a ceiling tile. Various parts of the flooring are damaged and have been tape temporarily repaired.

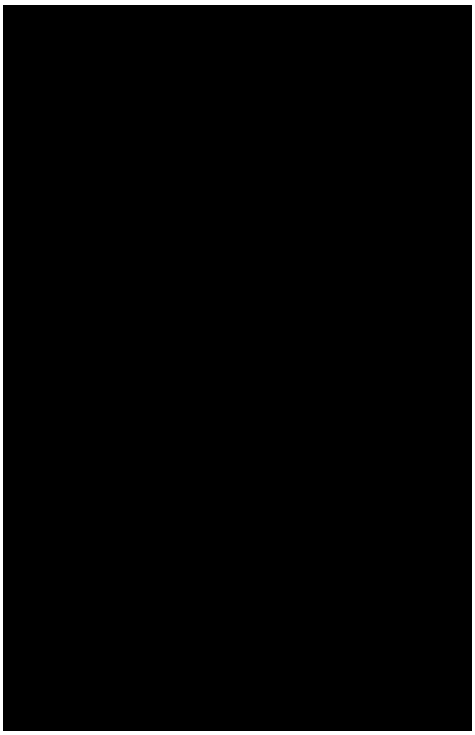
CONTROL ROOM KITCHEN

The control room kitchen has painted blockwork walls, a lay in grid suspended ceiling and vinyl floor. The kitchen is dated, with a number of redundant fixing locations in the blockwork wall. Plumbing and electrics are exposed, and the vinyl floor is damaged. It is not known if the kitchen is compliant with relevant environmental legislation.

F.O.H. FOYER OFFICE

Offices appear to have been retro fitted within the foyer space. The offices are dated. Studs are visible from the foyer within the walls, the office has a lay in grid suspended ceiling, painted plasterboard walls and a carpeted floor. The ceiling is poorly fitted with visible signs of leaks above the ceiling.



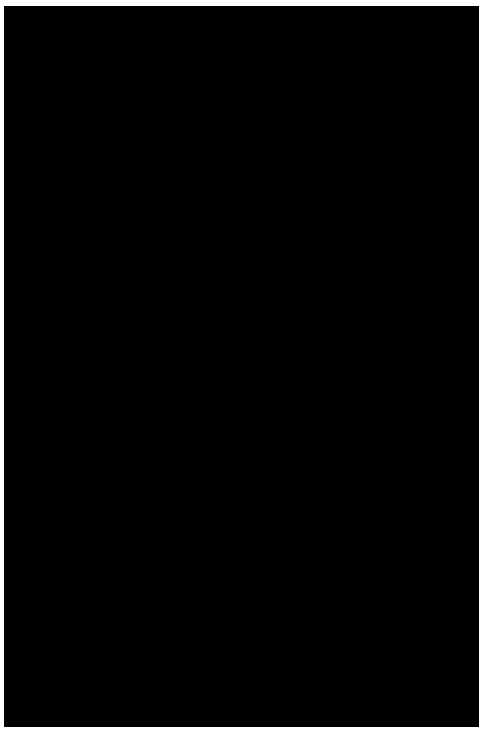


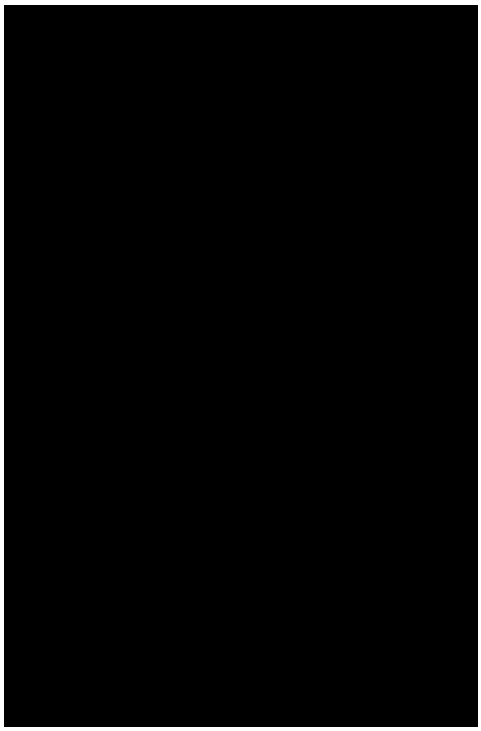
GIN BAR KITCHEN

The gin bar kitchen has tiled walls, a metal suspended ceiling, and a vinyl floor. Kitchen fittings are generally stainless steel. The kitchen is dated, a number of the ceiling tiles are dislodged and the vinyl floor joint is exposed and damaged.

GIN BAR CIRCULATION

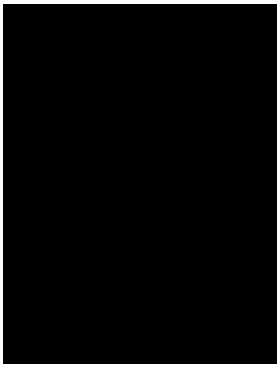
The gin bar circulation area has an egg crate type suspended ceiling, a carpeted floor, and a mixture of painted plasterboard walls, exposed concrete surfaces and areas of decorative timber panelling. There are areas of ceiling which are dislodged, the carpet is dated and dirty, concrete surfaces are dirty and stained. It is not known if timber panelling has been treated for surface spread of flame.





F.O.H. UNISEX WC

The F.O.H. unisex WC has a lay in grid suspended ceiling, painted plastered walls and a vinyl floor. The ceiling has a dislodged ceiling tiled, all pipework and drainage is exposed.



ROOF TERRACE

The roof terrace does not have level access, it is accessed via a set of timber decking type steps. The access doors have visible gaps to their perimeter as seals appear to be missing. The roof terrace has a solid paved finish, which has signs of moss growth which will be slippery.

FIFTH FLOOR

AUDITORIUM DOORS

F.O.H. doors are generally of solid timber veneered construction, with plastic coated ironmongery. Some doors are damaged locally, particularly at low level where a kick plate would normally be located and around handles.

AUDITORIUM FLOOR AND STEPS

The floor to the auditorium is a wood block floor. It is in a poor state of repair and there are recurring issues of the wood blocks debonding from the substrate, and buckling up. The floor has to be repaired on a regular basis. It looks dirty and scratched and scuffed due to wear and tear. A number of metal stair nosings are loose and move as they are stood on.

B.O.H. CIRCULATION

B.O.H. circulation has painted blockwork walls, painted exposed soffits with surface mounted M&E and exposed services at high level. Floors are carpeted. There is some clearestorey glazing at high level, doors are a mixture of solid paint grade and solid timber veneered. A number of the window push bar operators are broken.

CHANGING ROOMS

Changing rooms have a mixture of painted plastered walls, painted block walls and some areas of tiling. Floors are part tiled and part vinyl and soffits are painted. Doors are solid timber veneered, with plastic coated ironmongery. There are a number of rooflights within changing rooms some of which are damaged and show signs of leaking. Walls have a number of redundant fixing locations and some redundant M&E kit. Changing rooms have various changes in level within the space. WC's are basic with exposed plumbing and drainage.

ESCAPE STAIR

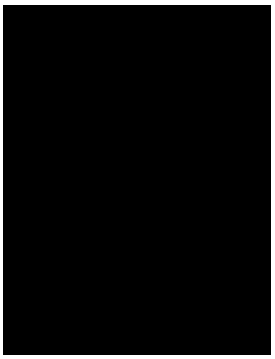
Escape stairs are sealed concrete with painted plastered walls. There is low level glazing within the escape stair, the perimeter of which is showing signs of water ingress or condensation localised damage to decoration. It is not known if the glazing is resistant to lateral load impact which could be encountered in an emergency situation or even in every day use.

F.O.H. WC'S

F.O.H. WC's have tiled floors and walls, timber veneered entrance doors with plastic coated ironmongery, lay in grid suspended ceilings, and largely exposed plumbing and drainage. The WC's are dated, areas of tiled floor have been repaired with epoxy / concrete type material. There are various areas showing damage from a leak, with a number of ceiling tiles displaced.

FOYER WALLS

Foyer walls are a mixture of painted plaster, painted plasterboard and exposed concrete. There are some elements of feature timber panels. The plastered walls are showing some signs of significant cracking which should be checked by a structural engineer. Exposed concrete surfaces are discoloured and dirty in some locations. It is not known if timber surfaces are treated for surface spread of flame.



FOYER STAIRS

Foyer stairs have exposed concrete side walls and exposed concrete soffits. The stairs are carpeted with applied metal nosings, the stairs have circular plastic coated handrails mounted onto the concrete side walls. The carpet is dated and dirty in areas, exposed concrete walls are discoloured and dirty in some locations with scuff marks from footwear at low level. An external wall is showing signs of water ingress.

FOYER ROOFLIGHTS

The foyer has large rooflights with inset opening lights with remote wire access for opening purposes. The opening lights are badly discoloured and rooflights are either very dirty or the glazing has deteriorated. The operating wires are unsightly. An adjacent wall is showing signs of water ingress from one of the rooflights. It is not known if the opening lights are in working order.

SERVICE YARD EXTERNAL WALLS

Service yard walls comprise of a mixture of profiled colour coated metal cladding, facing brickwork, stone, natural metal cladding and metal louvres. Most of the external materials are discoloured and badly stained and weathered.

Stiwdio
21a Allensbank Road
Cardiff
CF14 3PN

REPORT 2
EXTERNAL CONCRETE CLADDING SURVEY

Cardiff County Council

ST DAVID'S HALL

Structural Condition Survey of the external concrete cladding panels

70069626-S-1010
MARCH 2021

Cardiff County Council

ST DAVID'S HALL

Structural Condition Survey of the external concrete cladding panels

TYPE OF DOCUMENT (VERSION): CONFIDENTIAL
PROJECT NO.: 70069626
OUR REF. NO.: 70069626-S-1010
DATE: MARCH 2021

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QUALITY CONTROL

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CONTENTS

1 INTRODUCTION

1.1 THE SURVEY

- A structural condition survey of the external concrete cladding panels along the west-facing elevation of St David's Hall was undertaken; i.e. panels along the pedestrianised areas of Working Street and The Hayes.
- The visual survey was undertaken by [redacted] (Senior Structural Engineer, WSP's Cardiff Office) on the 3rd and 4th of March 2021.
  - This followed a hammer test survey undertaken by Restruct Ltd on the 1st and 2nd of March, who were appointed separately by Cardiff County Council.
- Weather conditions during the survey: light rain showers; light easterly winds; temperature around 7-degrees Celsius.

1.2 AUTHORITY

- Authority to undertake the survey was provided by Cardiff County Council. MEWP access ('cherry picker') was arranged and provided by Restruct Ltd and Cardiff County Council. Access into the building was made available by St David's Hall staff.

1.3 LIMITATIONS

- The survey by WSP was visual only, undertaken from:
  - a MEWP operated externally, positioned near the main entrance of the building;
  - a meeting / reception room on the third floor, above the main entrance area;
  - the fifth-floor roof terrace, above the main entrance area;
  - safely accessible external ground areas of Working Street and The Hayes.
- Not all cladding panels were inspected closely by WSP. However, a representative sample of panels was inspected from the MEWP (positioned near the main entrance).
- The building was closed to the public, due to COVID-19 restrictions in place at the time; a small number of staff were working in the building, who assisted the surveyor with access inside the building.
- No opening up works were undertaken by WSP. No finishes, fixtures or fittings were disturbed or removed by WSP. No material testing or other analysis has been undertaken, e.g. to determine composition, loadbearing capacity, etc.
  - The hammer test undertaken by Restruct Ltd included removal of loose concrete and making good some areas of damaged concrete and reinforcement with a concrete repair mortar system: we understand additional repairs required are subject to agreement with Cardiff County Council.
- Any measurements stated in this report are approximate and based on visual estimations only. No specialist measuring equipment was used. A boroscope (provided by Restruct Ltd) was used for limited inspection behind the cladding panels.
- This report shall be for the private and confidential use of the Cardiff County Council. It must not be reproduced in whole or part or relied upon by a third party without the express written authority of WSP.
- The report is not a specification and it must not be relied upon to prepare estimates.

2 SURVEY OBSERVATIONS

2.1 GENERAL DESCRIPTION OF THE BUILDING

- St David's Hall is a large concert hall building in Cardiff's city centre. It was constructed between 1977 to 1982, in tandem with the St David's Shopping Centre development which surrounds it on the north and east sides.
- The concrete framed building has precast concrete panels, of varying sizes, attached to all but the east-facing (rear) elevation. Only the panels on the west-facing elevation were considered during this survey (where the risk of injury to pedestrians is greatest). Some panels were inaccessible for close inspection or hammer testing due to the operating limits of the MEWP apparatus: these areas are highlighted in red below. Distant inspection did not identify any obvious defects and some observations were made by WSP during previous surveys, which are considered in this survey report.

2.2 GENERAL DESCRIPTION OF THE PRECAST CONCRETE CLADDING PANELS

- We have reviewed a report by Over Arup & Partners (November 1997), made available to us by Cardiff County Council. The report includes diagrams of the precast panels, which have:
  - an upside-down L shape cross section, with the horizontal portion secured to the top of an adjacent concrete edge beam, and the vertical portion extending down the face of the building;
  - varying heights to suit positioning of windows, louvres, and other façade features;
  - a number of bolts along the bottom edge, allowing the panels to be installed plumb (by adjusting the extension of the bolt from the rear panel);
  - a rear projection near their bottom edge, from which the bolts project.

- The following additional observations were made during this survey:
  - The bolts appear to be stainless steel, based upon their bright metal finish: only very minor corrosion staining was noted; no significant corrosion was noted that might lead to damage of the concrete.
  - The cross-section of the larger higher-level panels appears to be different to the smaller mid- and lower-level panels: the vertical portion of the panels appear to be uniform; however, the rear projection of the larger panels is approximately twice that of the smaller panels.
  - Linear hairline cracking was evident along the length of these rear projections, but more obvious along the larger projections of the larger panels. The hammer testing survey did not identify any defective / loose concrete in these areas at this time. However, pre-existing concrete defects were noted along the rear bottom edge of a number of panels (noted below).
  - Vertical joints between panels appear to be formed with a flexible material. This appears to have cracked, shrunk or degraded in areas.
  - Concrete walls, most likely cast in-situ, appear to exist behind the panels (apparent in photographs taken during the building's construction (available online)), but this could not be confirmed with certainty.

2.3 CONCRETE DEFECTS IDENTIFIED

- Restruct Ltd's surveyors reported a number of defects following their hammer test survey. The majority of these were pre-existing and have been identified by WSP during previous surveys and visits (refer to WSP report 70069626-S-1000). Refer to the annotated image below which locates the defects identified, and the survey photographs in **Appendix A** which shows the defects in more detail.

- The defects identified are tabulated below, noting: approximate dimensions; whether reinforcing steel ('rebar') is exposed; and when the defect was identified.

REF	DESCRIPTION	FLOOR LEVEL	DIMENSIONS	REBAR	HISTORY
1.	Defect to edge of 'waffle slab' floor. 300mm long.	2	300mm long	Y	Pre-existing.
2.	Defect to side of projecting column near light fitting.	2	200mm long	Y	Identified during this survey.
3.	Defect to front top corner of precast cladding panel below window.	2	250×200mm triangular area	Y	Identified during this survey.
4.	Small defect in front surface of precast concrete cladding panel.	3	50×50mm	N	Pre-existing.
5.	Small defect to front bottom edge of precast cladding panel.	3	100mm long	N	Pre-existing.
6.	Defect to front top corner of high-level precast cladding panel next to column.	4	150×150mm triangular area	Likely	Pre-existing.
7.	Defect along rear bottom edge of high-level precast cladding panel.	4	500mm long	Y	Pre-existing.
8.	Defect to front top corner of precast concrete panel at high level, below louvred panel.	4	200×500mm triangular area	Y	Crack pre-existing at planning visit March 2020. Loose concrete removed and extents identified this survey.
9.	Long defect to vertical corner of tall panels to side of window.	3	200×2000mm	Y	Pre-existing at planning visit March 2020.
10.	Small defect to front bottom corner of precast cladding panel over entrance canopy, partially obscured by glass fin feature cladding.	1	100×100mm	Y	Pre-existing.
11.	Surface degradation to the inner vertical edge of the panel.	3	300×2500mm	N	Pre-existing.
12.	Spalling concrete to corner of column, near doorway to roof terrace.	5	3 areas, up to 300×100mm each.	Y	Pre-existing at planning visit March 2020.
13.	Evidence of spalling concrete along rear bottom edge of precast cladding panel above window, 5th floor roof terrace.	5	Discontinuous lengths up to 1000mm	N	Pre-existing at planning visit March 2020.

3 DISCUSSION

3.1 CONCRETE DEFECTS

- Concrete defects, such as the spalling observed during this survey, are typically due to the following reasons:
  - inadequate 'cover' to the reinforcing steel (the thickness of concrete around the steel which limits its corrosion); and / or
  - carbonation of the concrete (where absorption of CO_2 from the atmosphere gradually reduces the alkalinity of the concrete (thereby reducing the chemical protection offered to the steel against corrosion).
- Loosened concrete increases the risk of water ingress into the concrete and subsequent corrosion of the reinforcing steel, which could lead to more significant structural defects.
- Loose fragments of concrete could cause serious injury / damage to persons / property below.

3.1.1. COVER

- Based on observations made during this survey, the cover offered to reinforcement appears to be adequate; for example, the rebar exposed at the significant defects (nos. 3, 8 and 9) appears to have around 40mm cover which is considered adequate for the exposure conditions. The actual cover was not verified using a cover meter.
- The cladding panels were, presumably, produced in a factory and this typically means workmanship and quality standards are higher. The isolated nature of the defects also suggests the defects are not a consequence of poor detailing or workmanship.

3.1.2. CORROSION OF EMBEDDED METAL FIXINGS

- The lack of significant corrosion to the alignment bolts suggests these fixings do not contribute to the defects noted.

3.1.3. CARBONATION

- We understand carbonation testing was not undertaken as part of Restruct Ltd's investigation scope. However, we would anticipate more extensive defects if carbonation was a contributing factor.
- In order to establish whether this is a contributory factor, carbonation testing should be considered.

3.1.4. DETAILS AND ARRANGEMENT OF REINFORCEMENT

- The arrangement of reinforcement in the panels was not verified using a cover meter and is not indicated on the diagrams in the Ove Arup report.
- It is possible that the rear projections of the smaller panels are not reinforced whereas the wider projects of the larger panels are reinforced: reinforcement was noted where concrete had come away from the larger rear projections, but not the smaller projections.

3.1.5. OTHER CONSIDERATIONS

- Minor damage during installation of the panels cannot be ruled out as a reason for the defects observed.
- There was no evidence of significant water ingress behind the panels due to the condition of the flexible joints.

3.2 REPAIRS

3.2.1. REPAIRS IMPLEMENTED DURING THE SURVEY

- Restruct Ltd implemented some repairs to the defective concrete, using a concrete repair mortar system: we understand a Sika system was used. Such repair systems typically:
  - comprise of a steel corrosion inhibitor/ primer/ bonding agent, and a cement-based mortar to rebuild the profile of the concrete;
  - require additional breaking out of concrete around reinforcing steel to allow the mortar to fully surround and protect the reinforcement;
  - may require insertion of replacement reinforcing steel where corrosion is significant.
- During WSP's attendance on site, repairs were implemented to defects nos. 8 and 9.
  - We cannot confirm what other repairs were implemented after WSP's surveyor had left site (whilst the MEWP was still available for use).
  - WSP's surveyor did suggested to Restruct Ltd's operatives that, as a minimum, the exposed rebar should receive an application of corrosion inhibitor / primer to limit further corrosion of the steel until a full repair could be completed.

3.2.2. FUTURE REPAIRS

- Additional repairs to address missing sections of concrete should adopt one of the many concrete repair systems available from various manufacturers.
- Coating systems are available to address carbonation of the concrete and limit further deterioration of the concrete, if carbonation is found to be a contributing factor to the defects observed.
- Access to implement repairs to the rear projections is somewhat restricted by the proximity of the concrete beams to the rear and general inaccessibility of the rear face. This should be given consideration when planning future repairs.

3.3 MONITORING

- Loose areas of concrete were identified and removed during this survey. However, further loss of concrete cannot be ruled out and periodic inspection of the concrete panels and other concrete elements should be undertaken to identify and remove additional areas of loose concrete.
- A metal canopy has been installed over the shop fronts at street level, which may prevent some concrete fragments from falling to the street. However, this is not the primary function of the canopy and there is no guarantee that it will eliminate the hazard completely.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

- The panels appear to be in fair to good condition generally. Flexible joints between panels appear to be in fair condition, but there was no evidence of significant water ingress through these joints.
- Based on observations made during the survey, and the results of the hammer testing undertaken by Restruct Ltd, the extents of concrete defects appears to be limited. Furthermore, there was limited evidence noted of inadequacies in the design and detailing of the panels to suggest future defects would become apparent with increasing frequency. Potential carbonation of the concrete has not been verified as part of the intrusive investigation carried out.
- The survey undertaken presents a 'snap shot' of the condition of the concrete panels at this time. No records have been made available to allow us to consider the timing of previous defects to assess the frequency of defects becoming apparent: the Ove Arup report, reference herein, considered two panels which were subsequently replaced with panel of slightly different detailing.

4.2 RECOMMENDATIONS

- The remaining unrepaired defects identified should be repaired with a concrete repair system. This may require partial dismantling of the glass fin feature cladding. Such repair systems typically:
  - require removal of all loose and defective concrete around the defect area;
  - require additional breaking out of concrete around reinforcing steel to allow the mortar to fully surround and protect the reinforcement;
  - may require insertion of replacement reinforcing steel where corrosion is significant;
  - comprise of a steel corrosion inhibitor/ primer/ bonding agent, and a cement-based mortar to rebuild the profile of the concrete.
- Concrete cladding panels not accessible for inspection by MEWP during this survey should be inspected more closely and suitable concrete repairs implemented. This includes other areas accessible to the general public or patrons, e.g. roof terraces.
- Carbonation testing of a representative sample of cladding panels should be undertaken to establish whether this is a contributing factor to the defects observed. Application of an anti-carbonation coating should be considered if carbonation is confirmed.
- In order to establish how frequently new defects become apparent, **we recommend the cladding panels are resurveyed in 2- to 3-years time**. However, if further defects become apparent before then, consideration should be given to undertaking the resurvey sooner.

APPENDIX A

SURVEY PHOTOGRAPHS

1 Capital Quarter
Tyndall Street
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Cardiff County Council

ST DAVID'S HALL

Inspection of the external concrete façade elements

70069626-S-1011
OCTOBER 2021

Cardiff County Council

ST DAVID'S HALL

Inspection of the external concrete façade elements

TYPE OF DOCUMENT (VERSION): CONFIDENTIAL
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CONTENTS

1 INTRODUCTION

1.1 THE SURVEY

- An inspection of the external concrete cladding panels / façade elements along the north- and east-facing elevations of St David's Hall was undertaken; i.e. panels / elements to the rear of the building (accessible from the loading bay area over St David's Shopping Centre).
  - This follows a similar inspection undertaken by WSP in March 2021 (report ref. 70069626-S-1010) of the concrete cladding panels / façade elements to the front elevation of the building (facing The Hayes). The latest report should be read in conjunction with the March 2021 report.
- The visual inspection was undertaken by [redacted] (Senior Structural Engineer, WSP's Cardiff Office) on the 10th of September 2021.
  - This followed a hammer test survey undertaken by Restruct Ltd (who were appointed separately by Cardiff County Council) over the preceding days.

1.2 AUTHORITY

- Authority to undertake the inspection was provided by Cardiff County Council. MEWP access ('cherry picker') was arranged and provided by Restruct Ltd and Cardiff County Council.

1.3 LIMITATIONS

- The inspection by WSP was visual only, undertaken from the safely accessible areas of the loading bay / rear of the building. The MEWP apparatus was not used for the inspection: following a review of the defects reported and repaired, use of the MEWP was not considered necessary.
- Not all concrete cladding panels / façade elements were inspected by WSP or Restruct. MEWP access was not possible along most of the north elevation due to obstructions (refer to section 2.1 below). This restriction was already acknowledged, and separate arrangements should be made by Cardiff Council to complete the inspection of concrete cladding panels / façade elements in this area.
- No opening up works were undertaken by WSP. No finishes, fixtures or fittings were disturbed or removed by WSP. No material testing or other analysis has been undertaken, e.g. to determine composition, loadbearing capacity, etc.
  - The hammer test survey undertaken by Restruct Ltd included removal of loose concrete and making good areas of damaged / defective concrete and reinforcement identified with a concrete repair mortar system.
- Any measurements stated in this report are approximate and based on visual estimations only. No specialist measuring equipment was used.
- This report shall be for the private and confidential use of the Cardiff County Council. It must not be reproduced in whole or part or relied upon by a third party without the express written authority of WSP.
- The report is not a specification and it must not be relied upon to prepare estimates.

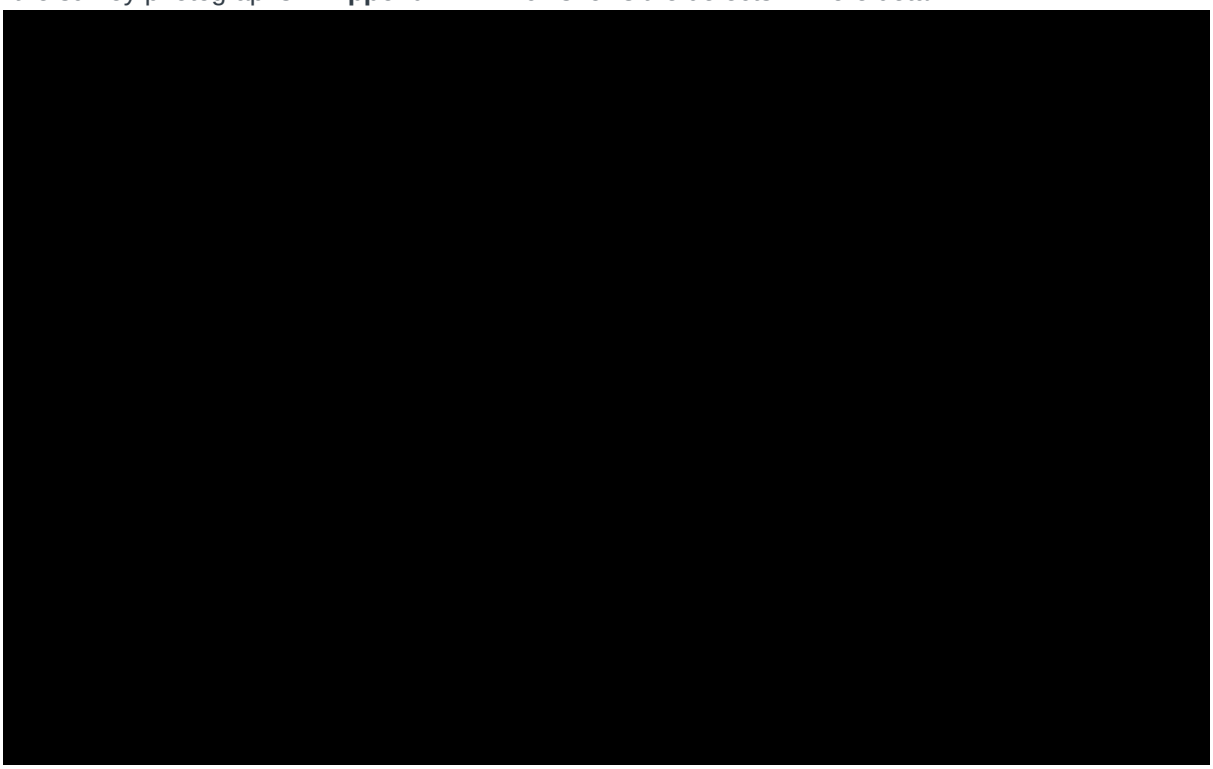
2 SURVEY OBSERVATIONS

2.1 GENERAL DESCRIPTION OF THE BUILDING

- St David's Hall is a large concert hall building in Cardiff's city centre. It was constructed between 1977 to 1982, in tandem with the St David's Shopping Centre development which surrounds it on the north and east sides.
- The concrete framed building has precast concrete panels, of varying sizes, attached to all but the east-facing (rear) elevation.
  - Only the panels on the north-facing elevation were considered during this survey.
  - However, these panels / elements were inaccessible for close inspection or hammer testing due to the operating limits of the MEWP apparatus or obstruction preventing access, i.e. items of mechanical plant and the glazed roof light structure over the western entrance 'arcade' of St David's Shopping Centre: this area is highlighted in red on the image below.
- There east-facing elevation has cast in-situ concrete façade elements (exposed structural beams, columns and walls), which were inspected (and subject to hammer testing and repair by Restruct Ltd). Panels of facing brickwork, windows or louvres are constructed off and between these concrete elements.

2.2 CONCRETE DEFECTS IDENTIFIED

Restruct Ltd's surveyors reported a number of defects following their hammer test survey, some were previously identified during WSP's building condition survey in January 2020 (report ref. 70069626-S-1000). Refer to the annotated image below which locates the defects identified, and the survey photographs in **Appendix A** which shows the defects in more detail.



- The defects identified are tabulated below, noting: approximate dimensions and when the defect was identified.

REF	DESCRIPTION	FLOOR LEVEL	DIMENSIONS	REBAR	HISTORY
1.	Defect to bottom edge of vertical column, over terrace.	5	25×450mm	No	Identified during this survey.
2.	Defect to left hand edge of column, near top.	6	50×50mm		
3.	Defect to right hand edge of column, near bottom LH corner of louvre panel.	4	50×100mm		
4. 5.	Small defect in to bottom edge of beam.		50×50mm		
6.	Defect to top corner of beam.		250×125mm triangular area		Pre-existing.

- In addition to the concrete defects, cracked / disturbed bedding mortar were noted at the interface between the top of the concrete beams and the brickwork cladding constructed and supported directly above.

3 DISCUSSION

3.1 CONCRETE DEFECTS

- Concrete defects, such as the spalling observed during this survey, are typically due to (and often a combination of) the following:
  - inadequate 'cover' to the reinforcing steel (the thickness of concrete around the steel which limits its corrosion); and / or
  - carbonation of the concrete (where absorption of CO_2 from the atmosphere gradually reduces the alkalinity of the concrete (thereby reducing the chemical protection offered to the steel against corrosion).
- Loosened concrete increases the risk of water ingress into the concrete and subsequent corrosion of the reinforcing steel, which could lead to more significant structural defects.
- Loose fragments of concrete could cause serious injury / damage to persons / property below.

3.1.1. COVER

- Based on observations made during this survey and limited effects identified, there is little evidence to suggest inadequate cover.

3.1.2. CARBONATION

- We understand carbonation testing was not undertaken as part of Restruct Ltd's investigation scope. However, we would anticipate more extensive defects if carbonation was a contributing factor.

3.1.3. THE DEFECTS, GENERALLY

- The majority of the defects affected the arrises of rectangular beams and columns. It is possible that these arrises suffered impact during construction, e.g. subsequent construction of the brickwork cladding or fitting of louvre panels, etc.: minor damage caused may have led to very localised loosening of concrete over time.
- With the exception of defect no. 6, the defects only became apparent during hammer testing.

3.1.4. CRACKED BEDDING MORTAR

- Weep holes noted at the interface between concrete beam and brickwork cladding indicates a cavity tray / DPC exists at this interface.
- It is possible that the bedding mortar at the interface has become saturated and, when subjected the freeze-thaw action during cold weather, the mortar has cracked and/or loosened.
- The mortar should be repaired in due course; however, this is not considered urgent at this time.

3.2 REPAIRS

3.2.1. REPAIRS IMPLEMENTED DURING THE SURVEY

- Restruct Ltd had implemented repairs to the defects identified (prior to WSP's visit), using a concrete repair mortar system. Such repair systems typically:
  - comprise of a steel corrosion inhibitor/ primer/ bonding agent (where rebar is exposed, but not required for the repairs implemented in this instance), and a cement-based mortar to rebuild the profile of the concrete;
  - require additional breaking out of concrete around reinforcing steel to allow the mortar to fully surround and protect the reinforcement, and / or be applied to a minimum thickness to avoid feathered edges;
  - may require insertion of replacement reinforcing steel where corrosion is significant (but not for the repairs implemented in this instance).

3.2.2. FUTURE REPAIRS

- Additional repairs to address missing sections of concrete should adopt one of the many concrete repair systems available from various manufacturers.
- Coating systems are available to address carbonation of the concrete and limit further deterioration of the concrete, if carbonation is found to be a contributing factor to the defects observed.

3.3 MONITORING

- Loose areas of concrete were identified and removed during this survey. However, further loss of concrete cannot be ruled out and periodic inspection of the concrete panels and other concrete elements should be undertaken to identify and remove additional areas of loose concrete.
- The north- and east-facing elevations are considered 'back-of-house' and not generally accessible to the public, which reduces the likelihood of injury / damage. However, these areas are still accessed by staff, deliver personnel and vehicles to St. David's Hall and the loading bays of St David's Shopping Centre, so the risk of injury / damage remains.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

- Based on observations made during the survey, and the results of the hammer testing undertaken by Restruct Ltd, the extents of concrete defects appears to be limited and minor in nature. Furthermore, there was limited evidence noted of inadequacies in the design and detailing of the areas inspected to suggest future defects would become apparent with increasing frequency. Potential carbonation of the concrete has not been verified as part of the intrusive investigation carried out.
- The survey undertaken presents a 'snap shot' of the condition of the concrete façade elements panels at this time. No records have been made available to allow us to consider the timing of previous defects to assess the frequency / timescales of defects becoming apparent.

4.2 RECOMMENDATIONS

- Concrete cladding panels / façade elements not accessible for inspection at this time should be inspected more closely and suitable concrete repairs implemented. This includes, primarily, the north-facing elevation areas above the roof light structure.
  - Suitable means of access will be required, possibly scaffold platforms or rope access techniques.
- Cracked / loose bedding mortar should be repaired in due course, perhaps in tandem with other planned maintenance work, or when the severity of the defect worsens significantly.
- **We recommend the cladding panels are resurveyed in 2- to 3-years time**. However, if further defects become apparent before then, consideration should be given to undertaking the resurvey sooner.

APPENDIX A

SURVEY PHOTOGRAPHS

1 Capital Quarter
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REPORT 3
CONCRETE ROOF PLANK SURVEY

Cardiff County Council

ST DAVID'S HALL

RAAC roof plank survey

70086249-S-1000
OCTOBER 2021

Cardiff County Council

ST DAVID'S HALL

RAAC roof plank survey

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CONTENTS

1 INTRODUCTION

This report presents the findings and recommendations of a survey to review the condition and establish the deflections of the RAAC (Reinforced Autoclaved Aerated Concrete) planks forming the two flatter roof slopes over the auditorium of St David's Hall, The Hayes, Cardiff. The survey follows the building condition survey undertaken by WSP in January 2020 (report ref. 70069626-S-1000, updated in May 2021), which identified the existence of the RAAC roof planks.

1.1 THE SURVEY

- A visual review was undertaken to identify any planks showing signs of defects or distress. This was undertaken by [redacted] (Senior Structural Engineer, WSP's Cardiff Office) on the 9th June 2021 (in advance of the Cardiff Singer of the World contest).
- A measured survey was undertaken, using laser-scanning techniques, to determine deflections of individual planks. This was undertaken by Azimuth Land Surveys (engaged by WSP) on the 1st July 2021 (following conclusion of the Cardiff Singer of the World contest).

1.2 AUTHORITY

- Authority to undertake the survey was provided by Cardiff County Council. Access was agreed and made available by Cardiff County Council and St David's Hall staff.

1.3 LIMITATIONS

- The visual and measured surveys were undertaken from safely accessible gantries / walkways within the roof space. Obstruction – such as ventilation ductwork, roof trusses, stage rigging apparatus, etc – limited observations meaning not all planks could be viewed, or measured with the laser-scanning equipment, the latter requiring line-of-sight to obtain measurements.
- The building was closed to the public during the surveys; staff and other persons were present, working on the stage below (relating to the contest).
- Limited mains lighting was available; WSP's surveyor utilised a handheld torch to inspect areas with limited lighting.
- No opening up works were undertaken. No finishes, fixtures or fittings were disturbed or removed. No material testing or other analysis has been undertaken, e.g. to determine composition, loadbearing capacity, etc.
  - intrusive investigations identified by WSP were not undertaken: refer to section 2.4 for further details.
- Measurements stated in this report are approximate.
- This report shall be for the private and confidential use of the Cardiff County Council. It must not be reproduced in whole or part or relied upon by a third party without the express written authority of WSP.
- The report is not a specification. It should not be relied upon for procurement, nor for preparation of estimates without review by an appropriately experienced / qualified person (e.g. quantity surveyor / cost consultant).

2 SURVEY OBSERVATIONS AND METHODOLOGY

2.1 GENERAL DESCRIPTION OF THE BUILDING

- St David's Hall is a large concert hall building in Cardiff's city centre. It was constructed between 1977 to 1982, in tandem with the St David's Shopping Centre development which surrounds it on the north and east sides.
- The large auditorium at its centre is encircled by foyers, circulation space and 'back-of-house' accommodation over six floors. A large clear-span steel framed mansard roof covers the auditorium and much of the 'back-of-house' accommodation, with terraced flat roofs covering the remainder, primarily to the south side.

2.2 VISUAL SURVEY OBSERVATIONS AND DEFECTS NOTED

a) The roof structure is comprised of:

- Deep trusses formed of steel UC and UB sections (universal columns / beams), set out at approx. 5.25m centres; the depth of the trusses vary to suit the variable roof- and ceiling-lines. The trusses project beyond the auditorium walls to support the steeper lead-clad sides of the mansard roof.
- Steel UB purlins spanning between the trusses, set out at 3.00m centres.
- RAAC planks spanning between the purlins or the perimeter masonry / concrete walls of the auditorium; the planks are generally 600mm wide, spanning 3.00m generally (some spans are up to 5.00m where they are supported on the perimeter walls) and have what appears to be a dark grey paint applied to their undersides. Archive drawings provided by Cardiff County Council indicate the 'Siporex' planks are 250mm deep.

b) The planks were visually inspected (with the aid of a hand-held torch) as far as practical from the access gantries / walkways within the roof space; particular attention was paid to the ends of the planks where these bear onto the purlins / walls.

2.3 MEASURED SURVEY METHODOLOGY

a) The planks appear to be set out symmetrically about the ridge line of the roof. An initial roof plank setting out drawing was prepared using scaled building CAD plans provided by Cardiff County Council, supplemented with the visual survey observations (i.e. purlin spans, plank widths, setting out). This allowed a plank referencing system to be established: columns (perpendicular to the planks / parallel with the steel purlins) were referenced A to N; rows (parallel with the planks) were referenced 1 to 82.

b) Laser scanning apparatus was brought into the building and positioned within the roof space; only the access gantries / walkways could be used for mounting the apparatus. Once correctly set up, the laser would scan the space, measuring and recording the distance to objects in sight of the laser; the laser scanner would then be repositioned to measure and record distances from different vantage points throughout the roof space.

c) Computer processing off-site produced a 3-dimensional 'point cloud' model, which is interrogated manually to determine the levels (relative to a chosen datum) of the support (on the purlins /walls) and mid-span of each plank.

d) A spreadsheet, set up to reflect the referencing system, was populated with:

- the left support, right support and mid-span levels of each plank;
- the spans of each plank (generally 3m).

plank ref. E40 used as an example (levels and span in metres)

	E		
	LEFT	MID-SPAN	RIGHT
40	53.365	53.360	53.367

	E
	PLANK SPAN
40	3.000

e) Further analysis was then undertaken to determine the plank deflection and span-deflection ratio, using the follows calculations:

Average of the plank support levels = theoretical mid-span level	53.365 + 53.397 = 53.366
Theoretical mid-span level minus the measured mid-span level = plank deflection	53.366 - 53.360 = 0.006m = 6mm
Plank span divided by the plank deflection = span-deflection ratio	3.000 ÷ 0.006 = 500 = span / 500

f) The spreadsheet data was then colour coded to: a) highlight the planks with highest deflection and b) categorise the plank span-deflection ratios in accordance with the assessment criteria. Initially, this allowed erroneous data (due to manual input errors) to be identified and verified against the 3D point cloud information: corrections were made where necessary.

2.4 ABORTED INTRUSIVE INVESTIGATION

- WSP proposed that intrusive investigation was included in the survey to establish:
  - length of the plank bearing over the steel purlin;
  - position of longitudinal and transverse reinforcing bars within the plank, particularly around the plank bearings.
- It was acknowledged that obstructions, positions of access gantries / walkways, etc. would limit the extents of such investigation, but it was hoped that a representative sample could be investigated.
- WSP met this Cardiff Council ([redacted], Structural Engineer, PDD) and their proposed contractor (Restruct Ltd, who were assisting with other surveys and repairs within St David's Hall) to consider the scope and practicalities of the investigation.
- The following conclusions were drawn:
  - the position of some gantries offered limited, difficult or no access to the adjacent plank bearings;
  - the height from the access gantries to the underside of the planks would require temporary working platforms to be erected off the gantries; the access route into and around the roof space, together with the gantry widths, would seem to limit this to step ladders;
  - in doing so, edge protection offered by the gantries would become ineffective, requiring additional fall-arrest provision.
- It was agreed to postpone this investigation until the conclusions of the visual and measured surveys was known.

3 SURVEY RESULTS

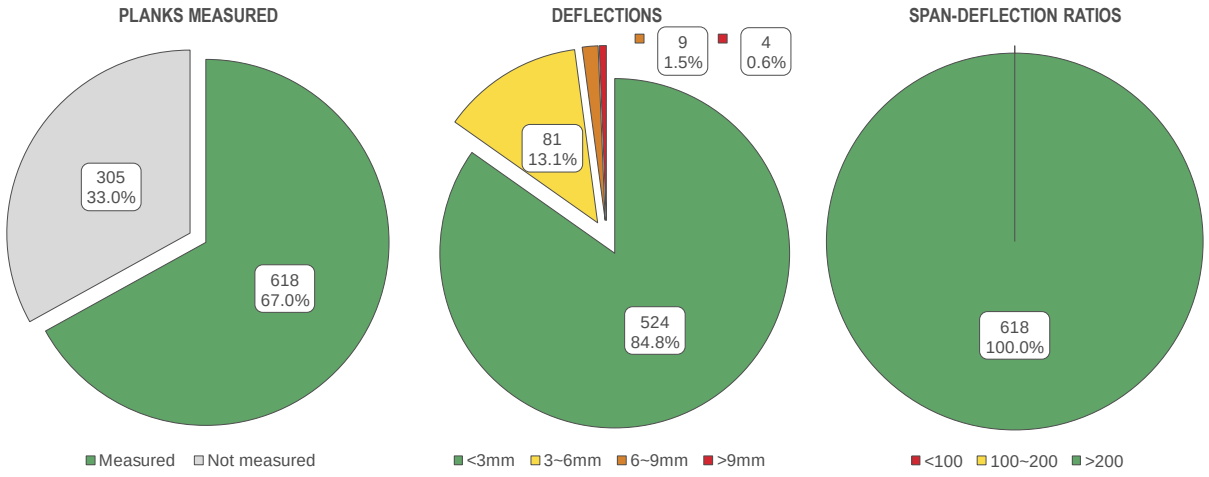
The full results are presented in Appendix A.

3.1 VISUAL SURVEY RESULTS

- Not all planks could be inspected from the observations made from the access gantries / walkways.
- No evidence of cracking, distress or obvious excessive deflections was noted.
- Evidence of, what appears to be, historic water ingress was noted in the north corner of the roof (plank refs. D1 and D2, near the access point into the roof space); however, there were no obvious structural defects noted.

3.2 MEASURED / DEFLECTION SURVEY SUMMARY

- Levels data could not be captured for all planks due to obstructions within the roof space, ventilation ductwork, steel trusses, etc.
- Observations and the measured survey data indicate there are 923 planks: levels data was captured, and deflections calculated for 618 planks, 67% of the total number of planks.
- The vast majority of planks (524, 85% of those with data) had deflections less than 3mm. The maximum deflection calculated was 11mm (equivalent to span / 272 for the 3m plank span).
- The calculated span-deflection ratios for all planks with data (618, 100%) were above (better than) span / 200.

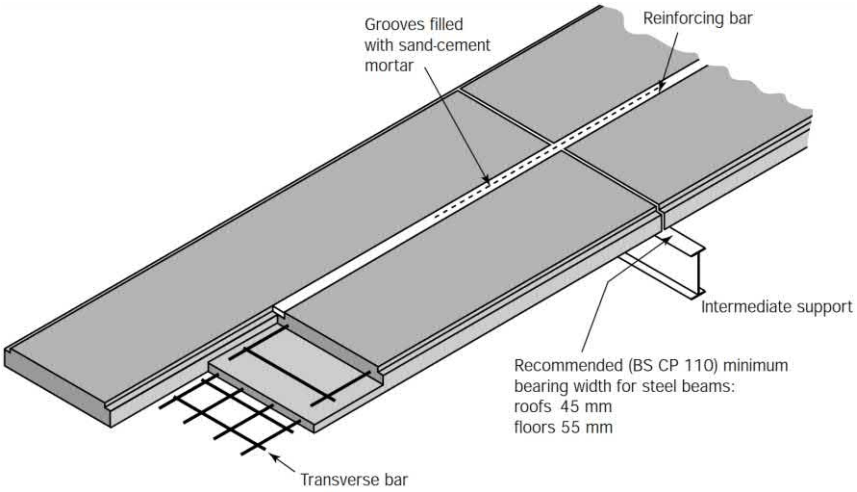


4 DISCUSSION

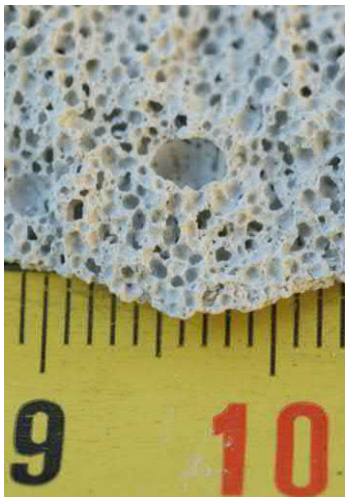
4.1 RAAC BACKGROUND INFORMATION

4.1.1. WHAT IS RAAC?

- Autoclaved Aerated Concrete (AAC) can be described as an aerated mortar of cement paste, often in combination with silica flour, ground blast-furnace slag or pulverized fuel ash. It is a lightweight material (oven dry density of 500 ~ 1000 kg/m3) where acceptable levels of strength and drying shrinkage are achieved by a high-pressure steam-curing process (autoclaving) during manufacture. Aluminium powder reacts with the lime in the mortar to produce hydrogen gas to foam the mortar.
- Development and use of this material for structural purposes began in the early 1930s in Sweden and was introduced to the UK in the late 1950s.
- Steel reinforcement was introduced to form RAAC (Reinforced Autoclaved Aerated Concrete). Longitudinal reinforcement was added to the top and bottom of the planks; transverse bars were welded to the top and bottom bars at intervals to overcome the otherwise limited anchorage / bond strength (see the figure below). Reinforcement was coated with a bituminous or cement-latex coating to provide resistance to corrosion, necessary because the AAC does not provide the alkaline protection to steel reinforcement afforded by normal concrete.
- Precast floor and roof planks were made in a range of widths, depths and lengths. Planks sold in the UK between the ealrly-1960s and late-1970s were usually marketed under two names: 'Durox' and 'Siporex', the latter referenced on the St David's Hall construction record drawings.



LEFT: TYPCIAL COMPOSIITON OF RAAC PLANKS USED FOR FLOOR AND ROOF CONSTRUCTION (IMAGE: BRE IP 10/96).



RIGHT: SAMPLE OF AAC MATERIAL HELD AGAISNT A MEASURING TAPE TO ILLUSTRATE THE SCALE OF THE FOAM STRUCTURE (IMAGE: WIKIPEDIA).

4.1.2. RECENT PROBLEMS WITH RAAC

- Concerns have been raised recently (by the Local Government Association[1] in late-2018 and by SCOSS[2] (Standing Committee on Structural Safety) in mid-2019) following the sudden collapse of a flat roof constructed using RAAC. More recently, the media recently reported of temporary remedial works and weight restrictions put in place at a number of NHS hospitals in England[3].
- The relevant SCOSS Alert identifies the following risk indicators, adding that most RAAC planks that exist today have likely exceeded their intended design-life. We have added *commentary* relevant to St David's Hall against each risk item:
  - cracking and disruption of the planks near the supports;
    none noted during the visual survey undertaken; the dark grey paint applied would seem to allow easier identification of such cracks – the pale material exposed within the crack would be highlighted against the dark grey surface.
  - short bearings (40mm or less) or reinforcement not extending to the bearing;
    could not be assess during this survey; refer to section 2.4 for further details.
  - excessive deflections (exceeding span/200), sometimes leading to ponding of rainwater and thus potentially leading to increased loading;
    all planks measured show deflections less than span/200; the generous roof slope limits the likelihood for ponding water, except around gutter outlets (which we understand require frequent unblocking).
  - replacement roof coverings where the loading has increased, or the thermal characteristics differ (e.g. a black surface finish where the original did not);
    as reported in our building condition survey report, we understand the roof covering has been replaced, from a grey finish to the present darker red finish.
  - the roof is leaking or has leaked in the past.
    limited evidence of active or significant water ingress noted during our surveys.

4.2 BRE STUDIES AND GUIDANCE

Based on review of BRE (Building Research Establishment) Information Paper IP 10/96 "Reinforced autoclaved aerated concrete planks designed before 1980".

4.2.1. RAAC PLANK TESTING

- In 1991, BRE conducted laboratory testing on RAAC roof planks removed from a housing development. The testing included materials analysis and strength testing, and load testing of the RAAC planks.
- Key observations and findings were as follows:
  a) RAAC planks still in use today are likely reaching or have passed their intended design-life.
  b) Excessive deflections and associated transverse cracking of the planks were observed in service. This behaviour was considered to arise from some degree of slippage between the reinforcement and the AAC; later studies suggest thermal cycling may be a contributing factor.

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/971528/RAAC-Guidance.pdf
[2] https://www.cross-safety.org/sites/default/files/2019-05/failure-reinforced-autoclaved-aerated-concrete-planks.pdf
[3] https://www.bbc.co.uk/news/uk-england-cambridgeshire-57941926

c) Whilst localised corrosion of the reinforcement was evident, significant section-loss had not occurred. However, high moisture content due to exposure of water (e.g. through breakdown of the roof covering) would likely lead to more severe corrosion in older planks.

d) The absence of transverse bars in the end zone (bearing) of a RAAC plank could substantially reduce the load capacity of the plank. A similar effect could also arise where the longitudinal reinforcement stops short of the bearing or where the welds (between longitudinal and transvers bars) are inadequate or have deteriorated.

e) Ultimately, the planks failed by local crushing, horizontal delamination and extensive cracking at the supports. These visual indications occurred in advance of the ultimate load capacity of the plank being reached, with deflections in excess of span/50 evident at the point of failure: adequate visual warnings were given prior to the ultimate failure conditions being reached.

4.2.2. SUGGESTED MAINTENANCE MEASURES

We have added *commentary* relevant to St David's Hall against certain measures

- Adopt good roof maintenance practices; in particular, ensure water outlets are clear and are at such a level that allows free drainage of water from roof areas.
  the current regular inspection and unblocking of roof drainage outlets should continue.
- If the internal surface of the planks is to be decorated, use paint which allows moisture vapour to pass through it. Protect external surfaces with a coating which provides an effective barrier against the transmission of liquid water.
- The following additional measures are advisable for constructions over 20 years old:
  - where appropriate, reduce the dead load on roofs by removing chippings and replacing them with an appropriate solar reflecting coating;
    there are no chippings or roof-mounted apparatus hence the current roof dead load is considered low; roof maintenance works where increased levels of personnel is likely (above that of general inspection / drainage unblocking) should be planned to minimise / control additional loading.
  - ensure that all waterproof membranes are maintained in good condition;
    the current regular inspection should continue.
  - keep records of deflections of RAAC planks and inspect the construction regularly.
- The **frequency of inspection** will depend on the condition of the construction:

  a) **Inspect annually** if:
  - the structure is in poor condition;
    no cracking, spalling or other signs of distress noted.
  - deflections are greater than 1/150 of the span;
    no excessive deflections noted / surveyed.
  - severe or persistent water penetration has occurred, or if the planks are located in a very humid environment, or where condensation or interstitial condensation might commonly occur, or if there is rust staining.
    no evidence noted.

  b) **Inspection at five-yearly intervals** should be sufficient if the structure is in good condition and deflections are generally less than 1/200 of the span, provided there are no other problems with the construction.
  deflection noted / surveyed were all less (better) than span/200.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 SURVEY CONCLUSIONS

- Based on the visual survey observations and the measures survey results:
  - No evidence of cracking, distress or excessive deflections were noted.
  - Deflections surveyed were all within acceptable limits. All span-deflection ratios calculated were above (better than) span/200.
- Based on the BRE studies and guidance:
  - All span-deflection ratios calculated are above (better than) that considered by BRE to indicate / raise concerns over structural integrity.
  - Re-inspection of condition and re-assessment of deflections is advised at five-yearly intervals, provided no deterioration in condition becomes apparent.
  - The building is almost 50-years old: the RAAC planks are likely reaching or have passed their intended design-life.

5.2 RECOMMENDATIONS

- Undertaking the **intrusive investigation** originally proposed is advised, in order to establish the risk of structural failure due to inadequate bearing length or inadequate provision of reinforcement at the plank bearings.
- Continued regular inspection of roof finishes and drainage outlets to identify and address defects and risks of water ingress.
- Considering the use of the building, height of the roof above persons below and, therefore, potential for serious harm should a structural failure occur, **WSP recommends**:

ANNUALLY	FIVE-YEARLY	AD-HOC
VISUAL INSPECTION to identify cracking, spalling or other signs of distress.	**REASSESSMENT OF DEFLECTIONS** likely adopting similar survey techniques	**VISUAL INSPECTION** following a significant water ingress event or heavy snowfall

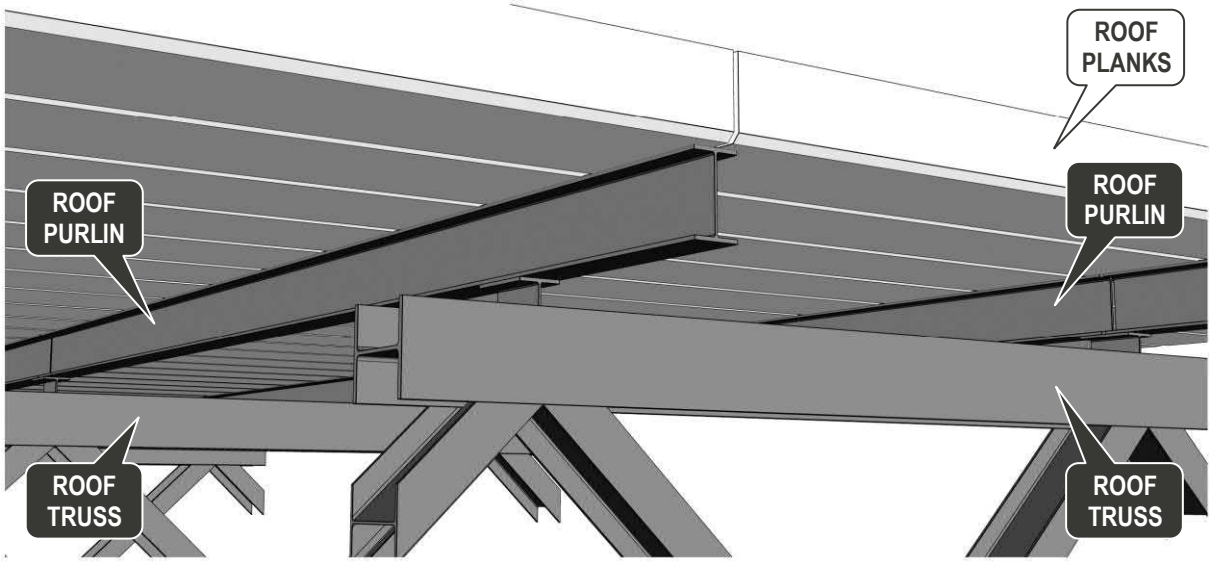
5.3 REMEDIAL WORKS

- Based on the results of this survey and review of BRE studies and guidance, remedial works are not considered necessary.
- However, in the absence of intrusive investigation to establish the provision of reinforcement at the plank bearings, the risk of failure cannot be ruled out. In addition, the planks may be nearing or have passed their intended design-life.
- Consideration should therefore be given to remedial works to enhance the plank support on the purlins / walls (unless intrusive investigation can demonstrate adequate bearing length and reinforcement), and / or eventual replacement of the planks.

6 REMEDIAL WORK OPTIONS

6.1 REMEDIAL WORKS

- To overcome the risk of failure at the support, it is proposed that additional steel framing is introduced to offer support at a distance – in the order of 100mm – away from the existing purlin.
- We outline and illustrate two methods to achieve this below.

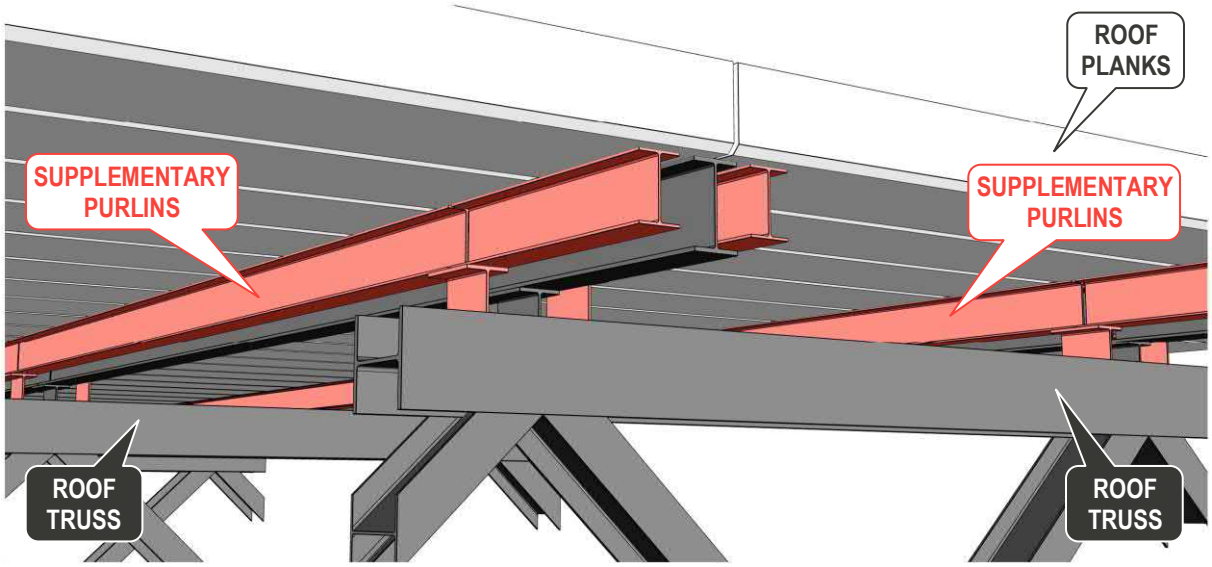


3D VIEW OF THE EXISTING ROOF PLANKS (UNDERSIDE) AND STRUCTURE

6.1.2. SUPPLEMENTARY STEEL PURLINS

- Install pairs of secondary purlins, parallel with and positioned astride of the existing purlins.
- The secondary purlins would need:
  - to be capable of supporting the roof loads (carried by the existing purlins) and span between trusses (5.25m, longer where they run diagonally and parallel with perimeter walls); we estimate pairs of 203x133x25 UB purlins would be required; each supplementary purlin would weight around 135kg.
  - bracketry to raise the purlins up to the underside of the planks and hold the purlins in position, likely attached to the existing purlins or top chord of the roof trusses;
  - offer at least 45mm bearing width to the planks (BRE guidance).
- Installation would likely require:
  - scaffolding erected within the auditorium to provide suitable working platforms; the height of the auditorium and extensive roof area will likely result in a substantial scaffold structure, or erection of scaffolding to part of the auditorium with allowance for its dismantling, relocation and re-erection in phases;
  - temporary removal of the waffle ceiling, mechanical and electrical services;
  - lifting apparatus to raise the supplementary purlins into position; this may be impeded by the scaffold working platforms.

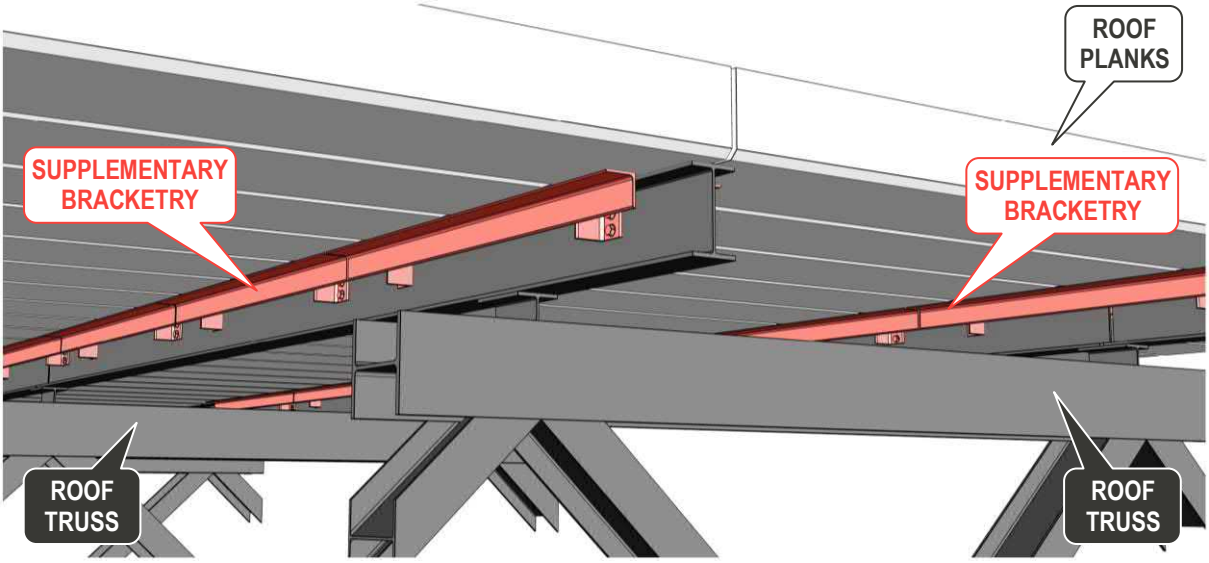
- If the ceiling, mechanical and electrical plant could be temporarily removed without scaffolding (i.e. dismantled within the roof space and lowered to the auditorium floor) then less extensive scaffolding may be possible, e.g. an elevated scaffold working platform constructed off and spanning between the roof trusses.



3D VIEW SHOWING THE PAIRS OF SUPPLEMENTARY PURLINS

6.1.3. SUPPLEMENTARY STEEL SUPPORT BRACKETRY

- The bracketry would provide the same additional support to the planks as the supplementary purlins outlined above. However, the bracket assembly would offer more favourable manual handling into position.
- We foresee the following arrangement:
  - a single bracket assembly would offer support to 3 adjacent planks; the bracket assemblies would be mounted in pairs, either side of the existing purlins; each assembly would weigh around 35kg;
  - angle-iron section around 1800mm long, to support the underside of the 3 planks;
  - 'stand-off' brackets bolted to the web (vertical face) of the existing purlin, positioning the angle-iron some 100mm to the side of the existing purlin; this would require bolted to be drilled through the web of the existing purlins.
- Installation would likely require:
  - scaffolding as outlined above;
  - temporary removal of the waffle ceiling, mechanical and electrical services; this could be more localised to reflect the improved handleability of the bracketry;
  - lifting apparatus to raise the bracketry to the roof space; this could be less onerous reflecting the weight of individual brackets and their handleability.



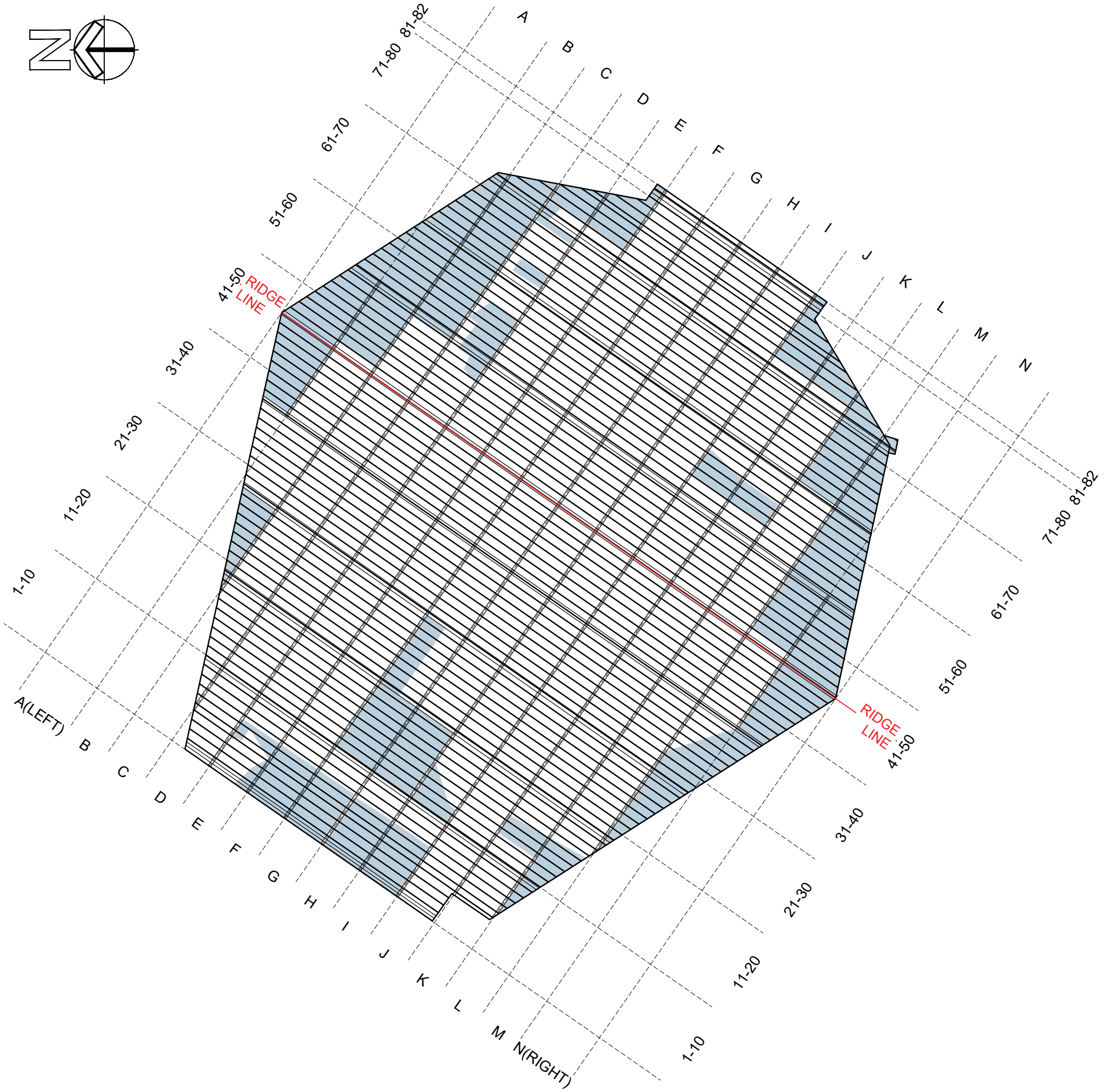
3D VIEW SHOWING THE BRACKETRY BOLTED IN PAIRS TO THE EXISTING PURLINS

6.2 REPLACEMENT

- Like-for-like replacement is not considered feasible or desirable: RAAC planks are no longer in general production and their inherent shortcomings (outlined in this report) remain.
- Normal weight reinforced concrete planks are likely to exceed the load capacity of the existing roof trusses.
- It seems reasonable to conclude that a built-up profiled metal deck roof system – typical of modern building construction – is the only viable option.
  - this will likely require lightweight cold-formed steel purlins to be introduced between (and bolted to) the existing purlins to support the new roof deck;
  - the built-up system would include thermal / acoustic insulation; input from an acoustician may be required to establish whether additional acoustic measures are required to replicate the existing acoustics as far as practicable.
- Roof replacement would likely require:
  - erection of a substantial scaffold enclosure to ensure the weathertightness of the building whist the roof covering is removed and replaced;
  - siting of a crane to lift construction materials to / from roof level; it would seem reasonable to assume that the crane would need to be sited in The Hayes / Hills Street unless the rear loading bay area (over St David's Shopping Centre) has adequate load capacity.
- Roof replacement presents opportunities to enhance the environmental credentials of the building, e.g. roof-mounted PV panels, 'green roof', replacement of ventilation equipment.

APPENDIX A

DEFLECTION SURVEY RESULTS



BLUE SHADED AREAS =	LIMITED POINT CLOUD DATA (DUE TO OBSTRUCTIONS OR POOR LINE-OF-SIGHT OF THE LASER SCANNER APPARATUS)

SURVEYED LEVELS (UNDERSIDE OF ROOF PLANKS)

LEVELS COLOURED RED HAVE BEEN ADJUSTED TO CORRECT ERRORS NOTED DURING VALIDATION BY WSP (e.g. TO CORRECT MANUAL INPUT ERRORS)

PLANK - NO DATA DATA FOR 618 OF 923 PLANKS = 67%

	A			B			C			D			E			F			G			H			I			J			K			L			M			N			
	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT		
82																																										82
81																									53.060	53.058	53.054																81
80																53.118	53.119	53.119	53.117	53.117	53.117	53.119	53.118	53.117	53.115	53.111	53.109																80
79																53.174	53.173	53.172							53.167	53.165	53.164																79
78																53.225	53.224	53.225	53.227	53.228	53.229	53.229	53.226	53.225	53.224	53.222	53.219																78
77																53.267	53.266	53.267	53.269	53.268	53.268	53.266	53.266	53.267	53.266	53.267	53.269																77
76																53.306	53.309	53.310	53.310	53.306	53.308	53.310	53.307	53.306	53.305	53.304	53.301																76
75																53.360	53.360	53.361	53.363	53.363	53.363	53.359	53.359	53.359	53.357	53.355	53.354																75
74																53.416	53.414	53.417	53.419	53.420	53.418	53.418	53.418	53.417	53.415	53.412	53.410																74
73										53.450	53.456	53.465	53.466	53.467	53.468	53.470	53.470	53.472	53.473	53.475	53.477	53.468	53.468	53.470	53.470	53.468	53.465	53.470	53.459	53.456	53.456	53.446	53.437								73
72										53.515	53.518	53.522																														72
71													53.579	53.578	53.576	53.578	53.579	53.581	53.584	53.583	53.584	53.585	53.584	53.583	53.582	53.579	53.576	53.578	53.575	53.570												71
70										53.627	53.626	53.627	53.631	53.632	53.635	53.635	53.635	53.636	53.640	53.637	53.639	53.638	53.638	53.637	53.637	53.636	53.635	53.635	53.627	53.621	53.620	53.619	53.617								70
69										53.678	53.682	53.689	53.691	53.690	53.692	53.692	53.689	53.694	53.694	53.692	53.694	53.693	53.693	53.693	53.694	53.692	53.691	53.694	53.686	53.681	53.681	53.678	53.674								69
68										53.746	53.747	53.748	53.747	53.748	53.750	53.752	53.750	53.751	53.753	53.750	53.750	53.750	53.748	53.752	53.752	53.748	53.747	53.745	53.743	53.740											68
67										53.798	53.799	53.803	53.805	53.805	53.807	53.810	53.806	53.809	53.807	53.809	53.810	53.810	53.809	53.809	53.809	53.804	53.803	53.804	53.807	53.796	53.795	53.793	53.791								67
66										53.855	53.860	53.862	53.864	53.863	53.864	53.865	53.866	53.867	53.867	53.865	53.865	53.867	53.867	53.867	53.864	53.862	53.864	53.865	53.861	53.859	53.858	53.855	53.852								66
65										53.913	53.915	53.918	53.920	53.921	53.925	53.924	53.923	53.924	53.924	53.926	53.928	53.927	53.925	53.927	53.925	53.920	53.921	53.923	53.918	53.917	53.918	53.914	53.911								65
64										53.974	53.975	53.980	53.982	53.983	53.983	53.982	53.982	53.982	53.982	53.981	53.980	53.983	53.983	53.983	53.982	53.979	53.979	53.981	53.978	53.978	53.980	53.975	53.970								64
63										54.031	54.031	54.038	54.042	54.038	54.039	54.038	54.039	54.040	54.039	54.037	54.036	54.035	54.037	54.038	54.037	54.035	54.033	54.035	54.036	54.037	54.032	54.028	54.024	54.030	54.028	54.026					63
62										54.088	54.090	54.092	54.093	54.094	54.095	54.096	54.092	54.089	54.094	54.095	54.095	54.097	54.097	54.098	54.095	54.091	54.089	54.091	54.092	54.093	54.092	54.086	54.083	54.083	54.079	54.077					62
61										54.145	54.147	54.150	54.154	54.151	54.151	54.148	54.148	54.148	54.150	54.150	54.152	54.153	54.152	54.152	54.149	54.148	54.147				54.149	54.147	54.144	54.144	54.138	54.136					61
60										54.206	54.209	54.211	54.214	54.212	54.210	54.210	54.209	54.208							54.205	54.206	54.206															60
59										54.262	54.265	54.269	54.272	54.270	54.269	54.267	54.268	54.269	54.268	54.270	54.271	54.257	54.262	54.266	54.266	54.265	54.265															59
58													54.327	54.328	54.327	54.325	54.326	54.328	54.330	54.325	54.320	54.322	54.323	54.322	54.322	54.321	54.321															58
57										54.383	54.384	54.384	54.384	54.384	54.383	54.381	54.382	54.385	54.387	54.384	54.379	54.381	54.382	54.383	54.382	54.380	54.386	54.387	54.386	54.385	54.382	54.379	54.376								57
56										54.449	54.446	54.444	54.444	54.446	54.445	54.445	54.444	54.445	54.445	54.442	54.438	54.441	54.440	54.445	54.440	54.439	54.438	54.441	54.438	54.439	54.438	54.437	54.436	54.438	54.436	54.435					56
55																																										55
54										54.559	54.559	54.559	54.559	54.560	54.563	54.566	54.565	54.564	54.565	54.566	54.566	54.565	54.558	54.556	54.554	54.554	54.555	54.555	54.554	54.554	54.559	54.558	54.557	54.557	54.554	54.552	54.551	54.550	54.549				54
53										54.615	54.614	54.614	54.614	54.615	54.618	54.621	54.618	54.614	54.616	54.622	54.622	54.623	54.618	54.616	54.615	54.613	54.615	54.614	54.613	54.615							54.610	54.608	54.609				53
52										54.674	54.671	54.671	54.670	54.673	54.675				54.676	54.676	54.677	54.678	54.679	54.678	54.676	54.674	54.671	54.673	54.673	54.673	54.672	54.669	54.671	54.670	54.666	54.664	54.664	54.664	54.664				52
51													54.726	54.730	54.735	54.732	54.730	54.731	54.735	54.733	54.732	54.734	54.730	54.732	54.733	54.732	54.731				54.728	54.727	54.728	54.727	54.722	54.719	54.718	54.715	54.720				51
50										54.785	54.785	54.784	54.784	54.787	54.790	54.788	54.789	54.790							54.788	54.785	54.784	54.786	54.785	54.784	54.784	54.784	54.785	54.785	54.781	54.778	54.778	54.776	54.775				50
49													54.844	54.842	54.844	54.852	54.849	54.850				54.844	54.844	54.846	54.837	54.840	54.840	54.841	54.840	54.842	54.841	54.840	54.843	54.842	54.839	54.835							49
48													54.902	54.897	54.901	54.903	54.905	54.904	54.903	54.905	54.907	54.906	54.899	54.892	54.899	54.898	54.897	54.898	54.897	54.896	54.900	54.899	54.898	54.902	54.895	54.892	54.893	54.892	54.891				48
47	RIDGE			54.964	54.965	54.966							54.969	54.969	54.970	54.966	54.964	54.965	54.966	54.966	54.967	54.968	54.968	54.960	54.961	54.959	54.958	54.958	54.959	54.960	54.963	54.964	54.964	54.965	54.959	54.956	54.958	54.954	54.953	54.952	54.950	54.949	RIDGE	47
46	LINE			54.932	54.933	54.934	54.935	54.934	54.937	54.935	54.936	54.938	54.936	54.932	54.939	54.937	54.939	54.942	54.941	54.940	54.936	54.943	54.943	54.942	54.935	54.934	54.936	54.941	54.942	54.940	54.941	54.939	54.935	54.932	54.928	54.929	54.929	54.928	54.927	LINE			46
45				54.832	54.833	54.834	54.834	54.834	54.832	54.828	54.829	54.832	54.835	54.836	54.835	54.837	54.836	54.841	54.842	54.844	54.845	54.844	54.837	54.837	54.835	54.835	54.835	54.840	54.839	54.837	54.837	54.834	54.835	54.830	54.831	54.832	54.830	54.829	54.828				45
44				54.734	54.735	54.737	54.738	54.739	54.740	54.741	54.738	54.738	54.736	54.734	54.735	54.735	54.737	54.740	54.741	54.741	54.740	54.741	54.738	54.733	54.732	54.733	54.733	54.738	54.738	54.735	54.736	54.737	54.737	54.738	54.738	54.739	54.734	54.731	54.728				44
43				54.636	54.635	54.638	54.638	54.638	54.640	54.637	54.634	54.635	54.642	54.636	54.638	54.639	54.641	54.643	54.638	54.638	54.638	54.640	54.639	54.638	54.639	54.635	54.633	54.641	54.638	54.636				54.633	54.632	54.631	54.634	54.634	54.633				43
42				54.535	54.535	54.535	54.538	54.536	54.537	54.536	54.534	54.537	54.538	54.535	54.536	54.538	54.534	54.537	54.536	54.538	54.540	54.542	54.537	54.534	54.532	54.533	54.535	54.535	54.535	54.536	54.536	54.534	54.532	54.532	54.529	54.530	54.530	54.528	54.527				42
41				54.433	54.435	54.436	54.436	54.435	54.435	54.434	54.435	54.437	54.438	54.433	54.432	54.435	54.437	54.438	54.438	54.438	54.438	54.439	54.439	54.439	54.440	54.435	54.433	54.435	54.434	54.433	54.434	54.430	54.428	54.428	54.428	54.430	54.431	54.429	54.427				41
40				54.333	54.335	54.335				54.332	54.334	54.335	54.337	54.336	54.338				54.342	54.340	54.338	54.339	54.339	54.339	54.336	54.335	54.334	54.337	54.333	54.331	54.332	54.331	54.330	54.332	54.333	54.334	54.335	54.331	54.328				40
39				54.236	54.236	54.241				54.239	54.237	54.242	54.241	54.242	54.244				54.244	54.243	54.240	54.241	54.240	54.241	54.239	54.237	54.236	54.238	54.237	54.236	54.234	54.235	54.246	54.235	54.234	54.234	54.234	54.234	54.232				39
38				54.135	54.136	54.138	54.140	54.138	54.140	54.140	54.142	54.145	54.147	54.146	54.148	54.146	54.144	54.144	54.145	54.142	54.140	54.141	54.139	54.139	54.140	54.143	54.144	54.141	54.140	54.139	54.136	54.136	54.137	54.136	54.137	54.138	54.136	54.134	54.133				38
37				54.032	54.037	54.040	54.040	54.040	54.038	54.037	54.041	54.047	54.051	54.049	54.047	54.047	54.044	54.046	54.045	54.044	54.043	54.043	54.039	54.041	54.042	54.040	54.043	54.041	54.039	54.037	54.039	54.039	54.040	54.041	54.040	54.039							37
36				53.928	53.931	53.938	53.941	53.941	53.941	53.937	53.941	53.947	53.949	53.947	53.947	53.950	53.946	53.947	53.947	53.947	53.948	53.947	53.946	53.945	53.946	53.945	53.946	53.946	53.941	53.943	53.940	53.938	53.938	53.940	53.939	53.939							36
35				53.830	53.833	53.835	53.839	53.845	53.850	53.838	53.837	53.845	53.851	53.845	53.850	53.852	53.846	53.851	53.851	53.850	53.848	53.849	53.847	53.848	53.849	53.845	53.849	53.850	53.842	53.841	53.841	53.841	53.842	53.839	53.837	53.835							35
34				53.728	53.730	53.732	53.734	53.735	53.741	53.741	53.745	53.750	53.752	53.750	53.750	53.750	53.750	53.752	53.748	53.748	53.749	53.752	53.750	53.749	53.749	53.748	53.750	53.750	53.742	53.739	53.740	53.742	53.745	53.743	53.742	53.740							34
33				53.628	53.629	53.635	53.639	53.640	53.645	53.644	53.648	53.651	53.653	53.648	53.653	53.654	53.654	53.657	53.652	53.652	53.652	53.656	53.654	53.652	53.653	53.652	53.654	53.655	53.645	53.643	53.645	53.643	53.644	53.646	53.645	53.643							33
32				53.529	53.534	53.541	53.543	53.545	53.550	53.551	53.549	53.553	53.556	53.551	53.557	53.560	53.559	53.563	53.564	53.560	53.558	53.560	53.558	53.557	53.555	53.554	53.556	53.558	53.546	53.541	53.544	53.545	53.550	53.552	53.550	53.545							32
31				53.434	53.436	53.440	53.442	53.446	53.451	53.452	53.458	53.459	53.461	53.458	53.468	53.469	53.467	53.466	53.465	53.464	53.462	53.462	53.460	53.459	53.461	53.460	53.460	53.464	53.453	53.450	53.450	53.449	53.450	53.454	53.459	53.443							31
30				53.334	53.339	53.344	53.346	53.347	53.356	53.355	53.358	53.364	53.365	53.360	53.367	53.368	53.370	53.374	53.369	53.368	53.368	53.370	53.368	53.369	53.365	53.366	53.369	53.370	53.363	53.356	53.355	53.352	53.350	53.352	53.348	53.344							30
29				53.234	53.241	53.245	53.247	53.250	53.259	53.261	53.264	53.266	53.268	53.274	53.276	53.278	53.275	53.278	53.275	53.274	53.273	53.275	53.272	53.269	53.270	53.269	53.271	53.272	53.265	53.260	53.260	53.256	53.254	53.263	53.259	53.248							29
28							53.138	53.142	53.148	53.150	53.153	53.159	53.160	53.162	53.170	53.173	53.169	53.172	53.170	53.168	53.169	53.169	53.168	53.167	53.166	53.164	53.164	53.165	53.160	53.158	53.155	53.146	53.149	53.148	53.139	53.137							28
27							53.046	53.052	53.061	53.060	53.060	53.067	53.070	53.069	53.078	53.080	53.078	53.083	53.080	53.079	53.079	53.079	53.079	53.080	53.079	53.075	53.074	53.075	53.070	53.070	53.065	53.062	53.060	53.064	53.048	53.046							27
26							52.950	52.958	52.970	52.969	52.970	52.975	52.968	52.975	52.985	52.986	52.988	52.991	52.990	52.990	52.990	52.992	52.990	52.989	52.983	52.983	52.985	52.988	52.980	52.976	52.975	52.966	52.959	52.957	52.955	52.954							26
25							52.840	52.853	52.859	52.863	52.857	52.871	52.877	52.879	52.880	52.882	52.883	52.885	52.885	52.884	52.885	52.886	52.885	52.885	52.884	52.882	52.880	52.885	52.880	52.870	52.870	52.862	52.856	52.857	52.852	52.847							25
24							52.743	52.749	52.762	52.763	52.764	52.772	52.782	52.774	52.784	52.785	52.788	52.792	52.790	52.789	52.790	52.791	52.790	52.791	52.788	52.780	52.780	52.784	52.778	52.773	52.770	52.764	52.760	52.761	52.753	52.749							24
23							52.645	52.652	52.664	52.665	52.669	52.682	52.680	52.679	52.684	52.688	52.690	52.695	52.693	52.691	52.692	52.693	52.694	52.696	52.690	52.686	52.681	52.682	52.680	52.680	52.675	52.667	52.664	52.662	52.656	52.651							23
22							52.546	52.552	52.565	52.565	52.569	52.584	52.583	52.578	52.589	52.592	52.594	52.600	52.597	52.597	52.597	52.598	52.599	52.600	52.600	52.593	52.588	52.588	52.587	52.586	52.584	52.571	52.566	52.564	52.559	52.553							22
21							52.446	52.452	52.462	52.463	52.470	52.478	52.485	52.482	52.489	52.490	52.493	52.496	52.496	52.497	52.498	52.498	52.500	52.501	52.501	52.497	52.495	52.498	52.489	52.485	52.483	52.475	52.471	52.468	52.457	52.450							21
20							52.343	52.350	52.363	52.362	52.370	52.376	52.378	52.379	52.389	52.391	52.393	52.396	52.396	52.397	52.398	52.399	52.399	52.400	52.402	52.396	52.394	52.393	52.390	52.382	52.382	52.374	52.368	52.363	52.354	52.348							20
19							52.244	52.254	52.265	52.266	52.271	52.281	52.282	52.285	52.290	52.294	52.297	52.303							52.303	52.299	52.297	52.300	52.294	52.285	52.285	52.276	52.269	52.266	52.256	52.247							19
18							52.143	52.149	52.163	52.164	52.170	52.180	52.192	52.195	52.200	52.196	52.198	52.202							52.208	52.203	52.202	52.203	52.193	52.184	52.186	52.175	52.170	52.169	52.153	52.142							18
17							52.039	52.048	52.063	52.062	52.069	52.077	52.082	52.086	52.091	52.093	52.094	52.095							52.102	52.096	52.098	52.100	52.090	52.086	52.084	52.070	52.064	52.063	52.048	52.035							17
16							51.943	51.945	51.955	51.960	51.963	51.970	51.985	51.987	51.990	51.992	51.995	51.998							52.009	52.003	51.997	51.997	51.989	51.989	51.989	51.968	51.964	51.963	51.948	51.938							16
15							51.856	51.864	51.875	51.876	51.883	51.890	51.893	51.901	51.912	51.911	51.913	51.915							51.920	51.917	51.915	51.914	51.908	51.902													15
14							51.746	51.746	51.755	51.759	51.770	51.776	51.777	51.787	51.797	51.796	51.799	51.801										51.796	51.792	51.783												14
13							51.648	51.648	51.660	51.659	51.670	51.677	51.680	51.687	51.696	51.695	51.699	51.704										51.697	51.687	51.684												13
12							51.549	51.549	51.563	51.565	51.573	51.584	51.583	51.590	51.595	51.596	51.602	51.607										51.594	51.592	51.590	51.589	51.575	51.568										12
11							51.456	51.456	51.462	51.461	51.469	51.474	51.490	51.492	51.502	51.503	51.506	51.514													51.490	51.479	51.473										11
10										51.368	51.381	51.390																														10
9										51.257	51.272	51.283	51.288	51.292	51.299	51.300	51.302	51.307	51.310	51.313	51.317	51.319	51.315	51.319	51.316	51.307	51.302	51.305	51.295	51.283	51.285	51.272	51.268								9
8										51.166	51.171	51.178	51.184	51.188	51.195	51.197	51.197	51.201	51.210	51.214	51.215	51.214	51.212	51.214	51.215	51.214	51.210	51.209	51.187	51.185	51.184	51.167	51.163								8
7										51.061	51.075	51.084	51.092	51.102	51.114													51.109	51.094	51.086	51.085	51.071	51.065								7
6										50.968	50.975	50.983	50.990	50.992	50.994													50.998	50.997	50.990	50.986	50.972	50.961								6
5										50.881	50.889	50.895	50.899	50.906	50.908													50.916	50.910	50.904	50.905	50.891	50.877								5
4										50.795	50.798	50.810	50.813	50.820	50.822													50.830	50.826	50.820											4
3										50.698	50.702	50.714	50.715	50.722	50.724													50.740	50.729	50.725											3
2										50.600	50.604	50.616	50.615	50.620	50.625													50.644	50.630	50.623											2
1										50.516	50.522	50.534	50.534	50.537	50.540													50.538	50.537	50.537											1
	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT	LEFT	CENTRE	RIGHT		
	A			B			C			D			E			F			G			H			I			J			K			L			M			N		

MEASURED PLANK SPANS

PLANK - NO DATA

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	
82															82
81									3.000						81
80						3.000	3.000	3.000	3.000						80
79						3.000			3.000						79
78						3.000	3.000	3.000	3.000						78
77						3.000	3.000	3.000	3.000						77
76						3.000	3.000	3.000	3.000						76
75						3.000	3.000	3.000	3.000						75
74						3.000	3.000	3.000	3.000						74
73				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000				73
72				3.000											72
71					3.000	3.000	3.000	3.000	3.000	3.000					71
70				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000				70
69				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000				69
68				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000				68
67				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000				67
66				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000				66
65				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000				65
64				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000				64
63				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			63
62				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			62
61				3.000	3.000	3.000	3.000	3.000	3.000		3.000	3.000			61
60				3.000	3.000	3.000			3.000						60
59				3.000	3.000	3.000	3.000	3.000	3.000						59
58					3.000	3.000	3.000	3.000	3.000						58
57				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000				57
56				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			56
55															55
54			3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			54
53			3.000	3.000	3.000	3.000	3.000	3.000	3.000			3.000			53
52			3.000	3.000		3.000	3.000	3.000	3.000	3.000	3.000	3.000			52
51				3.000	3.000	3.000	3.000	3.000		3.000	3.000	3.000			51
50			3.000	3.000	3.000			3.000	3.000	3.000	3.000	3.000			50
49				3.000	3.000		3.000	3.000	3.000	3.000	3.000				49
48				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			48
47	RIDGE	3.000		3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	RIDGE	47
46	LINE	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	LINE	46
45		3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000		45
44		3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000		44
43		3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000		3.000	3.000		43
42		3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000		42
41		3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000		41
40		3.000		3.000	3.000		3.000	3.000	3.000	3.000	3.000	3.000	3.000		40
39		3.000		3.000	3.000		3.000	3.000	3.000	3.000	3.000	3.000	3.000		39
38		3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000		38
37		4.809	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			37
36		4.567	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			36
35		4.325	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			35
34		4.083	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			34
33		3.842	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			33
32		3.600	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			32
31		3.359	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			31
30		3.117	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			30
29		2.872	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			29
28			3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			28
27			3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			27
26			3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			26
25			3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			25
24			3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			24
23			3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			23
22			3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			22
21			3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			21
20			3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000			20
19			3.000	3.000	3.000	3.000			3.000	3.000	3.000	3.000			19
18			3.000	3.000	3.000	3.000			3.000	3.000	3.000	3.000			18
17			3.000	3.000	3.000	3.000			3.000	3.000	3.000	3.000			17
16			2.702	3.000	3.000	3.000			3.000	3.000	3.000	3.000			16
15			2.460	3.000	3.000	3.000			3.000	3.000					15
14			2.215	3.000	3.000	3.000				3.000					14
13			1.971	3.000	3.000	3.000				3.000					13
12			1.729	3.000	3.000	3.000				3.000	3.000				12
11			1.492	3.000	3.000	3.000					3.000				11
10				3.000											10
9				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000				9
8				3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000				8
7				3.000	3.000					3.000	3.000				7
6				3.000	3.000					3.000	3.000				6
5				3.000	3.000					3.000	3.000				5
4				2.842	3.000					3.000					4
3				2.599	3.000					3.000					3
2				2.355	3.000					3.000					2
1				2.092	3.000					3.000					1
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	

CALCULATED MID-SPAN PLANK DEFLECTIONS

< 3mm | 3mm ~ 6mm | 6mm ~ 9mm | > 9mm | PLANK - NO DATA

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	
82															82
81									0.001						81
80						0.001	0.001	0.001	0.001						80
79						0.001			0.001						79
78						0.001	0.001	0.001	0.001						78
77						0.001	0.001	0.001	0.000						77
76						0.001	0.003	0.001	0.001						76
75						0.001	0.001	0.001	0.001						75
74						0.002	0.002	0.000	0.000						74
73				0.002	0.001	0.001	0.001	0.001	0.001	0.004	0.001				73
72				0.001											72
71					0.001	0.001	0.001	0.001	0.001	0.001					71
70				0.001	0.001	0.001	0.002	0.000	0.001	0.001	0.001				70
69				0.001	0.002	0.004	0.002	0.001	0.001	0.002	0.001				69
68				0.001	0.001	0.002	0.002	0.003	0.002	0.001	0.001				68
67				0.002	0.001	0.004	0.000	0.001	0.002	0.007	0.001				67
66				0.002	0.001	0.001	0.001	0.001	0.002	0.001	0.001				66
65				0.000	0.002	0.001	0.001	0.002	0.003	0.002	0.001				65
64				0.002	0.000	0.001	0.001	0.001	0.002	0.002	0.001				64
63				0.003	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001			63
62				0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.002	0.001			62
61				0.001	0.002	0.001	0.001	0.001	0.001		0.000	0.002			61
60				0.001	0.001	0.001			0.001						60
59				0.001	0.000	0.001	0.001	0.001	0.001						59
58					0.001	0.001	0.001	0.001	0.001						58
57				0.001	0.001	0.001	0.001	0.001	0.004	0.001	0.001				57
56				0.001	0.001	0.001	0.000	0.003	0.001	0.002	0.001	0.001			56
55															55
54			0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001			54
53			0.001	0.001	0.001	0.003	0.002	0.002	0.002			0.002			53
52			0.002	0.001		0.001	0.001	0.000	0.001	0.002	0.001	0.001			52
51				0.001	0.002	0.001	0.003	0.001		0.001	0.001	0.004			51
50			0.001	0.001	0.001			0.001	0.001	0.000	0.000	0.000			50
49				0.002	0.002		0.001	0.002	0.001	0.002	0.001				49
48				0.005	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.001			48
47	RIDGE	0.001		0.000	0.002	0.000	0.004	0.000	0.001	0.001	0.002	0.002	0.000	RIDGE	47
46	LINE	0.001	0.002	0.001	0.005	0.000	0.001	0.001	0.002	0.002	0.001	0.003	0.001	LINE	46
45		0.001	0.001	0.001	0.001	0.003	0.001	0.004	0.001	0.000	0.002	0.001	0.001		45
44		0.001	0.001	0.002	0.002	0.000	0.001	0.001	0.000	0.002	0.001	0.001	0.001		44
43		0.002	0.001	0.002	0.004	0.001	0.001	0.001	0.001	0.001		0.001	0.001		43
42		0.001	0.001	0.003	0.002	0.003	0.001	0.001	0.000	0.001	0.001	0.002	0.001		42
41		0.001	0.001	0.000	0.002	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001		41
40		0.001		0.001	0.002		0.001	0.001	0.001	0.001	0.001	0.001	0.001		40
39		0.003		0.003	0.001		0.001	0.001	0.000	0.001	0.005	0.000	0.001		39
38		0.000	0.002	0.000	0.002	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.001		38
37		0.001	0.001	0.001	0.001	0.002	0.001	0.003	0.003	0.001	0.001	0.001			37
36		0.002	0.001	0.001	0.001	0.003	0.001	0.001	0.001	0.003	0.001	0.000			36
35		0.001	0.001	0.004	0.005	0.006	0.001	0.002	0.004	0.004	0.000	0.001			35
34		0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.003	0.001	0.000			34
33		0.003	0.002	0.001	0.005	0.002	0.001	0.001	0.002	0.004	0.002	0.001			33
32		0.001	0.001	0.003	0.005	0.003	0.001	0.001	0.001	0.003	0.002	0.001			32
31		0.001	0.001	0.002	0.007	0.001	0.000	0.001	0.000	0.004	0.001	0.011			31
30		0.001	0.004	0.002	0.006	0.001	0.000	0.002	0.001	0.001	0.001	0.001			30
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12			0.007	0.002	0.001	0.000				0.001	0.003				12
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10				0.002											10
9				0.002	0.001	0.002	0.001	0.004	0.002	0.001	0.005				9
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1				0.003	0.001					0.000					1
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	

CALCULATED SPAN-DEFLECTION RATIOS

< SPAN / 100 | SPAN / 100 ~ SPAN / 200 | > SPAN / 200 | PLANK - NO DATA

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	
82															82
81									3000						81
80						5999	3000	3000	2999						80
79						3000			5999						79
78						2999	3000	2999	5999						78
77						2999	5999	5999	6000						77
76						3000	999	3000	2999						76
75						5999	3000	3000	5999						75
74						1200	1999	6000	6000						74
73				1999	3000	2999	3000	3000	5999	750	5999				73
72				5999											72
71					5999	5999	2999	3000	3000	2999					71
70				2999	3000	5999	1200	6000	3000	3000	5999				70
69				2000	1999	750	1499	3000	5999	1999	5999				69
68				3000	5999	1999	1999	999	1999	5999	3000				68
67				1999	3000	857	6000	5999	1500	428	3000				67
66				1999	3000	3000	3000	3000	1500	2999	3000				66
65				6000	1999	3000	3000	1499	999	1499	5999				65
64				1500	6000	3000	3000	3000	1999	1999	3000				64
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55															55
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53			5999	3000	5999	999	1999	1499	1999			1999			53
52			1999	5999		5999	2999	6000	3000	1200	2999	3000			52
51				5999	1999	5999	999	3000		2999	3000	750			51
50			5999	3000	3000			2999	3000	6000	6000	6000			50
49				1499	1499		3000	1999	2000	1500	5999				49
48				666	1999	3000	3000	3000	3000	3000	1499	3000			48
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42		3000	2000	1199	1499	857	3000	3000	6000	5999	3000	1500	5999		42
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38		6000	1499	6000	1999	3000	6000	3000	2999	3000	6000	3000	5999		38
37		4809	3000	2999	3000	1200	3000	999	1199	3000	5999	3000			37
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35		8649	5999	666	545	545	5999	1999	750	857	6000	3000			35
34		4083	1200	5999	2999	2999	5999	5999	1999	1199	5999	6000			34
33		1536	1499	5999	600	1999	3000	3000	1999	750	1999	5999			33
32		3600	2000	999	545	1199	3000	5999	2000	857	1500	2000			32
31		3359	5999	1200	461	5999	6000	5999	6000	750	2999	285			31
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27			1999	857	600	857	6000	6000	2000	1199	5999	428			27
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25			857	299	6000	6000	3000	5999	3000	1199	3000	3000			25
24			857	857	333	5999	3000	3000	750	5999	3000	1499			24
23			1200	666	999	1999	2000	6000	5999	3000	1200	5999			23
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21			1499	5999	600	3000	3000	5999	3000	1199	1500	1499			21
20			999	3000	666	5999	3000	5999	1500	1200	3000	1999			20
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14			492	1199	3000	6000				1200					14
13			328	1499	2999	5999				857					13
12			247	1999	2999	6000				3000	857				12
11			497	1999	749	1200					1200				11
10				1500											10
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4				631	1200					3000					4
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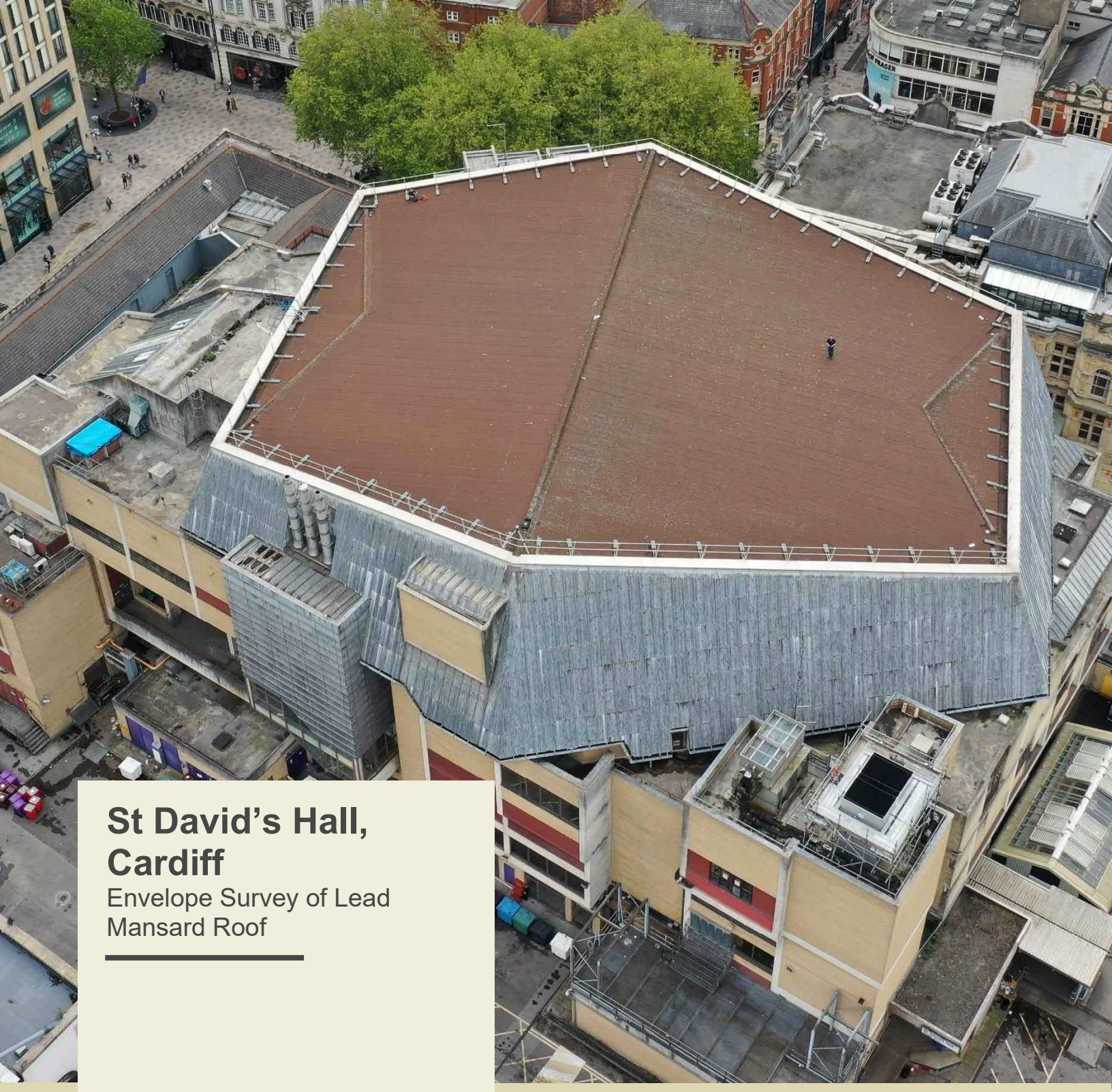
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	

1 Capital Quarter
Tyndall Street
Cardiff
CF10 4BZ

wsp.com

REPORT 4
LEAD-SHEET MANSARD ROOF SURVEY



St David's Hall, Cardiff

Envelope Survey of Lead Mansard Roof

JULY 5 2021

TALIESIN CONSERVATION

Authored by: [redacted]

MSc WSA Sustainable Building Conservation

TALIESIN CONSERVATION

TABLE OF CONTENTS

1.0 GENERAL

1.1 TERMS OF ENGAGEMENT:

As per email by [redacted] 23rd January 2021 our brief is to survey and report on the condition of the lead covering to the mansard roof at St David's Hall, Cardiff. This was followed up by a Purchase Order issued 22nd March 2021 (PO No 4501657271).

Our brief is to try and understand how the lead covering to the mansard roof has failed/deteriorated in various locations across the mansard roof. To assist in trying to determine possible contributory causes we have welcomed the opportunity to review a copy to 4257 - CBLD - ST DAVIDS HALL REROOFING WORKS PHASE 1 (copy appended), which has proved useful and informative.

The survey was carried out by UAVs (drones) equipped with a Hasselblad 35mm equivalent 20mp, 1" sensor, 4k UHD camera and a 35mm equivalent (24mm) camera with a 12mp 1/2.3" CMOS sensor. The aerial survey was tied into the Ordnance Survey National Grid and Datum using an EMLID Reach GN55/ Glonass (GPS) Receiver and data logger with a <20mm tolerance. All 3D models were produced using proprietary photogrammetry software and aligned using known ground control points (GCPs). Dimensional control was then be applied to each model and then reprocessed using the new parameters and optimised cameras to create dense point clouds and high face count meshes. All high-resolution orthographic renders (orthomosaics) were exported and scaled in raster (TIFF) format.

The mansard roof survey created a dense point cloud of 92,870729 million points and high face count textured meshes (8192x8192 pixels) exported to OBJ format with a mean RMS error of 0.13cm. The Ground Sampling Distance (GSD) achieved was a great 0.97cm/pixel. Seven GCPs were used with a sub-20mm error margin to OSGB36 (National Grid).

From the images and detail collated, the objective is to gather the information needed to diagnose defects, consider potential ways forward and in doing so, provide budget costs.

1.2 ADDRESS OF PROPERTY SURVEYED:

St David's Hall
9-11 The Hayes
St David's Centre
Cardiff
CF10 1AH

1.3 CLIENT:

[redacted] – [redacted]
Cardiff Council
County Hall
Atlantic Wharf
Cardiff
CF10 4UW

1.4 SURVEY TEAM LED BY:

[redacted]
MCIOB MSc WSA Sustainable Building Conservation

1.5 DATE OF SURVEY:

This survey was carried out over one day – 31/05/2021

1.6 WEATHER CONDITIONS AT THE TIME OF SURVEY:

The weather conditions at the time of the survey were dry with intermittent spells of rain.

1.7 CURRENT USE

The building is used as a performing arts and conference venue.

1.8 BUILDING DESCRIPTION & SIGNIFICANCE

St David's Hall, opened in 1982, is the National Concert Hall and Conference Centre of Wales. Public and political desire for a such a venue dated back to the 1950s. The hall took only five years from conception to completion.

Architects Seymour Harris Partnership had the task of fitting a major 2000 seat, acoustically perfect auditorium, with surrounding dressing rooms, bars, foyers, a restaurant, offices, and spacious concourse into a cramped city centre space.

St David's Hall is now the National Concert Hall and Conference Centre of Wales. It hosts the annual Welsh Proms, the International Orchestral Series and the biennial BBC Cardiff Singer of the World Competition. As well as classical music it also plays host to jazz, soul, pop, rock, dance, children's, r&b, musicals and other forms of world music, as well as light entertainment artists like Joan Collins. The foyers in the centre are open and have regular free performances from music groups. The foyers, balconies and bar areas are also used to host art exhibitions. It also has its own restaurant.

Fig.1 – St David's Hall during construction in August 1980. Source: WalesOnline

1.9 LIMITATIONS

A Non-intrusive survey undertaken by Drone (due to access/cost considerations Drone was the most practical and effective arrangement)

The photogrammetric survey area was located in Cardiff city centre on the corner of Working Street and Hill's Street at NGR ST 318396.065,176358.249.

St David's Hall is located within controlled Class D airspace (3000ft to FL105), Cardiff CTA 4. The photogrammetric (aerial) survey area was not positioned within restricted airspace. Restricted airspace within 10nm included Cardiff CTR (Surface to FL105) and Cardiff City Heliport and Cardiff University Hospital Heliport. Upper airspace included Cardiff CTA 4 (3000ft – FL105) and Cotswold CTA 12 (Class A 75-FL195FL).

A Non-Standard Flight (NSF) request was submitted to Civil Aviation Authority (CAA) on 23/02/21. The response received from Cardiff ATC confirmed the proposed flight had no restrictions.

2.0 FINDINGS AND OBSERVATIONS

Our survey has identified failures and deterioration of varying degrees across all elevations of the lead-covered mansard roof. The characteristics of lead sheet need to be considered when designing or renewing details – the considerations can be briefly summarised as corrosion, thermal movement and wind lift and weight. When correctly specified and installed lead roofing products can have a lifespan that can exceed 100 years, in some instances it has been documented to last over 200 years. As St David's Hall opened in August 1982, some 39 years ago, it is evident the lead covering has fallen significantly short of its anticipated lifespan. We believe this is due to inappropriate specification, as we will explain in detail below.

Corrosion:
Lead is one of the most in-corrodible metals. It is exceptionally resistant to town, country, and marine atmospheres and is resistant to any attack from most water supplies. Corrosion of lead can occur if it is in direct contact with timbers when they remain damp or are poorly seasoned. (Plumbers Handbook, 1950)

We understand from the report (*William Bordass Associates – Investigations carried out on 13 May 1996*) the makeup of the deck (*3 Construction of the Roof / Item 7*) is as follows: "15mm birch plywood panels with aluminium foil backing and Code 4 milled lead, factory pre-bonded to the outside with sprayed neoprene contact adhesive".

We have looked at the use of Neoprene as a spray adhesive for metal sheeting. As well as acting as an adherent, the Neoprene is moisture resistant. If correctly applied, it should prevent acetates leaching from the plywood panels - a possible cause of the corrosion evident to the underside of the lead. Neoprene is a polymer of Chloroprene and has chlorine in its' resin base. At high temperatures (circa 50^{o}C), Neoprene can become unstable and volatile, producing hydrogen chloride gas. (Allen and Allen, 1996)

Lead sheets on a roof can reach temperatures of 90^{o}C to 100^{o}C in direct sunlight, as advised by Lead Sheet Association. We would suggest, it is highly plausible that during spells of hot weather, the Neoprene has been subject to significant rises in temperature due to direct contact with the lead sheet, become unstable, and hydrogen chloride gas has been produced. Once the temperature drops, the gas, if it has no means of escape, will condense, and form hydrochloric acid (Ciullo and Haber, 2007). The hydrochloric acid will sit on top of the moisture impermeable neoprene adhesive and corrode the underside of the lead. When hydrochloric acid reacts with lead, it displaced the hydrogen and created lead chloride (Kirk, Othmer, Grayson and Eckroth, 1984). Lead chloride is an insoluble salt meaning it would not dissolve and would rather appear as a white residue (Meyers, 2004). This white

residue is highly visible in an image on Page 7 of William Bordass Associates Report – when investigations were carried out on 13 May 1996.

Thermal Movement:
The most common cause of failure with lead sheet roof coverings is “over fixing” which can prevent or inhibit thermal movement during changes in temperature.

Lead has a high coefficient of linear expansion, and when the difference between the winter and summer temperatures are considered, the expansion could increase the length of 2M sheet by +6mm. If thermal expansion and contraction cannot occur freely, there is a risk of distortion and stress, which in time will cause the lead to buckle and crack.

In St David’s Hall, the lead sheets are factory bonded to the plywood beneath. The plywood has a lower coefficient of linear expansion compared to lead, and as a result, the lead sheets are attempting to expand and contract at a different rate to the ply and cannot freely move. As the expansion and resultant contraction on cooling have not taken place freely, the lead sheets have been exposed to a concentration of alternating (fatigue) stress, which has caused the lead to fail and crack in areas. These areas are then exposed to wind lift.

Wind Lift and Weight:
In areas of the lead covered mansard roof, there is clear evidence of wind uplift. Wind uplift can occur when an air current has contact with the lead sheets. Once wind encounters a vertical surface (such as a wall), it will be forced upwards while simultaneously accelerating. This creates an area of negative pressure known as a “void”. If the wind is strong enough, such negative pressure can begin to lift the sheets from the underlying structure. Lead sheet edges are the most likely areas to be affected by wind uplift. Lead is a naturally heavy material and by its very nature has some protection against wind lift. However, the code of lead specified needs to be fit for purpose in relation to the function it is to perform and the location in which it is to be installed.

In this instance, the weight of the lead has contributed to wind lift. Historical records show that the existing covering is Code 4 lead, which is too thin and lightweight for its use according to the Lead Sheet Association guidelines. The Lead Sheet Association states, lead sheets used in this manner should be a minimum of code 6 or 7. To put this into perspective, code 7 is 3.15mm thick and weighs 35.72Kg/m2, whereas code 4 lead is 1.8mm thick and weighs 20.41Kg/m2 – almost half the recommended thickness and weight.

Conclusion:

In conclusion, it appears that numerous factors have, and are continuing to contribute to the failure of the lead covering. Briefly, these are: inappropriately specified substrate make-up to accommodate the lead sheet, the use of neoprene as a bonding agent and inappropriately specified lead coding.

There is an argument for a complete roof covering replacement, justification for which can be categorised as follows:

- **Health and safety considerations** – the risk of falling materials potentially causing injury or fatality
- **Sustainability of the current building structure** – the condition will continue to deteriorate if no action is taken. Holding repairs are likely to prove ineffective and costly.
- **Business interruption** – continuous ad hoc and isolated repairs could be detrimental to the day-to-day operation of the performing arts and conference venue and nearby retail outlets.
- **Economics** – Holding repairs are likely to prove ineffective and costly.

3.0 SUGGESTIONS

A new lead roof covering would have to be correctly specified to include the substrate makeup. The Lead Sheet Associated Guidelines and BS EN 12588 recommends code 6 or 7 lead depending on exposure. *Given the additional weight this would require structural engineer input to determine whether the structure can take the increased load*. Design and specification should make allowances for thermal expansion and follow the Lead Sheet Association Guidance noted above.

As opposed to reinstating a correctly detailed lead roof covering, the client may wish to consider terne-coated stainless steel covering or similar (subject to any approvals required). Fundamentally, it is cheaper and much lighter in weight.

Terne coated stainless steel refers to a sheet that has been given a surface treatment to produce a durable, non-shiny appearance. Terne coatings, originally developed in the late 1960s, weather to a light grey and were intended to unite the corrosion resistance of stainless steel with the aesthetics of lead. An added advantage was that terne-coated stainless-steel sheets could be readily joined together by soldering as the coating allowed the solder layer to bond to it. Thus, offering protection from water ingress when correctly soldered.

Terne coated stainless steel has certain advantages over lead which, in some circumstances, make it attractive as an alternative to lead for roof coverings. One of the main benefits is, being a rigid sheet, it is harder to remove from a roof and, being a composite material, it has lower scrap value, making it less prone to theft.

The thermal expansion of terne-coated steel is nearly three times less than that of lead, so it can be laid in much longer lengths.

Lead weighs five times more than stainless steel, so the installation process is less labour intensive, and it has less of a loading impact on the structure. For reference, a terne coated steel roof sheet weighs 6.78kg/m2 compared to Code 7 lead which weighs 35.72Kg/m2.

For balance, terne coat stainless steel roof coverings need to be acoustically insulated. Some, but not all installations, have experienced surface discolouration after several years, which can be mistaken for rust. The discolouration can be entirely removed through the application of phosphoric acid.

NB: If the suggestion of using Terne Coated Steel is applied, supplier specifications and detailing would be required.

Fig.2 – Example of terne-coated steel roof covering to Swan Theatre, Stratford-upon-Avon

4.0 BUDGET COSTS

4.1 PRELIMINARIES TO CONSIDER

4.1.1 Ecology
4.1.2 Refurbishment and Demolition Survey
4.1.3 Welfare and preliminaries
4.1.4 Scaffolding to undertake works
4.1.5 Business disruption

4.2 OPTION 1 – CODE 7 MILLED ROLLED LEAD

4.2.1 Replacement of the Northeast elevation (Pink) – 372m2 = [redacted]
Stripping = [redacted]
New deck = [redacted]
New covering = [redacted]

4.2.2 Replacement of the North Elevation (Green) – 307m2 = [redacted]
Stripping = [redacted]
New deck = [redacted]
New covering = [redacted]

4.2.3 Replacement of the Northwest Elevation (Blue) – 323m2 = [redacted]
Stripping = [redacted]
New deck = [redacted]
New covering = [redacted]

4.2.4 Replacement of the Southeast Elevation (Red) – 223m2 = [redacted]
Stripping = [redacted]
New deck = [redacted]
New covering = [redacted]

4.2.4 Replacement of the Southwest Elevation (Teale) – 502m2 = [redacted]
Stripping = [redacted]*100.00*
New deck = [redacted]
New covering = [redacted]

4.2.5 Replacement of the South Elevation (Yellow) – 338m2 = [redacted]
Stripping = [redacted]
New deck = [redacted]
New covering = [redacted]

TOTAL FOR LEAD = [redacted]

NB: The above costs do not include access scaffolding, or any other means to undertake the aforementioned works. Please be aware of costs relating to the above. No cost has been allowed for the re-casting of old lead. In most cases this is often cost neutral to the stripping cost. **These budget costs are based on figures at the time of the report, market forces are currently volatile, and costs have the potential to increase**

4.3 OPTION 2 – TERNE COATED STAINLESS STEEL

4.3.1 Replacement of the Northeast elevation (Pink) – 372m2 **=** [redacted]

Stripping = [redacted]

New deck = [redacted]

New covering = [redacted]

4.3.2 Replacement of the North Elevation (Green) – 307m2 **=** [redacted]

Stripping = [redacted]

New deck = [redacted]

New covering = [redacted]

4.3.3 Replacement of the Northwest Elevation (Blue) – 323m2 **=** [redacted]

Stripping = [redacted]

New deck = [redacted]

New covering = [redacted]

4.3.4 Replacement of the Southeast Elevation (Red) – 223m2 **=** [redacted]

Stripping = [redacted]

New deck = [redacted]

New covering = [redacted]

4.3.5 Replacement of the Southwest Elevation (Teale) – 502m2 **=** [redacted]

Stripping = [redacted]

New deck = [redacted]

New covering = [redacted]

4.3.6 Replacement of the South Elevation (Yellow) – 338m2 **=** [redacted]

Stripping = [redacted]

New deck = [redacted]

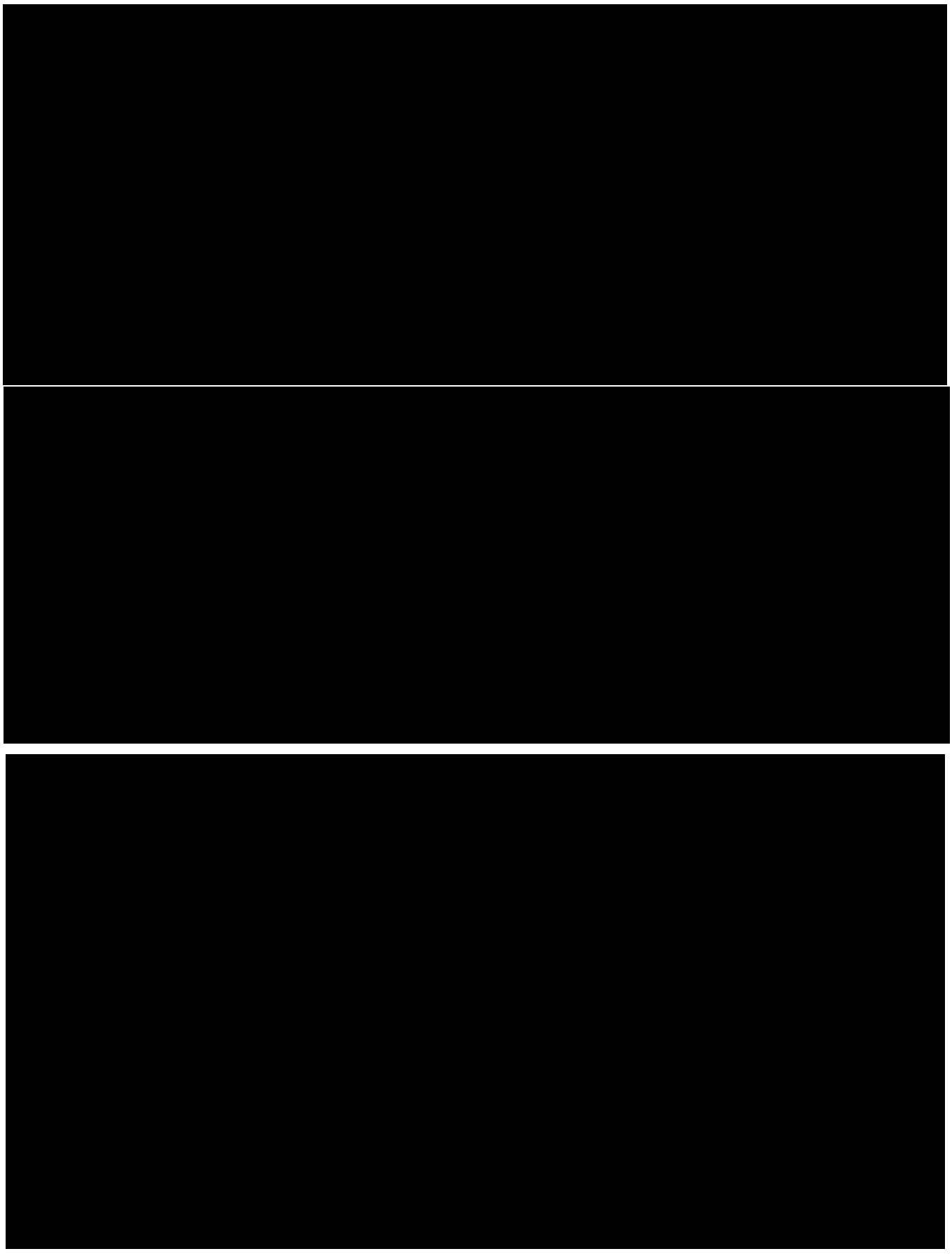
New covering = [redacted]

TOTAL FOR LEAD = [redacted]

NB: The above costs do not include access scaffolding, or any other means to undertake the aforementioned works. Please be aware of costs relating to the above. **These budget costs are based on figures at the time of the report, market forces are currently volatile, and costs have the potential to increase.**

5.0 IMAGES

NB: Please see links in Appendix 1 ‘Deliverables’ for further images



6.0 APPENDIX 1

DELIVERABLES:

Interactive 3D Model of St David's Hall, Cardiff – With Annotations and Dimensions

[redacted]

Interactive 3D Model – Without Annotations

[redacted]

NB: Using the above links, you are able to measure volumes, linears and areas and use the 'inspect' tool to view HD images of a given area of the roof. Information on how to use the inspect tool can be found here [redacted]

The deliverables for this project, in addition to the high face count 3D mesh noted above, include four detailed drawings in multiple formats accompanying this report together with 2D and 3D data:

- CAD Drawing Set (PDF, .3dm and .dwg) – x1 plan, x6 elevations (in x3 drawings)
- 3D textured mesh (.obj)
- Digital Surface Model (.geotiff)
- General HD aerial photographs
- Orthomosaic plan (.geotiff)
- 3D Point cloud (.las)

7.0 BIBLIOGRAPHY

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RAG COST REPORT

Document: Feasibility Estimate **(RIBA Stage 1)**

Revision: Rev - B

Date: 05/11/2021

Job Title: St David's Hall Refurbishment

Reference: RPA.21.116

Author: [redacted]

Checked by: [redacted]

Rev.		Issue Date		Author:	Checked by:
-					
A		02.11.21		[redacted]	
B		05.12.21		[redacted]	

St David's Hall Refurbishment
Feasibility Estimate (RIBA Stage 1)
Nov-21
Rev - B

Clarifications:

1 Stage 1 Feasibility Study / Cost Estimate

Information Used for Cost Estimate:

Drawings / Reports

1 Building Services Condition Report
2 Architectural Fabric Report
3 Structural Condition Survey
4 RAAC Roof Plank Survey
5 Envelope Survey of Lead Mansrad Roof
6 Existing Site Layout Plans Level 1 to 8

Exclusions:

1 Site acquisition costs and associated legal fees.
2 Planning application fees and any additional works arising from planning.
3 Abnormal/upgrade of incoming services.
4 Remediation works.
5 Abnormal ground conditions or contamination.
6 Ground Investigation Report costs.
7 Geo-Physical site investigation costs.
8 Cost associated with the removal of WWII unexploded ordnance.
9 Demolition / Asbestos Survey Report Costs
10 Post Demolition Topographical Survey costs.
11 BAT Surveys.
12 Tree Surveys.
13 Commuted Sum for Development Tariff.
14 Costs associated with Ecological Issues.
15 Road Closure costs.
16 Relocation of street lighting
17 Performance Bond
18 Developers Contingency
19 Pre Contract Fees, Including; Employers Agent, Architect, Engineer, M&E Consultant & BREEAM Assessor fees.
20 Demolition Works - See Clarifications
21 Community Infrastructure Levy (CIL)
22 COVID-19 and Brexit delays and any subsequent factors effecting the construction industry.
23 Removal/diversions of existing services/drainage
24 Surveys, report and subsequential works associated with ecology
25 Off site highways, footpaths works via S278 or highway request
26 SuD's Commuted Sum
27 Any requirement to treat surface water discharge (including the removal of phosphate and the alike)
28 VAT

Basis for Cost Estimate:

1 All costs based on 4th Quarter 2021
2 No allowance included for inflation.
3 Form of Contract to be used JCT D&B 2016.
4 Competitive select tender list.

Other Information

ST DAVID'S HALL REFURBISHMENT - STAGE 1 BUDGET COST ESTIMATE							RED	AMBER	GREEN
ITEM	DESCRIPTION	QUANTITY	UNIT	RATE	TOTAL	COMMENTS	ESSENTIAL	CONSEQUENTIAL	FUTURE
1	**SUBSTRUCTURE**	0.00	m²	£ -	£ -	No work to existing.			
2A	**FRAME**								
	Supplementary steel purlins to support RAAC roof panels	2,070.00	m²			Replace with Composite steel lightweight concrete		£ -	£ -
	Scaffolding; designed to suit; internally	1.00	P Sum			Specialist design quotation required		£ -	£ -
2B	**UPPER FLOORS**	0.00	m²	£ -	£ -	No work to existing.			
2C	**ROOF STRUCTURE & COVERINGS**								
	Lead sheet roof covering replacement	2,065.00	m²			Based on Taleisin Report dated 5th July 2021		£ -	£ -
	Flat roof replacement	2,070.00	m²					£ -	£ -
2D	**STAIRS**								
	Repairs to existing; internally	13,500.00	m²				£ -		£ -
	Upgrade steps; at main entrance	1.00	Item				£ -		£ -
2E	**EXTERNAL WALLS**								
	Upgrade / repairs to existing cladding to ensure compliance with current building regulations / fire regulations	13,500.00	m²				-		£ -
2F	**EXTERNAL WINDOWS & DOORS**								
	Main entrance double doors; remove & replace	6.00	Nr				£ -	£ -	
	Lobby; double doors; G022	1.00	Nr				£ -	£ -	
	Fire exist doors; G024 / g005	2.00	Nr				£ -		£ -
	Loading Bay doors 1048	2.00	Nr					£ -	£ -
	Sub-Station double doors 1043	2.00	Nr				£ -	£ -	
	Balcony Glazing First Floor	1.00	Item				£ -	£ -	
	Balcony Glazing Second Floor	1.00	Item				£ -	£ -	
	Removal and replace existing windows; upgrade to current regulations	1.00	Item				£ -		£ -
2G	**INTERNAL WALLS & PARTITIONS**								
	Repairs to existing walls only; no demolitions and new walls allowed for	13,500.00	m²			Budget allowance only, based on GIFA calculation	£ -	£ -	
2H	**INTERNAL DOORS**								
	Remove single doors; replace	225.00	Nr			see attached schedule	£ -		£ -
	Remove double doors; replace	185.00	Nr			see attached schedule	£ -		£ -
3A	**WALL FINISHINGS**								
	Patch repairs to existing wall plaster where necessary, prepare walls for new decoration	13,500.00	m²			Budget allowance only, based on GIFA calculation	£ -	£ -	
3B	**FLOOR FINISHINGS**								
	Remove existing floor finishes; replace with carpet, ceramic tiles, hardwood: etc as necessary	13,500.00	m²			Budget allowance only, based on GIFA calculation		£ -	£ -
3C	**CEILING FINISHINGS**								
	Remove existing suspended ceilings; provide new as necessary	13,500.00	m²			Budget allowance only, based on GIFA calculation	£ -		£ -

ST DAVID'S HALL REFURBISHMENT - STAGE 1 BUDGET COST ESTIMATE						RED	AMBER	GREEN
ITEM	DESCRIPTION	QUANTITY	UNIT	RATE	TOTAL	COMMENTS	ESSENTIAL	CONSEQUENTIAL	FUTURE
4	**FURNITURE, FITTINGS & EQUIPMENT**								
	Box Office - Counter - G003	1.00	Item				£ -	£ -	
	Shop - G023	1.00	Item				£ -	£ -	
	Commercial Kitchen - Room 1027	1.00	Item				£ -	£ -	
	Restaurant Fit-Out - 1008	251.00	m²			Tables / Chairs: etc	£ -	£ -	
	Kitchen - Room 2036 / 2076	2.00	Item				£ -	£ -	
	Bar - 3100	1.00	Item				£ -	£ -	
	Kitchen - Room 3034	1.00	Item				£ -	£ -	
	Kitchen - Room 3075	1.00	Item				£ -	£ -	
	Laundry - 5016 / 5046	2.00	Item				£ -	£ -	
	Remove existing; replace main auditorium seating	2,000.00	Nr				£ -	£ -	
	Fixed fittings to box office; dressing rooms; cloakrooms; workshops; front & back bar areas; servery counters; lockers and main information point	13,500.00	m²				£ -	£ -	
5A	**SANITARY FITTINGS**						£ -	£ -	
	Male WC - G014	1.00	Item				£ -	£ -	
	Male WC - G016	1.00	Item				£ -	£ -	
	Female WC - G017	1.00	Item				£ -	£ -	
	WC - 1050	1.00	Item				£ -	£ -	
	Female WC - 1025	1.00	Item				£ -	£ -	
	Male WC - 1022	1.00	Item				£ -	£ -	
	Male WC - 1034	1.00	Item				£ -	£ -	
	Female WC - 1033	1.00	Item				£ -	£ -	
	Disabled WC - 1017	1.00	Item				£ -	£ -	
	Female WC - 2116	1.00	Item				£ -	£ -	
	Disabled WC - 2117	1.00	Item				£ -	£ -	
	Male WC - 2978	1.00	Item				£ -	£ -	
	Disabled WC - 2079	1.00	Item				£ -	£ -	
	Male Staff WC - 2077	1.00	Item				£ -	£ -	
	Female Staff WC - 2075	1.00	Item				£ -	£ -	
	Managers Changing - 2074	1.00	Item				£ -	£ -	
	Staff WC - 2110 / 2113 / 2114	1.00	Item				£ -	£ -	
	Male WC - 3085	1.00	Item				£ -	£ -	
	Female WC - 3081	1.00	Item				£ -	£ -	
	WC - 3071 / 3008 / 3006 / 3013 / 3015 / 3018 / 3020	7.00	Item				£ -	£ -	
	WC - 3022	1.00	Item				£ -	£ -	
	Male WC / Shower - 3027	1.00	Item				£ -	£ -	
	Female WC / Shower - 3030	1.00	Item				£ -	£ -	
	Female WC - 3054	1.00	Item				£ -	£ -	
	Disabled WC - 4033	1.00	Item				£ -	£ -	
	Male WC - 4019	1.00	Item				£ -	£ -	
	Female WC - 4020	1.00	Item				£ -	£ -	
	Male WC - 5038	1.00	Item				£ -	£ -	
	Female WC - 5033	1.00	Item				£ -	£ -	
	Disabled WC - 5036	1.00	Item				£ -	£ -	
	WC - 5011 / 5012 / 5015	3.00	Item				£ -	£ -	

ST DAVID'S HALL REFURBISHMENT - STAGE 1 BUDGET COST ESTIMATE							RED	AMBER	GREEN
ITEM	DESCRIPTION	QUANTITY	UNIT	RATE	TOTAL	COMMENTS	ESSENTIAL	CONSEQUENTIAL	FUTURE
5B	**MECHANICAL INSTALLATION**								
	Remove existing installations	13,500.00	m²	[redacted]		Provisional Sum - Budget based on Spons M&E 2021	[redacted]	£ -	£ -
	Incoming Services	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Water Installation System	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Heating System	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Cooling System	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Ventilation System	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Distribution System	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Sprinkler System	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Domestic Water Services	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Drainage System	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	BMS & Control System	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
5C	**ELECTRICAL INSTALLATION**								
	Remove existing installations	13,500.00	m²	[redacted]		Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Incoming Electrical Services	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Main LV Switchgear	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Standby Generator	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Lighting Installation	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Emergency Lighting Installation	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Small Power Installation	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Fire Detection & Alarm Installation	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Telecommunication Installation	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Lighting Protection Installation	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Intruder Alarm Installation	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	Emergency Voice Control Communication Installation	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
	CCTV Installation	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021		£ -	£ -
5D	**SPECIALIST INSTALLATION**								
	Remove existing installations	13,500.00	m²	[redacted]		Provisional Sum - Budget based on Spons M&E 2021	£ -	[redacted]	£ -
	Orchestra Lift Pit	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021	£ -		£ -
	Chair Wagon	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021	£ -		£ -
	Adjustable Reflectors over Orchestra Platform	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021	£ -		£ -
	Lighting Bridges	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021	£ -		£ -
	Equipment Bars & Acoustic Systems in Audience Areas	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021	£ -		£ -
	Sound & Communications Systems	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021	£ -		£ -
	AV Installation	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021	£ -		£ -
	Specilaist Lighting	13,500.00	m²			Provisional Sum - Budget based on Spons M&E 2021	£ -		£ -
5E	**LIFTS & TRANSPORT INSTALLATIONS**								
	Remove & replace: Escalator Nr.01	1.00	Nr	[redacted]		Provisional Sum - Budget based on Spons M&E 2021	[redacted]	£ -	£ -
	Remove & replace: Escalator Nr.02	1.00	Nr			Provisional Sum - Budget based on Spons M&E 2022		£ -	£ -
	Remove & replace: Escalator Nr.03	1.00	Nr			Provisional Sum - Budget based on Spons M&E 2023		£ -	£ -
	Remove & replace: Escalator Nr.04	1.00	Nr			Provisional Sum - Budget based on Spons M&E 2024		£ -	£ -
	Remove & replace: Passenger Lift room Nr. G002	1.00	Nr			Provisional Sum - Budget based on Spons M&E 2025		£ -	£ -
	Remove & replace: Goods Lift Room 1049	1.00	Nr			Provisional Sum - Budget based on Spons M&E 2026		£ -	£ -
	Dock Leveller Installation - Room 1048	1.00	Nr					£ -	£ -

ST DAVID'S HALL REFURBISHMENT - STAGE 1 BUDGET COST ESTIMATE							RED	AMBER	GREEN
ITEM	DESCRIPTION	QUANTITY	UNIT	RATE	TOTAL	COMMENTS	ESSENTIAL	CONSEQUENTIAL	FUTURE
5E	**BWIC WITH M&E INSTALATIONS**								
	Percentage allowance based on costs above	1.50	%						
6A	**EXTERNAL WORKS**								
	No external works.	0.00	m²	£ -	£ -		£ -	£ -	£ -
6B	**DRAINAGE / ATTENUATIONS / SUDS**								
	No drainage amendments	0.00	m²	£ -	£ -		£ -	£ -	£ -
6C	**STATUTORY SERVICES**								
	No upgrades to existing services	0.00	m²	£ -	£ -		£ -	£ -	£ -
	SUB-TOTAL								
7	**MAIN CONTRACTOR PRELIMINARIES @ 12%**								
	SUB-TOTAL								
	Main contractors OH&P @ 5%								
	SUB-TOTAL								
8	**CONTINGENCY @ 5%**								
	SUB-TOTAL								
9	**PROFESSIONAL & DESIGN FEES @ 12%**								
	TOTAL BUDGET COST ESTIMATE								
	Cost / m²								