ACOUSTIC DESIGN OF THE REFURBISHMENT OF THE HALLS, WOLVERHAMPTON

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The Grade II listed Wolverhampton Civic Hall was built in 1938. It was closed in 2015 for a major refurbishment and reopened in 2023. The building contains two main performances spaces, the Civic Hall and the Wulfrun Hall, with new capacities of 3,400 and 1,200 respectively.

Major works to the halls included the addition of a balcony to expand capacity in the Civic Hall, new finishes and seating, new roofs to the halls and new building services systems. The works also included the creation of new bars and ancillary spaces, including a new multi-use space referred to as the Lantern Bar.

This paper describes the acoustic design of the refurbishment including:

- the design of the new Civic Hall balcony to provide an additional 400 seats
- the provision of new acoustic finishes within the halls
- enhancements to the building envelope to control environmental noise ingress and entertainment noise egress
- enhancements to the sound insulation performance of key internal separating elements
- control of noise from new building services within the building and to nearby noise sensitive premises.

1 INTRODUCTION

The Halls is a publicly funded building in Wolverhampton developed by Wolverhampton City Council containing two performance spaces, Civic Hall and Wulfrun Hall along with bars and ancillary spaces. The Halls opened in 2023 following closure for refurbishment in 2015.

This paper describes the key acoustic design features of the building.

2 DESIGN TEAM

The design team members were as follows:

- Client: Wolverhampton City Council
- Project manager: Faithful & Gould
- Main contractor: Willmott Dixon Interiors
- Architect: Space & Place
- MEP: Space & Place
- Structural engineer: Furness Partnership
- Heritage Consultant: LANPRO
- Fire Engineers: Tenos
- Acoustic consultant: Sandy Brown

3 HISTORY OF THE BUILDING

The historic Grade II listed Wolverhampton Civic Hall, built in 1938.

It was closed in 2015 for major refurbishment and reopened in 2023, following delays associated with significant structural issues and the discovery of significant amounts of asbestos. The building contains two main performance spaces, the Civic Hall and the Wulfrun Hall, with new capacities of 3,400 and 1,200 respectively.

The Halls is located in Wolverhampton in a city centre location. The surrounding area is mixed use with residential properties located near to the site. Refer to Figure 1.

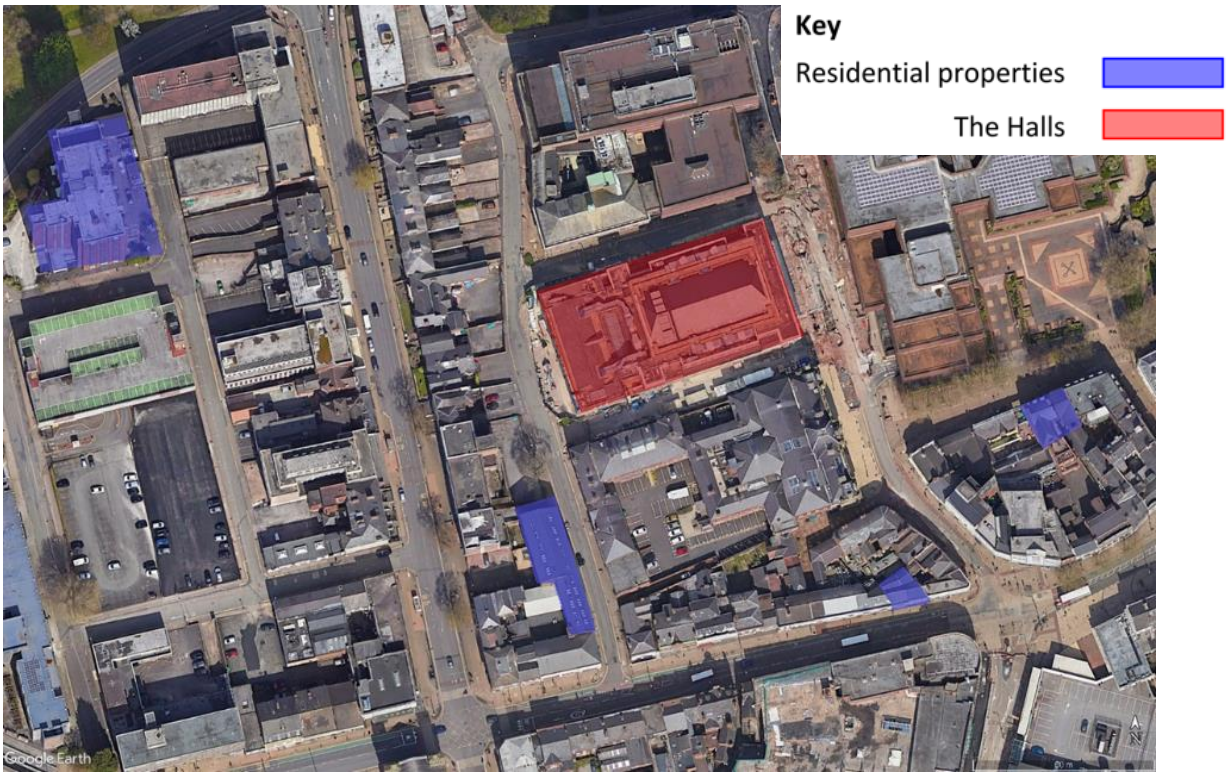

Figure 1 Location of The Halls (image courtesy of Google Earth Pro)

The Halls are used for various types of events focusing predominantly on rock & pop concerts to spoken word and comedy use, though other uses such as club nights are also held. The building has significant cultural relevance, having played host to many famous names over the last 90 years.

4 PREVIOUS TESTING AND PROJECT AIMS

The overall aim for the acoustic design of the project was to maintain, or improve where appropriate, the acoustic parameters of the existing spaces.

Benchmark testing of the existing space was undertaken in 2015 by others prior to Sandy Brown's involvement with the scheme. The survey included measuring reverberation time in both the Civic and Wulfrun Halls and identifying any strong unwanted reflections audible in the audience or stage areas.

5 BUILDING ENVELOPE

The main aim of the building envelope design was to maintain the level of sound insulation provided by the existing constructions. This was to control both environmental noise ingress and entertainment noise egress to the nearby residential noise sensitive receptors. There were a number of noise egress paths to consider such as the roof and existing skylights to each hall which were to be replaced, the facade including glazed areas and automatically opening smoke vents were to be installed on the roof.

5.1 Existing envelope

The construction of the existing elements forming the building envelope was determined by reviewing the historic drawings for the Halls.

Figure 2 shows a section of the Civic Hall taken from the historical records. The existing roof was of slate tiles, infilled rooflights with a heavy ceiling formed of lath and plaster below. The predicted sound insulation performance of this build-up formed the basis of the review of the proposed constructions.

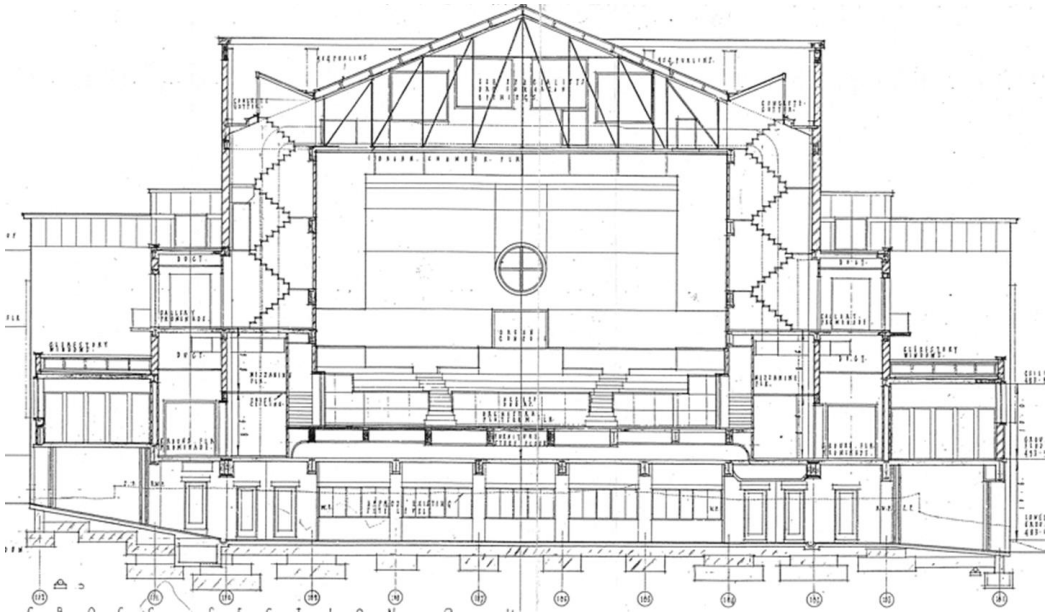

Figure 2 Historic section drawing of the Civic Hall

5.2 Development of new building envelope elements

To the upper level of the Civic Hall, a U-shaped gallery was introduced, housing bars, and providing access to the new upper balcony. The facades of this were glazed, and enclosed the existing masonry facade of the hall.

To finalise the design of the new roof to both halls, there was an iterative process with the design team to provide a build-up that was suitable to meet the acoustic and fire requirements. The new design also had to be accommodated structurally within the restraints of an existing building. This was complex acoustically due to the removal of the existing mass barrier ceiling which provided a significant level of sound insulation.

An existing, but recently permitted, noise sensitive receptor was identified at close proximity to the Wulfrun Hall. To allow the impact of the new and previous hall to be compared, a review of the predicted noise egress to this receptor was undertaken. This included consideration of noise transfer paths from the roof, facade (including existing glazing) and smoke ventilators.

The Civic Hall is located further from noise sensitive premises, as well as benefitting from additional screening. The review of this space therefore focused on maintaining the sound insulation performance of the previous roof arrangement with the inclusion of new automatic opening smoke ventilators.

The smoke vent design was a bespoke arrangement with an acoustic damper to the underside of the vent, large cavity with sound absorbent reveals and an acoustically enhanced 'lid' to the roof side. The same arrangement was used for both halls.

Structural limitations of the existing building limited the overall mass of the ceiling. Modelling of the sound insulation performance of a high number of roof build-ups was carried out, with focus on the single figure sound reduction index (with a $+C_{tr}$ correction applied) in additional to reviewing the 63 Hz octave band performance to ensure that the comparison of the systems included consideration of low frequency performance.

The replacement roof build-up to both halls comprised a slate roof tiles on battens, 2 layers of cement board to form a cavity filled with dense mineral wool insulation with a steel liner tray below. To increase the sound insulation performance of the roof as far as practicable, mineral wool insulation was also provided within the cavity formed by the raft ceiling system below.

Within the Wulfrun Hall, new secondary glazing was specified to the windows, to ensure that noise breakout via this path was significantly reduced.

6 ROOM ACOUSTICS WITHIN THE HALLS

6.1 Proposed changes to halls

The most significant change to the Civic Hall was the construction of a new balcony at Level 3, to increase the overall capacity by providing additional seating.

In addition, to accommodate the new ventilation solutions, the previously imperforate castellated ceiling design was replaced with a series of suspended baffles, to allow the ceiling void to be used as a return air plenum.

Whilst the introduction of the new balcony resulted in a reduction in overall volume, the revised ceiling detail had the potential to result in the plenum acting as an acoustically coupled space.

A new balcony was also installed at the rear of the Wulfrun Hall, along with comparable works to the ceiling. As with the Civic Hall this resulted in a slight reduction in overall volume.

6.2 Acoustic modelling

Extensive acoustic modelling of both halls was carried out using ODEON software to review various sound absorbent treatment options, extents and locations. This process was carried out while liaising with the architect to ensure that the heritage constraints were met. Images of the acoustic models are presented in Figure 3.

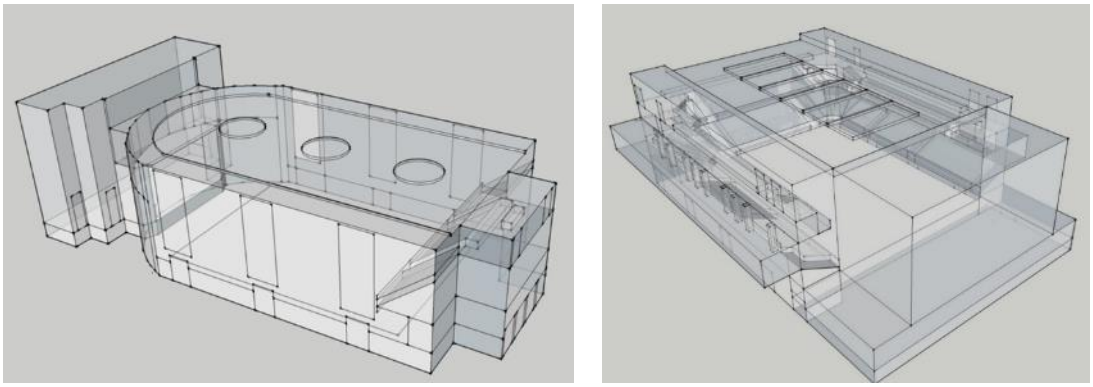

Figure 3 3D wire image model of Wulfrun Hall (left) and Civic Hall (right)

The aim of the room acoustic strategy was to reduce reverberation times within the halls to focus on use for spoken word and amplified music and control low frequency rise.
The key areas of sound absorbent treatment in both halls are:

- Monolithic central ceiling with an “acoustic plaster” system applied to a perforated board
- The same system installed to the underside of balconies
- Acoustic baffles around the perimeter of the ceiling to replace the previously castellated ceiling detail
- Sound absorbent wall panels to the front of balustrade and to the stage walls
- Fabric seating with perforated underside

The sound absorbent treatment to the front of the Civic Hall balconies was specified to assist with reducing the previously identified audible reflections from the front of the Level 1 balcony.

Within the Wulfrun Hall sound absorbent wall panels were provided at high and low level to the side walls as well as to the rear balcony and rear wall, to control strong reflections from the stage.

Images showing the treatment are provided in Figure 4 and Figure 5.

Figure 4 Wulfrun Hall acoustic finishes


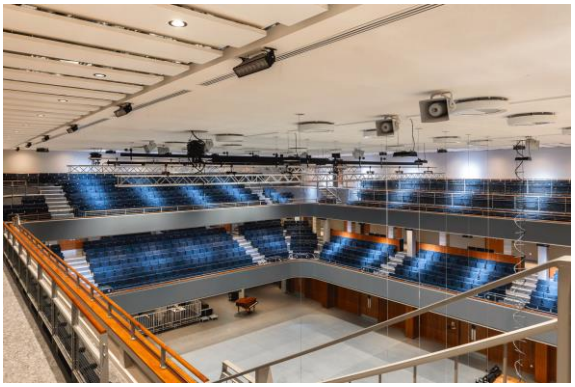

Figure 5 Civic Hall acoustic finishes

6.3 Room acoustic measurements

6.3.1 Measurement methodology

Room acoustic measurements were carried out using IRIS system using the impulse response method.

The source was an omnidirectional speaker located on the stage using a sine sweep. Receiver measurements were undertaken with a tetrahedral microphone. The measurement locations were chosen to be representative of listening positions within the halls and were within the balconies and on the main floor of each hall. Measurements were undertaken within 100 Hz to 16 kHz third octave frequency bands frequency range and arithmetically averaged.

6.3.2 Measurement results

Measured reverberation times are presented in Table 1 with comparison to the benchmarking measurements undertaken at the start of the project.

Table 1 Summary of measured reverberation time

Space	Measured reverberation time (s)			Previous measured reverberation time (s)[	
	$T_{20,mid}$	$T_{20,125\text{-}250\ Hz}$	EDT	$T_{60,mid}$	$T_{60,125\text{-}250\ Hz}$
Wulfrun Hall	0.9 (average) 0.9 (main floor) 0.9 (balcony)	0.9 (average) 0.9 (main floor) 0.9 (balcony)	0.8 (average) 0.9 (main floor) 0.6 (balcony)	1.9	1.9[
Civic Hall	1.9 (average) 2.2 (main floor) 1.8 (balconies)	1.6 (average) 1.7 (main floor) 1.5 (balconies)	1.4 (average) 1.8 (main floor) 1.2 (balconies)	2.4[1]	2.1[1]

[1] No seats deployed to the main floor during the measurement

The reverberation time measured showed a reduction compared to the existing condition.

The low frequency rise was also very well controlled in both halls, and in both cases is comparable to the rise previously experienced within the halls.

Within the Civic Hall, the measured EDT is significantly lower than the measured $T_{20,mid}$ suggesting multiple slopes of sound decay. This is considered to be a result of the more complex geometry of this hall, compared to the simpler design of the Wulfrun Hall, with only a single balcony at the rear of the space. Within the Wulfrun Hall, the EDT on the main floor of the Wulfrun Hall was comparable to the measured $T_{20,mid}$, reflects the simpler geometry of the space.

7 BUILDING SERVICES DESIGN

7.1 Criteria

One of the main aims of the refurbishment process was to improve ventilation to the halls.

Whilst a variety of acoustic benchmark measurements were undertaken prior to our involvement in the project, these did not include measurements of the previous building services plant noise levels within the halls.

To ensure internal services noise was suitably controlled, initial building services noise limits of NR25 were recommended for both halls. However, recognising that spatial constraints of the existing building may limit what could be achieved in practice, and that the primary design of the halls was for amplified speech and music, the option of a potential 5 NR relaxation was discussed, if considered necessary.

7.2 Design and restrictions

The design was based on the installation of multiple air handling units serving each hall, with a high number of ducted supply terminals and a single extract duct per air handling unit.

The main restrictions on the building services design, in terms of acoustic performance, were:

- Location of the Civic Hall air handling units within existing space located directly adjacent to the hall roof, leading to very short duct runs and significant levels of case radiated noise incident on the roof build-up
- Requirement for relatively long throw supply, as a result of the significant floor to ceiling heights to the stalls

As a result of the above restrictions, it was necessary to relax the building services criteria to NR30.

To address the very limited space for incorporating primary attenuation, bend attenuators were specified.

Supply ventilation to each hall was via ducted connections located within the central raft ceiling, utilising 300 mm diameter supply grilles and linear slot diffusors serving the balconies.

The extract air termination points were located above the raft ceilings within each hall, essentially using the void as a plenum, utilising the perimeter openings to draw air from the area below. The provision of a layer of mineral wool laid directly above the raft ceiling assisted with controlling noise build-up from the extract ductwork and any other duct borne noise.

8 SOUND INSULATION

8.1 Changes to the halls

As part of the works, an additional floor level was introduced at Level 3 of the Civic Hall. This introduced a number of new adjacencies, including bar and toilets located to the sides and rear of the hall respectively.

Within the Wulfrun Hall, other than the introduction of the balcony, which required some remodelling of circulation spaces, no significant changes were made in terms of adjacencies.

A new bar, referred to as the Lantern Bar was also introduced, have adjacencies with the Civic Hall, the Wulfrun Hall, and the Wulfrun Hall bar.

8.2 Sound insulation design

As an existing building with a set layout, there were limits as to what could be achieved in terms of acoustic separation.

An initial site inspection was undertaken to identify any significant sound transfer paths between the three keys areas, the Civic Hall, Wulfrun Hall, and Lantern Bar, as well as from any proposed plant rooms. The Lantern Bar is located between the two halls and key adjacencies were identified as between the Lantern Bar and to the Wulfrun Hall and Civic Hall., as shown in Figure 6.

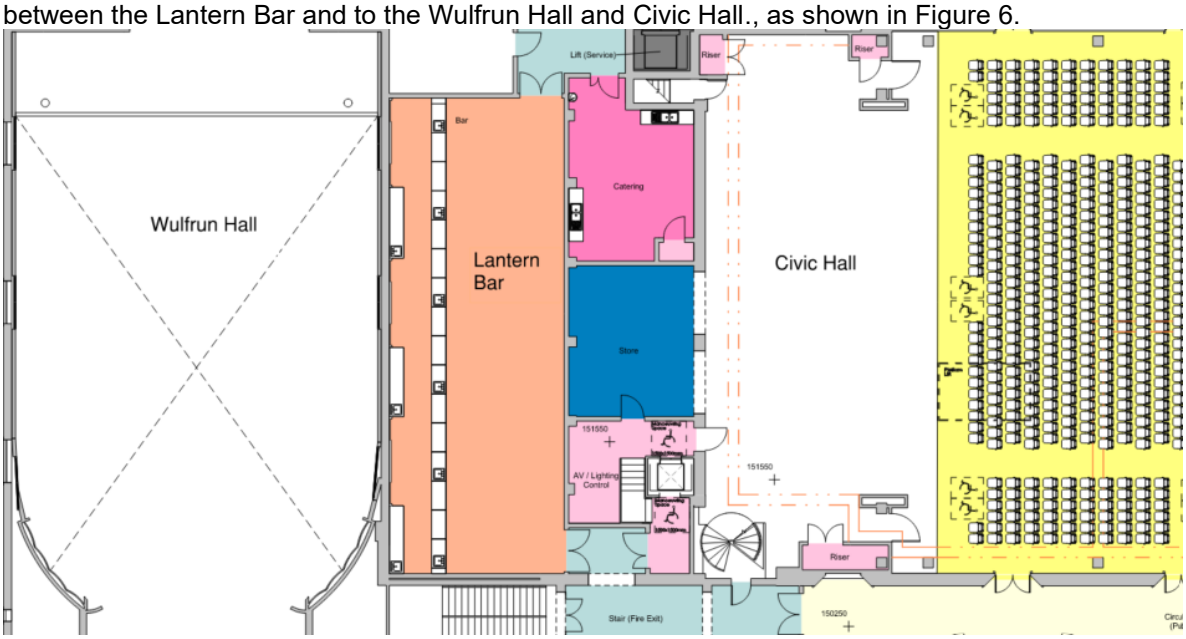

Figure 6 Sensitive adjacencies

The client required a flexible use for the lantern bar, acting as the primary bar for the Civic Hall, but also being usable as a conferencing space.

8.3 Lantern Bar to Wulfrun Hall

The Lantern Bar shares both a separating wall (containing glazed elements) along with a separating floor with the Wulfrun Hall. The goal within the Wulfrun Hall was to retain the visual appearance of the space, which included the presence of the glazing. The existing glazed elements were retained and sealed, before having independent linings added within the Lantern Bar, to increase the level of acoustic separation as far as practicable.

For the separating floor, as this element separated the Lantern Bar from the bar serving the Wulfrun Hall, high levels of sound insulation performance were not as critical, and the use of a standard metal frame ceiling system was deemed to be acceptable.

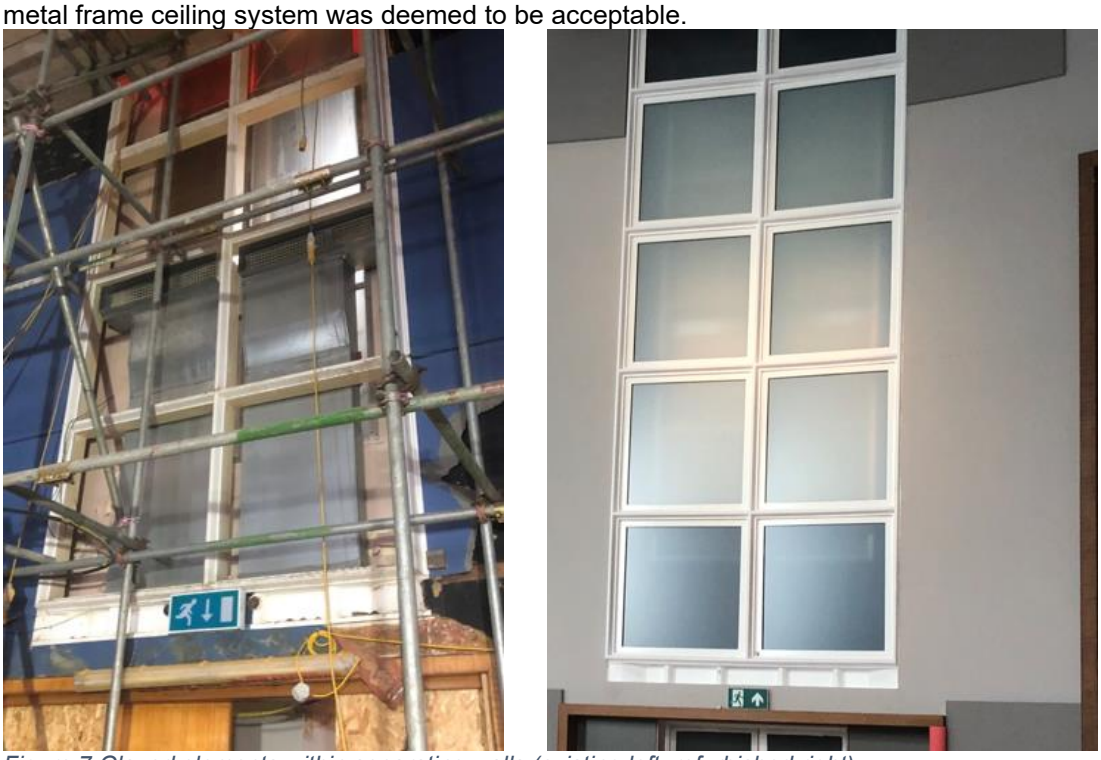

Figure 7 Glazed elements within separating walls (existing left, refurbished right)

8.4 Lantern Bar to Civic Hall

Whilst floor levels varied, as a result of extensions and additions created at various points, the Lantern Bar was located directly behind the rear of the stage / under stage store. Where present, the existing walls were relatively thick masonry, however, these contained openings and penetrations, both existing as well as required for the use of the newly refurbished building.

A minimum sound insulation performance of D_w 60 dB was targeted between these spaces. Whilst the separation benefitted from provision of a shutter, it was considered appropriate to provide the majority of the acoustic separation through the provision of additional partitions to seal openings. To achieve this a large twin stud partition was installed, formed using independent linings set at various levels. In addition, plasterboard bulkheads were formed within the lantern bar, to accommodate the various services penetrations that occurred at high level.

8.5 Noise from bars and toilets

One of the elements that remained ongoing throughout the development was the specification of the doors separating the Civic Hall from surrounding spaces.

The layout of the halls is such that bars, cloakrooms and toilets are all accessed via corridors surrounding them. Additionally, noise transfer via the corridors was also identified as potentially significant sound transfer path.

Whilst original proposals were for the existing doors to be retained, the client decided on replacement of these doors, allowing specification of solid core doors rated at R_w 35 dB. The selected doors utilised a combination of batwing and triple fin seals to achieve the required performance.

8.6 Commissioning

Sound insulation testing was undertaken between the key adjacencies on site. These are presented in Table 2.

Table 2 Summary of measured sound insulation performances

Source room	Receiver room	Measured (dB)	Comments
Wulfrun Hall	Lantern Bar	$D_{nT,w}$ 63 dB	Considered to be an appropriate level of sound insulation to allow flexible use of the spaces.
Lantern Bar	Civic Hall (shutters closed)	D_w 62 dB	Considered to be an appropriate level of sound insulation to allow flexible use of the spaces, on the basis that the Lantern Bar typically serves the Civic Hall when in use.
Lantern Bar	Civic Hall (shutters open)	D_w 61 dB	
Lantern Bar	Wulfrun Bar	$D_{nT,w}$ 59 dB	This measurement was background limited by building services. In practice the level of sound insulation is likely to be higher. There were no obvious weaknesses in the floor construction.

High levels of sound insulation performance were measured on site, with no obvious acoustic weaknesses noted as part of the testing.

Into performance spaces, the D_w performances were presented, as these were fully furnished at the time of the testing. Within the bar areas, as these were not complete, a $D_{nT,w}$ value, based on a 1.0 second reverberation time was adopted.

The impact of the Lantern bar on the Civic Hall was considered, to assess noise transfer during times when quieter performances (including spoken word) were being held within the hall whilst the Lantern Bar was in use. Testing was therefore undertaken from the smaller bar to the larger hall.

It was notable that operating with the shutters open, only resulted in a 1 dB reduction in sound insulation performance, reducing operational restrictions placed on the end user.