

FORMANT.
STRAIGHTFORWARD ACOUSTIC DESIGN

PRINCESS ROYAL THEATRE PORT TALBOT

STAGE 3 ACOUSTIC DESIGN REPORT

Project no. P1253
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REVISION HISTORY

Date	Revision	Notes
29/08/2024	P01	For Information

EXEC SUMMARY

Formant has been appointed to provide acoustic advice for the proposed refurbishment/extension of Princess Royal Theatre Port Talbot. This report sets out our understanding of the project acoustic brief, acoustic criteria, baseline survey results and the acoustic design issues which have been addressed during RIBA Stage 3.

EXISTING BUILDING ACOUSTICS AND CLIENT BRIEF

The acoustic condition of the existing auditorium have been benchmarked and a detailed summary is provided Section 4 of this report. Key points are summarised as follows:

- No significant upgrades to the building envelope are required to reduce noise break-out.
- Internally, auditorium noise levels were dominated by ventilation system noise at around 40 dBA and this needs to be reduced significantly.
- Environmental noise break-in to the auditorium was around 30 dBA and this should be reduced as much as practicable.
- Room acoustics in the auditorium were mixed and measures should be developed to improve the 'muddy' sound under the balcony whilst trying to maintain the room acoustics elsewhere in the room.
- Concert noise transfer to adjacent meeting rooms was high but it is not practicable within the scope of this project to mitigate this.

ACOUSTIC DESIGN STRATEGY

Improvements to the auditorium building envelope sound insulation are proposed via a high performance get-in door, additional acoustic lining to the soffit above the stage and high sound insulation walls/roof to the new extension. The upgrades represent the best practicable improvements working to achieve the '*no worse than existing*' brief, but the sound insulation performance will ultimately still be limited by the retained elements.

Sound insulation ratings have been provided for all new internal elements (i.e. doors, partitions, etc). Acoustic lagging of rainwater pipes in the auditorium is essential and this needs to be developed during Stage 4.

The auditorium balcony overhang is fundamentally too deep and whilst a radical re-design is not possible within the scope of this project, improvements are being sought by bringing in the rear wall of the ground floor and changing the acoustic performance of the balcony soffit to provide slightly more acoustic reflections. We have identified some uncertainties with the performance of the timber wall panelling and the main auditorium ceiling and to mitigate this risk it has been agreed to include some areas for 'tuning absorption' should this be required after completion of the auditorium works.

The ventilation system should target a lower noise target of 30 dBA. The proposed FCU heating strategy is not a common design solution for use in theatres and our initial review of the proposed FCU selections concluded that they may exceed this limit. During Stage 4 Hydrock will need to provide a detailed design for our review, including silencer and equipment selections for FCUs and ASHPs, so we can confirm the proposed design strategy is capable of meeting the noise criteria.

1 INTRODUCTION

Formant has been appointed to provide acoustic design advice for the proposed refurbishment and extension of Princess Royal Theatre Port Talbot. This report should be read in conjunction with the Baseline Noise Survey Report, reference P1189/REP01, dated 13 May 2022, which contains full details of the baseline noise survey and noise break-out tests undertaken at the existing building.

This report provides:

- 1) Our understanding of the client's acoustic brief
- 2) A summary of the applicable on-site acoustic criteria
- 3) Acoustic design advice for the building envelope, internal elements (e.g. floors, walls, doors, etc.), room acoustic treatments and building services noise control.
- 4) Acoustic issues for further development in Stage 3.

2 PROJECT DESCRIPTION/CLIENT BRIEF

2.1 EXISTING SITE

The existing site comprises a purpose-built theatre which was constructed in the 1990s. The building has operated as a live music venue throughout this time and we understand from conversations with the client and the Local Authority Environmental Health Officer (EHO), that it has not been subject to any complaints from neighbours about music or entertainment noise break-out.

The building comprises a 3-storey steel/concrete framed building with brick external cladding and a pitched slate roof with PIR insulation. The existing building directly adjoins the Neath Port Talbot Civic Centre building to the west and is bounded by the Civic Square to the south, the B4286 to the north and car park/river Afan to the east.

Nearby residential properties comprise a multi-storey block approx. 80 m to the south, terraced houses approx. 120 m to the east and a chapel located 30 m to the south. Other buildings in the local area are predominantly retail and are not considered noise-sensitive. An elevated section of the M4 runs approximately 65 m north of the building and the B4286 runs between the two, approximately 25 m from the north corner of the building. The Afan river runs to the south-east of the site and is an audible sound source in some areas close to the site. A site location plan of the existing site is provided in Figure 1, including a mark-up of the location of nearby residential NSRs and the measurement positions used in the noise survey (MP1-10).

2.2 CLIENT BRIEF

The proposed refurbishment will not involve any fundamental changes to the use of the venue, i.e. it will remain as a theatre and live music venue. The days and hours of operation and the types of events are also expected to remain largely the same as the existing venue.

During Stage 2 we had conversations with the client and design team to explain that the scope of the project is unlikely to be able to make fundamental changes to the noise break-out or room acoustics in the auditorium, but that where affordable, the project should take all practicable steps to improve both issues, in particular aiming to provide auditorium room acoustic conditions which would better support unamplified speech.

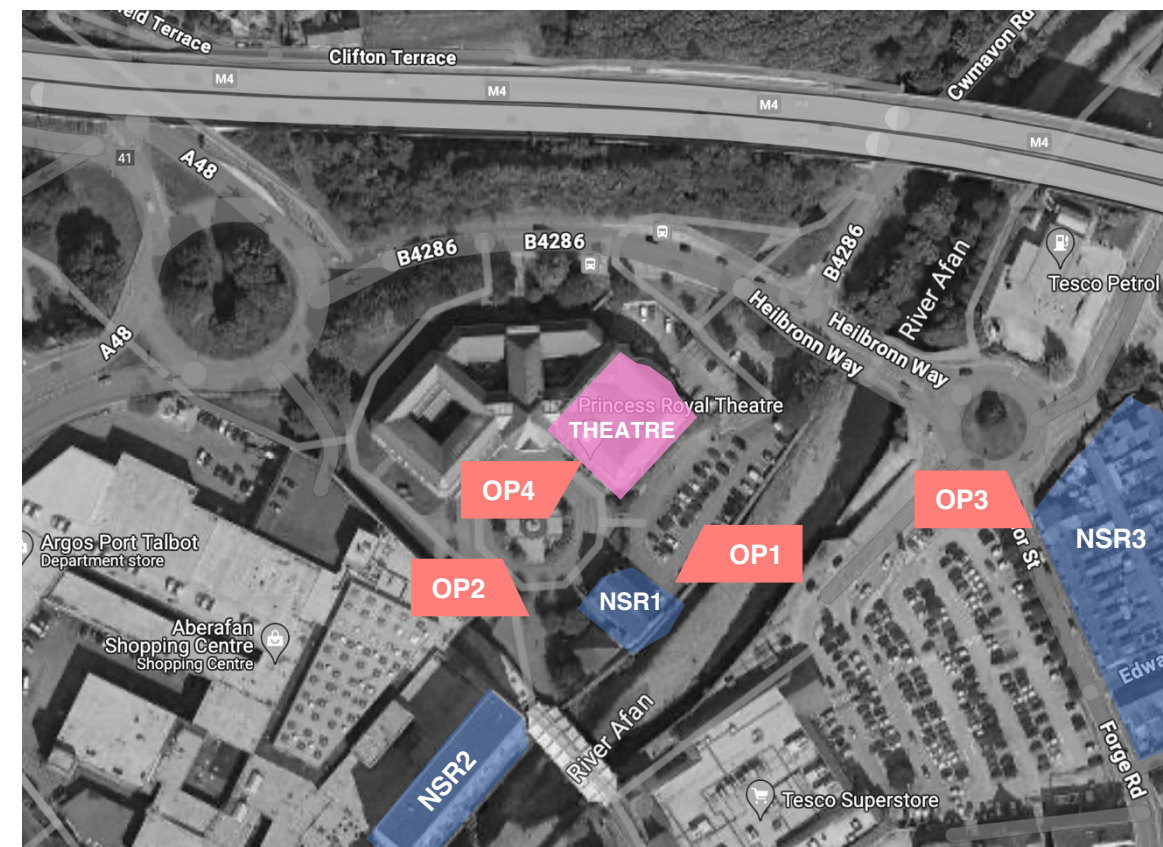


Figure 1: Site aerial view showing nearest NSR locations (NSRs 1-3), outdoor measurement positions (OP1-4)

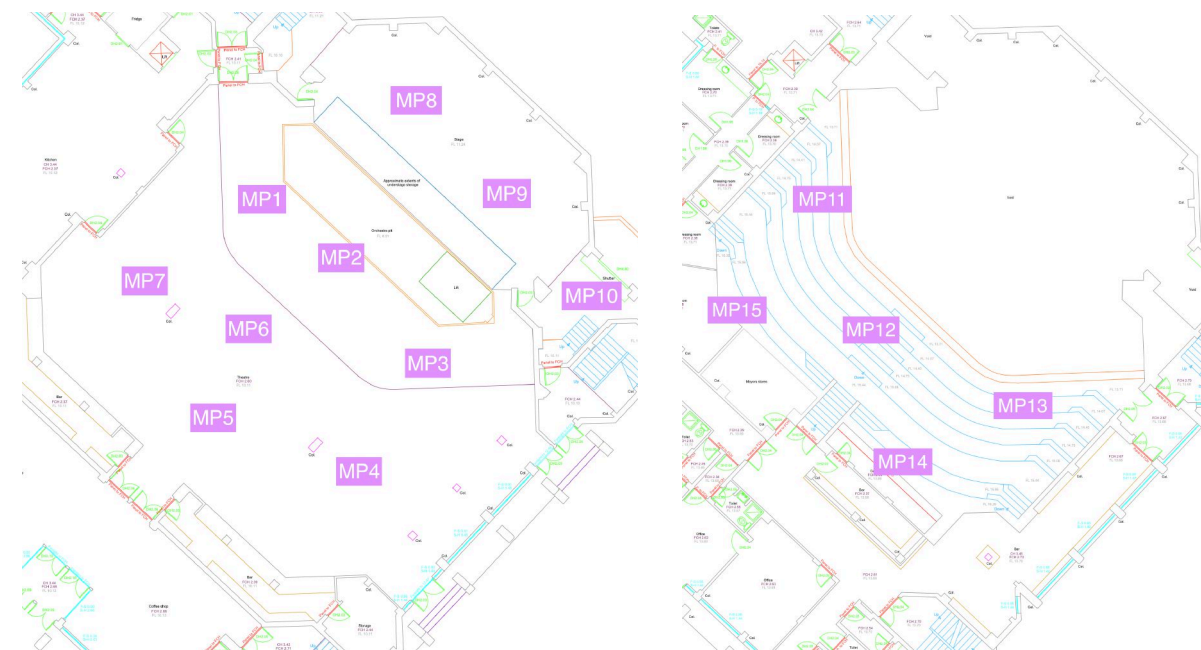


Figure 2: Existing theatre floor plans showing internal measurement positions (IP1-15).



3 ACOUSTIC CRITERIA

3.1 ENTERTAINMENT NOISE BREAK-OUT

There is no requirement to undertake a detailed assessment of entertainment noise break-out from the venue because the baseline survey did not identify any significant issues which need to be addressed. For new building envelope areas (e.g. the roof/walls of the back-stage extension) the sound insulation performance should be benchmarked against the existing building envelope rather than an external noise level target.

3.2 INTERNAL AMBIENT NOISE LEVELS (IANL)

Sources that may contribute to the IANL include external noise sources (e.g. road traffic, aircraft, etc.) and internal sources such as building services noise (e.g. heating and ventilation). The IANL excludes noise from performance activities or people using the building.

Type of space	IANL criteria, L_{Aeq1hr} (dB)	Guideline building services plant noise limits
Auditorium	30*	NR20**
Meeting rooms	35	NR30
Staff Rooms, Dressing Rooms, Offices	40	NR35
Bar/Café/Foyer areas	45	NR40
Kitchen/Toilets/Circulation	50	NR45

Table 1: IANL criteria and guideline plant noise limits

* The proposed IANL criterion is based on the results of the baseline noise survey which showed that existing internal noise levels were around 30 dBA with the ventilation system off. Whilst options to reduce noise break-in will be explored by the design team, it is not considered practicable to significantly reduce the IANL levels therefore the design is based upon the existing IANL remaining around 30 dBA.

** The building services noise limit has been selected to aim for an overall IANL no higher than 30 dBA when the ventilation system is running. Reducing the existing ventilation system noise around NR20 would provide a significant improvement in baseline conditions and (along with improvements to the room acoustic conditions) may enable unamplified speech performances to take place. It is not clear at this stage whether a target of NR20 is practically achievable working within the space constraints of the existing building (e.g. plantroom size, ventilation duct distribution routes, etc), but for amplified performances, a higher level of ventilation system noise would be acceptable. The NR limit will be reviewed during Stage 4 once the ventilation system design is fully developed.

3.3 BUILDING SERVICES ENVIRONMENTAL NOISE

In line with BREEAM Pol5, we propose a target noise limit set '5 dB below background' at nearby noise sensitive receptors (NSRs). If this is not achievable, a limit of 'no higher than background' should still be acceptable on the basis that it is described as a 'low impact' in BS 4142. Based on the results of the baseline survey, the limits are as follows:

Time period	Measured background sound level $L_{A90,T}$ (dB)	Rating sound target* at NSR, $L_{A,r}$ (dB)
Daytime (0700-2300 hrs)	51	46
Night (2300-0700 hrs)	46	41

* A 5 dB relaxation on the limit is considered acceptable if it is not possible to achieve the target at all NSRs

Table 2: Plant environmental noise limits

3.4 INTERNAL SOUND INSULATION CRITERIA

The internal sound insulation between most spaces will not be affected by the proposed refurbishment, with the following exceptions:

- 1) The client has expressed a wish to improve the sound insulation between the 2nd floor meeting rooms and the auditorium. We have explained that this issue could be slightly improved at high frequencies by upgrading the doors, but the overall performance is dominated by low frequency noise, an issue which is beyond the scope of this project. Therefore, it does not make sense to set an on-site performance target, and the design should instead aim to make the best practicable improvement.
- 2) A new fixed partition is proposed between two 2nd floor meeting rooms which are currently separated by a moveable partition. We propose an on-site sound insulation target of $D_{nT,w}$ 45 dB for this partition.
- 3) The proposed layout includes moveable partitions between the Multi-Purpose Room and the Auditorium. When tested on-site, moveable walls typically fall well short of their laboratory rating therefore there is limited benefit to setting an on-site sound insulation target. Instead, we will work with the quantity surveyor to specify the best affordable moveable wall sound insulation specification and to provide junction detailing which maximises its performance. **The client needs to be aware that no moveable wall will enable total flexibility of use and the venue staff will need to manage bookings to avoid noisy activities in one space whilst noise-sensitive activities take place in the other.**

3.5 ROOM ACOUSTICS CRITERIA

The baseline survey showed that the reverberation time in the main auditorium was around 0.7 seconds. This is slightly low for a theatre of this size, but the room acoustic baseline assessment showed that the room acoustic conditions are generally good (see Section 4) therefore no significant changes are proposed to the existing RT.

In the meeting rooms, we recommend an RT target of 0.8 seconds (averaged between 500 Hz and 2 kHz). Acoustic absorption may be recommended to control reverberation in other spaces as well, but no on-site criteria apply.



4 BASELINE ACOUSTIC CONDITIONS

The Baseline Acoustic Survey Report (ref: 26CC03-FOR-10-XX-T-OJ-0001) contains the full results of internal and external measurements made at the existing building. A summary of the key results is as follows:

4.1 AUDITORIUM INTERNAL NOISE MEASUREMENTS

A series of internal noise measurements were made at 15 positions within the auditorium to quantify the sound levels with the existing ventilation system on/off and the sound levels from the existing in-house PA system. The overall spatial averages are shown in the table below, under the following test arrangements:

- a) Background noise (L_{A90}) measurements (ventilation system running at normal duty)
- b) Background noise (L_{A90}) measurements (ventilation system and bar refrigerators off)
- c) Sound pressure level (L_{Aeq}) measurements with the PA system at 'live concert' noise levels.

Internal measurement position	Test (a) L_{A90} (vent on)	Test (b) L_{A90} (vent off)	Test (c) PA system L_{Aeq}	Variation in PA system L_{Aeq}
Spatial average (ground floor)	38.6	29.5	106.5	+0.7
Spatial average (balcony)	37.6	28.7	104.9	-0.9
Spatial average (whole hall)	38.1	29.1	105.7	+2.9 / -2.5
* Measurement was of AV server noise (not included in overall averages)				

Table 3: Internal measurement results

Key observations from the room noise measurements are:

- The ventilation system is much noisier than it should be for a professional theatre.
- Even without the ventilation system, background noise in the hall is 5-10 dB above the target
- The equipment racks in the stage wings are very noisy.
- The variation in PA system dBA levels around the room is significant, particularly at mid/high frequencies under the balcony (see Figure 3). These frequencies are critical for clarity/brightness and explain why the sound was 'muddy'/quiet under the balcony but 'bright'/loud elsewhere in the room.

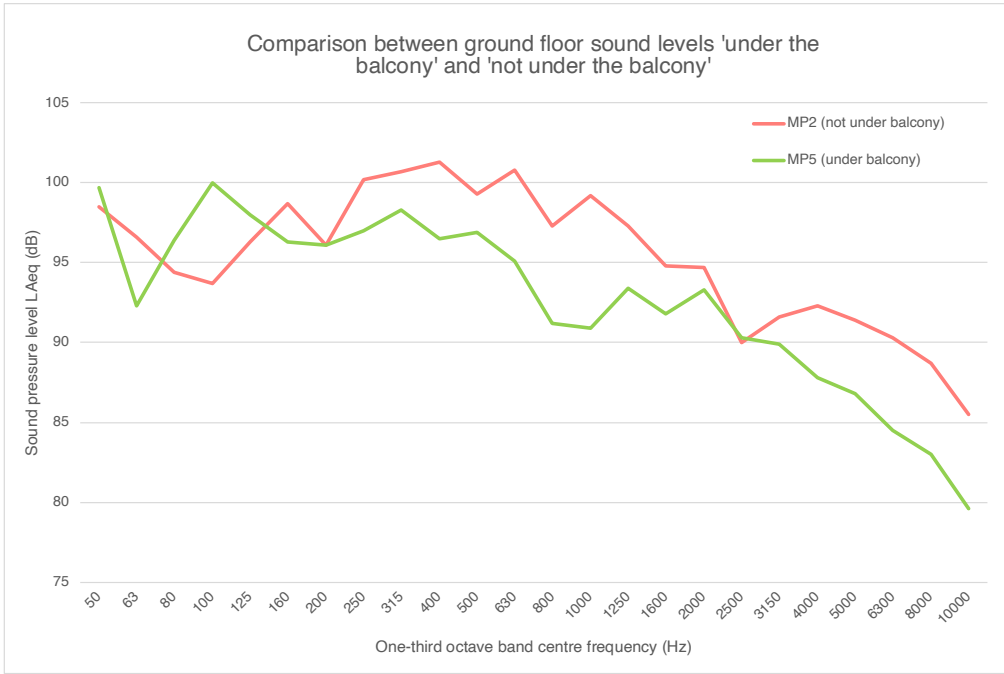


Figure 3: Comparison between PA system levels at different frequencies on the ground floor of the auditorium

4.2 NOISE LEVELS WITHIN THE MEETING ROOMS

Whilst the concert was taking place, a measurement was made of the sound pressure levels in the 1st floor meeting rooms, where the client has identified issues with noise disturbance. The results are illustrated in Figure 4, alongside a typical background noise spectrum for a meeting room and an approximate 'inaudibility curve', showing how low the concert noise would need to be to be inaudible in the meeting room.

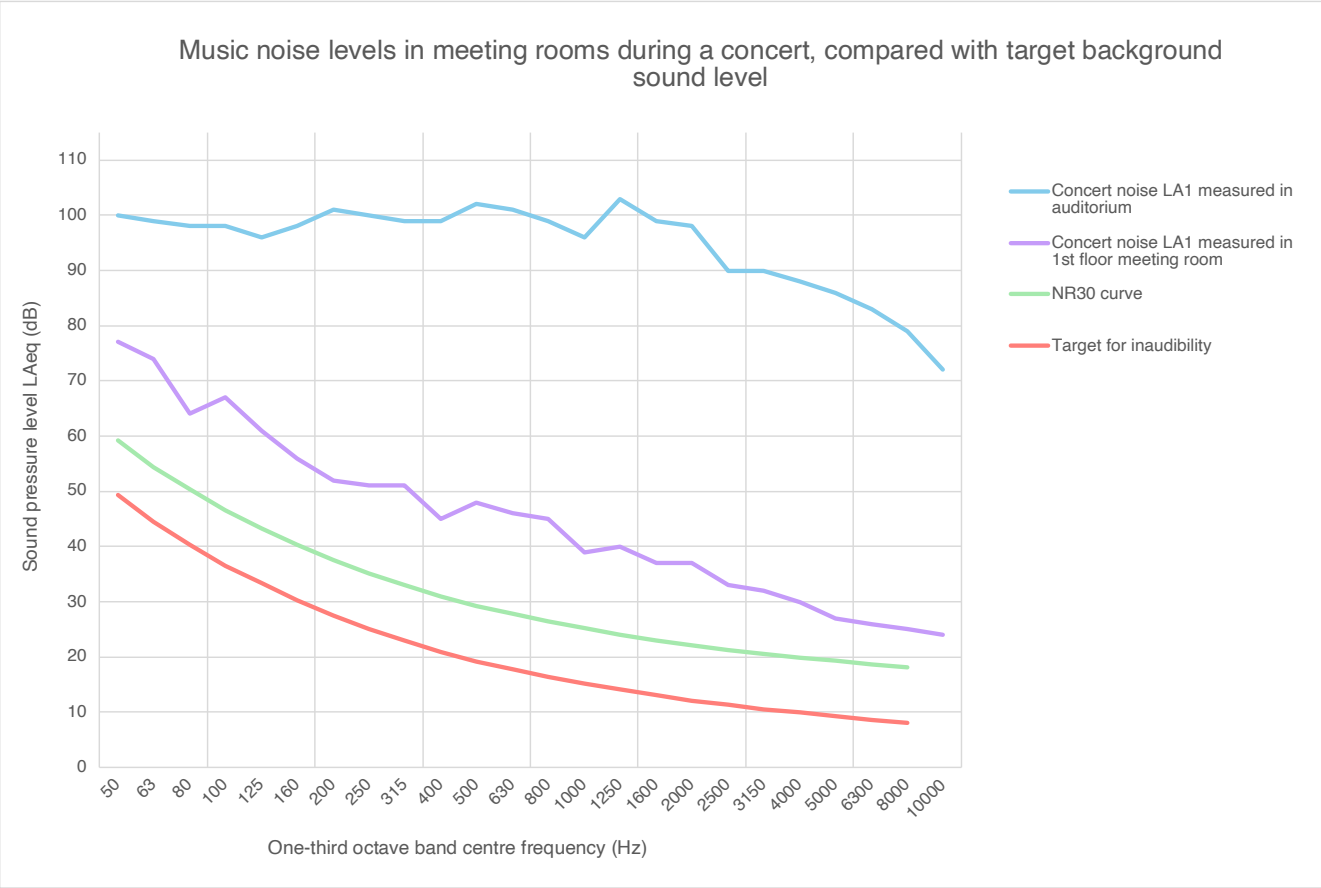


Figure 4: Concert noise levels measured in the 1st floor meeting rooms and comparison with room noise rating (NR) curve

The results show the sound insulation between the auditorium and meeting rooms is quite good, however the noise level in the meeting rooms is still well above the NR curve and the target for inaudibility. A reduction of around 25-30 dB would be required to achieve inaudibility and this is unlikely to be practicable at low frequencies due to structure-borne noise transmission between the spaces, which cannot practicably be mitigated. Mid-high frequency sound insulation could be improved by replacing the existing doors with better acoustic doors/seals.

4.3 ROOM ACOUSTIC MEASUREMENTS

The room acoustic measurement results are shown on the reverberation time (RT) plot in Figure 5. Key findings from the room acoustic measurements are that RT is quite short across all frequencies with a particularly pronounced 'roll-off' at high frequencies. This type of RT shape, coupled with a short overall RT can be indicative of a lack of musical 'brightness' or 'clarity', but it also indicates that there are no major room acoustic anomalies (e.g. flutter echoes, focussing or slap-back echoes). This would make it easier for the sound engineers to achieve a well-balanced sound.

There is not a much variability between the RT in the different locations we measured. This is surprising given that the under-balcony positions have a very low acoustically absorptive ceiling, although it is not a bad thing – a uniform RT throughout the room is desirable.

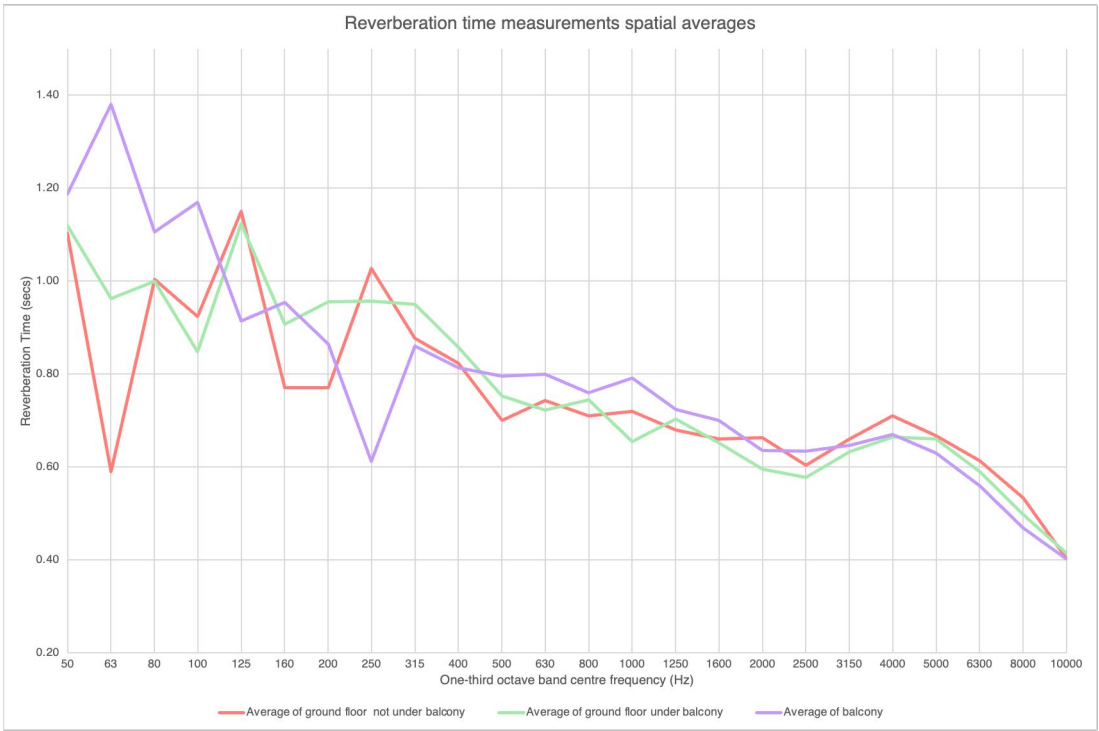


Figure 5:
Auditorium RT
measurement
results

4.4 SUBJECTIVE ASSESSMENT OF THEATRE SOUND QUALITY

A subjective assessment was made of the sound quality during the concert. In general, the sound was considered to be relatively high quality, with the sound system providing clear, well-balanced and undistorted music in most parts of the room. Room acoustic conditions did not have a noticeably negative impact on the sound quality, which was generally considered good for an amplified rock concert. The only exceptions were:

- 1) The ground floor area under the balcony overhang, where a very distinct drop in sound level and sound quality occurs as soon as you step under the balcony. The effect is worst at the rear of the hall, where the sound quality is more ‘muffled’ and there is a lack of clarity. The venue has sought to address this issue with additional speakers hung underneath the front edge of the balcony and it may be possible to improve the issue by increasing the sound level of these units, however the issue is primarily due to poor room acoustic design rather than any deficiency in the PA system design.
- 2) On the 1st floor balcony, the sound level varied significantly between the central area and the sides, with the level being slightly too high and with a less agreeable balance in the seats on the sides of the balcony. This is likely to be due to two factors:
 - a. The 1st floor L-R PA system speakers are located quite close to the side walls and there is no centre speaker, meaning that the system is unable to deliver an even distribution of sound across the entire balcony area.
 - b. The wall and ceiling finishes around the balcony are acoustically reflective and the walls are parallel, meaning that the sound levels increase as one gets closer to the reflective walls and flutter echoes off the parallel walls may be adversely affecting the sound quality.

Being a fairly noisy amplified concert, the ventilation system noise was not an issue and was not clearly audible at any point. However, it is likely that it would be more problematic during a quieter performance e.g. a live theatre or unamplified (e.g. classical) music performance, when the relatively high noise levels would provide unwanted noise masking/background noise during quieter moments on stage. We discussed the use of the auditorium with the theatre technicians and they confirmed that they do not use the hall for unamplified speech or music.

4.5 ENVIRONMENTAL NOISE MEASUREMENTS

External baseline noise measurements were undertaken between 21-24 March 2024 at three locations outside the building (OP1-3), representative of the location of the three nearest NSRs. The measurements were repeated between 20:00 and 20:45 whilst a ‘typical noisy event’ took place in the theatre (live band: The Blockheads). An unattended noise logger was left running at the site at position OP4 between 05 and 09 May 2024. The key results at each position are shown below and in the time history graph in Figure 6.

Location/Time	Time	Period T	L _{Aeq,T} (dB)	L _{Amax(F)} (dB)	L _{A90,T} (dB)	Photo
OP1 Car park adjacent to Theatre, representative of the façade of the church. Soundscape dominated by motorway traffic noise from the north.	Daytime (no event noise)					
	12:12	15min	57	74	54	
	Evening (during live concert)					
	21:16	5min	53	63	51	
OP2 Plaza in front of the Theatre, representative of the location of the residential flats above the shopping centre. Soundscape dominated by both motorway traffic noise from the north and water in the river.	Daytime (no event noise)					
	12:28	15min	57	72	53	
	Evening (during live concert)					
	21:22	5min	50	57	49	
OP3 Prior Street, on the opposite side of the river to the east of the Theatre, representative of residential terraced houses. Soundscape dominated by traffic on the Prior Street plus distant motorway traffic from the north.	Daytime (no event noise)					
	12:57	15min	66	82	61	
	Evening (during live concert)					
	21:30	5min	59	72	53	
OP4 Unattended noise logger position on the 1 st floor balcony on the front of the Theatre building. Soundscape dominated by motorway traffic noise from the north plus activity in the square and wider town centre.	Day	18hrs	58	78	51	[No photo]
	Night	6hrs	50	73	46	

Table 4: Noise survey results summary

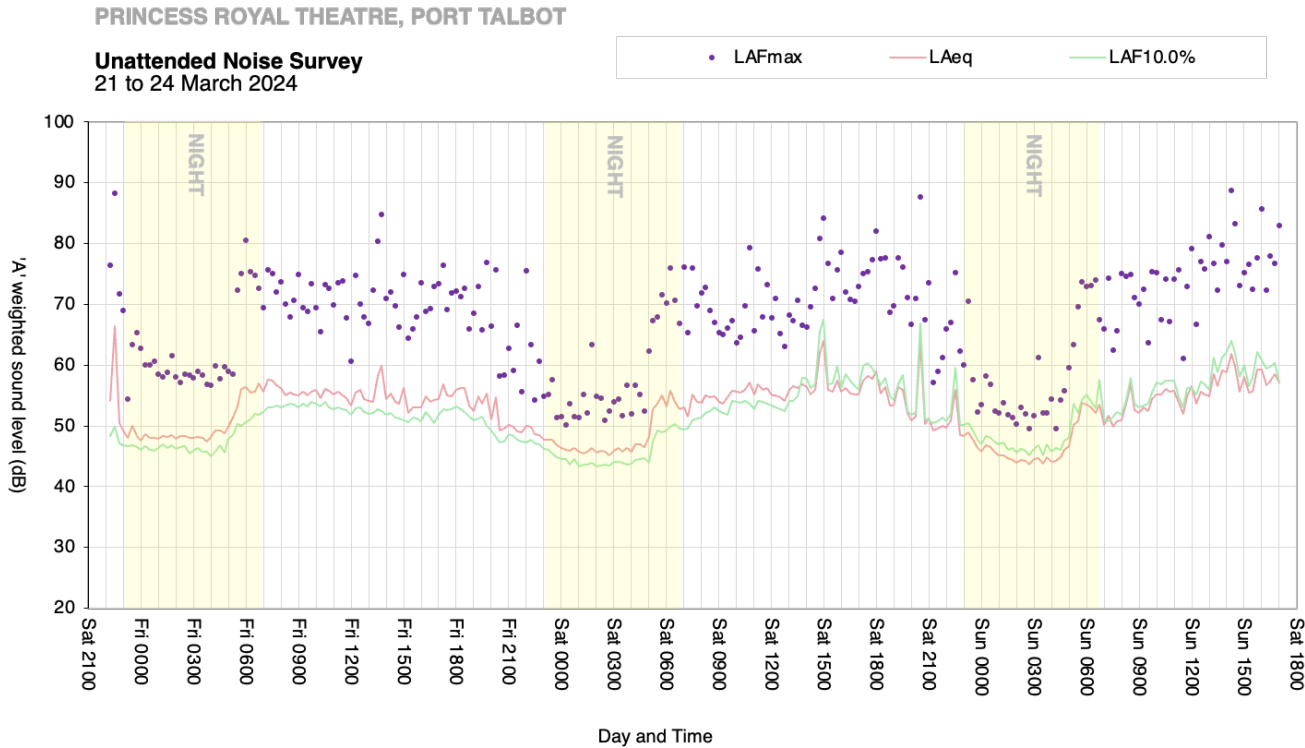


Figure 6: Time history graph for noise logger results at OP4

4.5.1 CONCERT NOISE BREAK-OUT

During the concert, music was just audible at locations OP1 and 2, which are in close proximity to the theatre, however it did not dominate the soundscape at either location. Instead, the soundscape was dominated by traffic noise from the M4 and the sound of water in the river.

At OP3, music was not clearly audible and the soundscape was dominated by traffic noise from the M4 (constant) and from local roads (more sporadic).

In general, our subjective assessment was that entertainment noise break-out from the auditorium would be unlikely to result in any significant adverse noise impacts at any of the NSR locations.

4.6 SUMMARY OF KEY BASELINE ISSUES AND NEXT STEPS

Issue	Issues to be addressed	Stage 3 progress and next steps
Music noise break-out	During the concert, music was audible at two NSR locations close to the theatre, but it did not dominate the soundscape at either location. At the third NSR location, music was not audible. Our subjective assessment is that noise break-out is unlikely to result in significant adverse noise impacts at NSRs.	Opportunities to reduce noise break-out from the auditorium have be taken where practicable (see Section 5.1) and the proposals are in line with the ‘no worse than existing’ brief.
Auditorium internal noise levels and noise break-in	The ventilation system dominated the noise levels in the auditorium. At around 40 dBA, it is much noisier than it should be for a professional theatre (typically targeting 20-25 dBA). As a result, the venue has to mic up performers, even for theatre performances which would not normally use speech amplification.	Initial noise assessment of the ventilation system design raised concerns with the proposed FCUs. This needs to be resolved asap during Stage 4 to ensure the proposed design strategy is capable of compliance.
	With the ventilation system off, background noise was around 30 dBA, some 5-10 dBA above the target. Traffic noise break-in from the M4 was audible, but this type of ‘steady state’ noise is less of a concern than the seagulls which were audible and the poorly lagged rainwater pipes running in the ceiling void/wings (not audible during the survey but understood to be noisy during heavy rainfall).	Proposals have been developed to upgrade the soffit above the stage and to ensure the new get-in door provides a high level of sound insulation. The design team is aware of the need to address rainwater pipe noise and this needs to be further developed during Stage 4.
	Equipment racks in the wings are very noisy and would be a problem without the ventilation noise.	The proposed plans show the racks being relocated remote from the auditorium.
Auditorium room acoustics	Variation in PA system dBA levels around the room is significant, with a drop-off in mid/high-frequency noise levels under the balcony. These results help explain the concert sounding ‘muddy’/quieter under the balcony, in comparison to the ‘brighter’/louder sound elsewhere in the auditorium.	Balcony overhangs cannot be changed within the scope of this project, so a strategy has been developed which aims to use surface finish changes to make a slight improvement to the situation under the balcony (see Section 6).
	The RT is short with a particularly pronounced ‘roll-off’ at high frequencies. This can indicate a lack of ‘brightness’/‘clarity’ but it also indicates that there are no major unwanted room acoustic anomalies. RTs are consistent across the room, which is good.	Strategy under development with further refinement to be done in Stage 4 (see Section 6).
Sound insulation to meeting rooms	There is a good level of sound insulation between the auditorium and meeting rooms, however the concert noise in the meeting rooms was still at a level which would be problematic for meetings.	Door upgrades are proposed (see Section 5.2.3) but no significant improvements are practicable within the scope of this project.

Table 5: Key results and next steps



5 BUILDING ENVELOPE SOUND INSULATION

The EHO has not cited any complaints about noise from the venue and our baseline assessment concluded that there is no need to provide significant upgrades to the existing building envelope to control noise break-out.

Noise break-in to the auditorium is a significant issue, as demonstrated by the baseline survey results which show unoccupied noise levels of around 29 dBL_{Aeq} even when the ventilation system is switched off. Each of the weaknesses we have identified in the building envelope are addressed below.

5.1 RETAINED/REPLACED BUILDING ELEMENTS

5.1.1 RETAINED AUDITORIUM ROOF

The existing roof build-up appears to comprise roof slates mounted on PIR foam with no ceiling underneath. The auditorium ceiling is unlikely to not provide significant enhancements to the sound insulation because it is not continuous and contains open sections to accommodate lighting rigs, ventilation grilles etc.

A sound insulating plasterboard ceiling fixed to the underside of the PIR insulation is proposed in the outline architectural specification, comprising 2 x 15 mm Soundbloc plasterboard suspended on a light steel grid, with at least 100 mm mineral wool laid in the void above. This is a suitable upgrade acoustically and should provide a substantial improvement in sound insulation.

We have discussed the possibility of improving the sound insulation of the auditorium ceiling when it is replaced, by closing up the open sections, but we understand that the intention is to keep the design as per existing in order to allow for stage lighting to be concealed within the ceiling.

Rain noise on roof (not including rainwater pipes running through the auditorium) has not been identified as a significant issue with the existing roof therefore no specific measures are proposed to address this in the auditorium, although the stage soffit lining will help to some degree.

5.1.2 RETAINED AUDITORIUM WALLS

No acoustic issues have been identified with the existing auditorium walls, which appear to be a cavity masonry construction, therefore no sound insulation upgrades are required to the existing auditorium walls.

5.1.3 REPLACEMENT AUDITORIUM WINDOWS/DOORS

The west-facing auditorium doors and windows are a significant weak-point in the building envelope. The proposed plans include new lobbies and storerooms which will act as a buffer for these locations. Recommended acoustic ratings for the walls and glazing were provided in the Stage 2 acoustic report and these have now been incorporated into the architect's Stage 3 Acoustic plans.

5.2 NEW EXTENSIONS

5.2.1 NEW FRONT-OF-HOUSE EXTENSION

No significant noise break-out issues because the auditorium is generally lobbied from this space. The proposed glazing and cladding materials in the architect's Stage 3 plans are acceptable acoustically.

5.2.2 NEW BACK-STAGE EXTENSION WALLS

The proposed back-stage extension will form the building envelope separating the stage area from the noise of the M4 and the walls and roof need to provide sufficient sound insulation. During Stage 3 we have reviewed the sound insulation performance of the proposed build-up and recommended that the internal drylining be changed to 2 layers of plasterboard (with additional plywood or other similar internal finish, if required for robustness). Although there is some significant uncertainty in calculating the sound insulation performance of this type of wall, we are confident that the proposed build-up should be capable of achieving close to the target sound insulation of $R_w + C_{tr}$ 55 dB without any upgrades.

5.2.3 NEW BACK-STAGE EXTENSION ROOF

The proposed roof build-ups for the new extension comprise a Bauder green roof system. We have contacted Bauder to source sound insulation performance figures but they are not available for this exact buildup. We have calculated the sound insulation performance based Bauder's approximate surface mass for each layer in the system and the calculations suggest the performance will exceed the required sound insulation performance, therefore the proposed build-ups are likely to be acceptable acoustically. We will continue to chase Bauder for further test data during Stage 4.

5.2.4 NEW BACK-STAGE EXTENSION GET-IN DOORS

The new get-in door does not face the M4 but it will still be required to provide a good standard of sound insulation. The current plans show this as a roller shutter.

During Stage 3 we have worked with the architect and a specialist supplier from ClarkDoor and it has been agreed that a double hinged doorset is the best practicable solution to meet the client brief for staging access and working with the site constraints. ClarkDoor have advised that this type of door is capable of providing sound insulation performance of around R_w 53 dB, which falls slightly short of our recommended target of R_w 55 dB, but is acceptable given the site/access constraints and the fact that it is likely a significant improvement on the existing roller shutter door.

6 INTERNAL SOUND INSULATION

6.1 INTERNAL PARTITIONS AND DOORS

We have not identified any areas where acoustic upgrades are required to retained existing walls.

Sound insulation performance recommendations for new internal walls and doors were provided on a set of markups at Stage 2 and these recommendations have been incorporated into a set of Acoustic Plans prepared by the Architects during Stage 3. We have reviewed the Acoustic Plans and our comments are included in the Appendix to this report.

6.1.1 PARTITION BUILD-UPS

Partition build-ups which are capable of meeting the recommended ratings have been developed by the architect during Stage 3, based on British Gypsum laboratory tested systems. We have reviewed the proposed build-ups and have not identified any acoustic issues. All acoustic partitions should be built full-height from slab to slab and service penetrations should be avoided where possible.

6.1.2 INTERNAL DOORS

In most areas, standard acoustic doorsets (R_w 30 dB) are acceptable, but for some areas, a higher specification is recommended:

- Auditorium and Studio Theatre doors are generally lobbied and these are specified as R_w 35 dB.
- Where no lobby can be provided, an R_w 40 dB door is recommended on the basis that this is likely to be the upper limit for a door which has a reasonable opening force for use by the public when accessing the auditorium.

It should be noted that where lobbies cannot be incorporated, there will be significant levels of sound break-out from the auditorium when people open the doors to enter/exit.

In addition to the acoustic rated doorsets, we recommend acoustic linings be provided on the ceilings and preferably also the walls of the sound lobbies, to reduce noise break-out through the lobbies when one or both sets of doors are open.

Please note that the door sound insulation ratings apply to the doorset, not just the door blank. All acoustic doorsets will require full perimeter and threshold seals in order to meet the required sound insulation ratings.

6.2 FLOORS/CEILINGS SOUND INSULATION

We have not identified any areas where retained existing floors require acoustic upgrades and the only new structural floor separates one circulation space from another, therefore no specific acoustic requirements apply.

Where new floor finishes are proposed, a resilient floor finish may be required for hard-floored spaces on Level 1 and 2 which are located above a noise sensitive space. We have reviewed the proposed floor finish plans and have not identified any areas where this issue occurs, therefore at this stage no resilient acoustic floor finishes or underlays are required.

6.3 FLANKING TRANSMISSION

Flanking noise transmission must be controlled via provision of suitable details. In general, the sound insulation performance of any flanking path must be at least 10 dB better than the sound insulating element around which the sound is flanking. No specific flanking risks have been identified at this stage but this should be reviewed during Stage 4.

7 ROOM ACOUSTICS

7.1 AUDITORIUM ROOM ACOUSTIC MODEL

During Stage 2 we built a 3D computer room acoustic model of the existing auditorium to investigate options for changes to the room design. Full details of the modelling exercise are provided in the Stage 2 Acoustic Report and a summary of the key issues is as follows:

7.1.1 BASELINE MODEL

- **General uncertainty:** The model has been calibrated to match the existing measured room acoustic conditions, but there is always uncertainty in modelling existing auditoria because the acoustic characteristics of existing surfaces have to be estimated based on 'best fit' lab-tested surfaces.
- **Surfaces providing significant absorption:** The model suggests the existing seats, timber wall panels and under-balcony ceiling appear to provide the majority of acoustic absorption. The main auditorium ceiling appears to be a ceramic tile, provide minimal absorption.
- **Comparison with design target:** The baseline model shows the existing conditions are close to the target RT. Only the high frequencies fall slightly outside of the target range, possibly due to various furniture being stored in the auditorium during the measurements. Once the furniture is removed, we expect the RT to be slightly higher across all frequencies.

7.1.2 PROPOSED CHANGES TO THE AUDITORIUM

- **The proposed changes to the ground floor layout** are positive because they will reduce the amount of floor space with the worst room acoustics and make the room slightly more symmetrical.
- **Opening up the back-stage wall** to access the new back-stage extension was found to have a neutral effect on the room acoustics.
- **Replacing the existing timber wall panels** was found to have a neutral effect, provided that the new panels provide similar acoustic absorption to the existing finish. Further details are provided in Section 7.1.3.
- **Changing the main ceiling from a ceramic tile grid to timber acoustic panels** was found to have a neutral effect, provided that the new finish provides the required level of acoustic reflections to match the existing ceiling. Further details are provided in Section 7.1.4.
- **Changing the ceiling under the balcony to a timber finish** has a potentially positive effect on the room acoustics under the balcony provided that the new finish is not as absorptive as the existing ceiling tiles. Further details are provided in Section 7.1.4.
- **The existing stage drapes have a significant effect on room acoustics and additional drapes could offer further improvements:**
 - o Providing a location to stow the curtain from the back stage wall has a potentially positive effect as it could improve projection from the stage, which is good for some uses, but the model suggests that it increases the RT outside of the target range. Drapes along the stage wall are beneficial for amplified music so should be left in place for those types of event.
 - o Adding heavy drapes around the walls at ground floor level was found to have a positive effect as it provides additional acoustic flexibility (e.g. drapes can be deployed for amplified music, but stowed for other events where a low RT is not so important).

7.2 REFURBISHED TIMBER PANELLING

During Stage 3 Morgan Sindall undertook investigations into the existing timber wall panels which confirm that they are a veneered chipboard panel with open tubes running vertically (see Figure 10) set in front of a void of circa 25-50 mm, with no acoustic absorption in the void.

When calibrating the acoustic model, we identified a Topakustik slatted panel with a 200 mm void plus mineral wool infill as the 'best fit' approximation for the existing wall linings (www.topakustik.ch/en/products/classic/topakustik-classic-18-3-m). However this panel would not achieve the same performance without the mineral wool and 200 mm void behind, therefore the model calibration is unlikely to be as good as was predicted at Stage 2.

This increased uncertainty leads us to recommend a zone be provided on the auditorium walls (and in the costplan) for 'tuning absorption', where additional acoustic treatments can be provided post-construction, should the room acoustic conditions not match the predicted performance in the model (see Section 7.1.5).

The Stage 3 architectural specification proposes a micro-perforated (rather than slatted) wall panel as a replacement for the existing panels. We have reviewed the acoustic data for the different micro-perforated options and we believe the most suitable is the 1.8/1.8/0.5 pattern, which achieves Class A absorption when installed with 40 mm mineral wool on a 60 mm void. The absorption performance of this product is not as good as the acoustic model predicted was required at low frequencies, however following the site investigations, we do not believe the existing panels are providing the same level of absorption, therefore this option is considered suitable subject to provision of an allowance for tuning absorption (see Section 7.1.5).



Figure 7: Cut-away view of existing timber wall panels

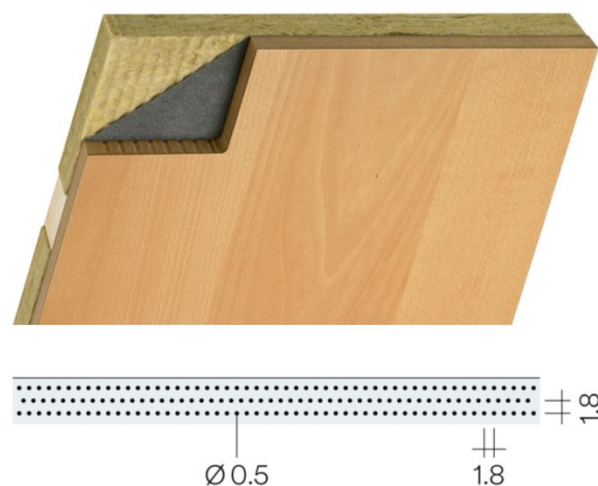


Figure 8: Topakustik Microperforated 1.8/1.8/0.5

7.3 AUDITORIUM CEILINGS

7.3.1 UNDER-BALCONY CEILING

Based on a visual inspection, we have assumed the existing ceiling underneath the balcony comprises an absorptive ceiling tile e.g. mineral fibre with Class A absorption and a varying depth void above (depth depending on the height of the raked seating structure above).

The ceiling underneath the balcony should be changed to a surface which provides slightly less absorption than the existing mineral fibre tile. This could be achieved with a mix of some perforated and some non-perforated timber panels, or with a 'mid-range' perforated panel throughout.

During Stage 3 the architect has suggested a Topakustik micro-perforated timber panel. We have reviewed the acoustic data for the different micro-perforation options and the most suitable is the 3/3/0.5 pattern, which achieves Class C absorption. During Stage 4 we will include this option in the updated room acoustic model and check suitability.

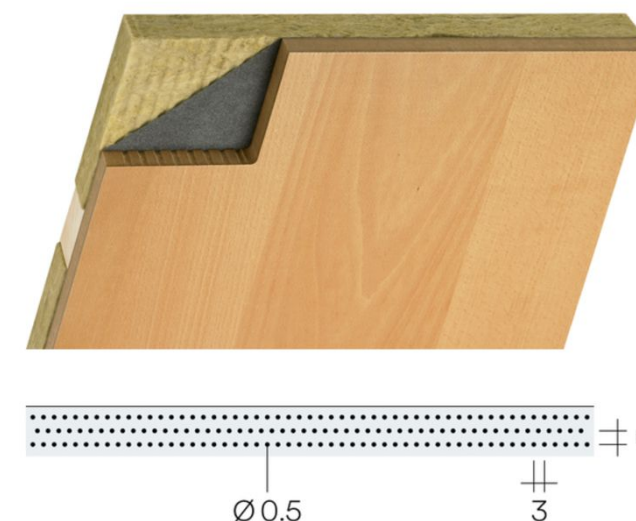


Figure 9: Topakustik Microperforated 3/3/0.5

Despite the potential room acoustic improvements that can be achieved via the proposed architectural changes under the balcony, **it will still be critical that the PA system design for the refurbished theatre takes account of the inherent limitations of the room acoustics under the balcony.** A system with a larger number of small loudspeakers distributed throughout the under-balcony area is likely to offer the best coverage and can be used to mitigate the 'muddy' sound quality which is currently experienced in this space.

7.3.2 MAIN AUDITORIUM CEILING

Whilst the ceramic tile ceiling to the main room volume would not provide significant levels of absorption in itself, it is likely to be permitting a degree of low frequency sound to pass through the tiles and into the ceiling void, thus providing a degree of low frequency absorption in the room. On this basis we have modelled the ceiling as providing equivalent absorption performance to a single sheet of solid plasterboard with a void behind.

The architect has expressed a preference for a timber acoustic panel ceiling. At this stage we recommend the costplan includes an allowance for a similar product to the Topakustik panels proposed for the under-balcony ceiling. During Stage 4 we will explore product and performance options in the acoustic model and work with the architect to develop a suitable product specification.

7.4 TUNING ABSORPTION

As described above, the inherent uncertainty in the acoustic modelling of existing materials means we cannot predict the exact room acoustic conditions, therefore **we recommend an area of ‘tuning absorption’ be allowed for on the architectural plans and in the costplan.**

The suggested location for the absorption zones is on the rear walls of the auditorium and ground and balcony level, as marked up on the floor plans below:

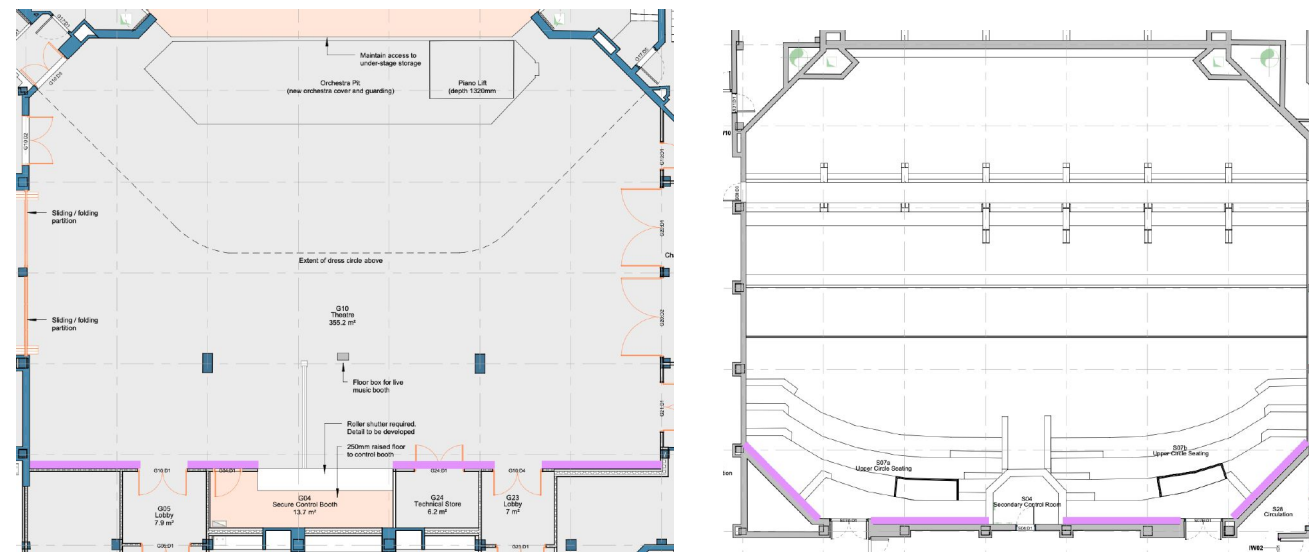


Figure 10: Suggested acoustic tuning absorption zones on ground floor (L) and balcony (R) rear walls.

We recommend allowance be made for an acoustic panel absorber with a worst-case depth of 200 mm formed by timber battens, 50-100 mm mineral wool in-fill and a finish comprising either solid or perforated plywood.

The above recommendation is a ‘worst-case’ assumption: It is possible that the auditorium room acoustic conditions are acceptable without the provision of any of the tuning absorption, or only part of the area may be required. Therefore this issue should be treated as a risk item with a provisional sum allocated to it, rather than a fixed cost.

7.5 CIRCULATION AND SOUND LOBBIES

A Class A absorptive ceiling is recommended in all circulation spaces and sound lobbies. We have reviewed the Stage 3 RCPs which show a mineral fibre lay-in-grid ceiling in most circulation spaces. This is a suitable product to meet the acoustic absorption recommendations.

Acoustic wall linings are also recommended for sound lobbies serving the auditorium, but they are not essential (e.g. GB Acoustics Recycled PET Felt Panels: www.gbacoustics.co.uk/products/polyester-acoustic-panels-premium).

7.6 BAR AND FOYER SPACES

We recommend that acoustically absorptive finishes be provided in the bar and foyer space. There is no maximum quantity – the more acoustic absorption that is provided, the better for controlling noise build-up and supporting clear speech and conversation when the space is fully occupied.

The outline architectural specification proposes Hunter Douglas Heartfelt Origami Curve ceiling panels covering the majority of the soffit. This product provides α_w 0.75, which is roughly equivalent to a Class B or C absorber, which is a suitable specification.

Additional absorption will be provided by the soft furnishings, carpet flooring and by the proposal to re-use some of the maple stage flooring to create feature wall panels. In order for the feature wall panels to provide effective acoustic absorption, they should be mounted on a frame of at least 50 mm depth, with 25 mineral wool installed behind the panels and gaps left between the panels to achieve at least 15% open area.

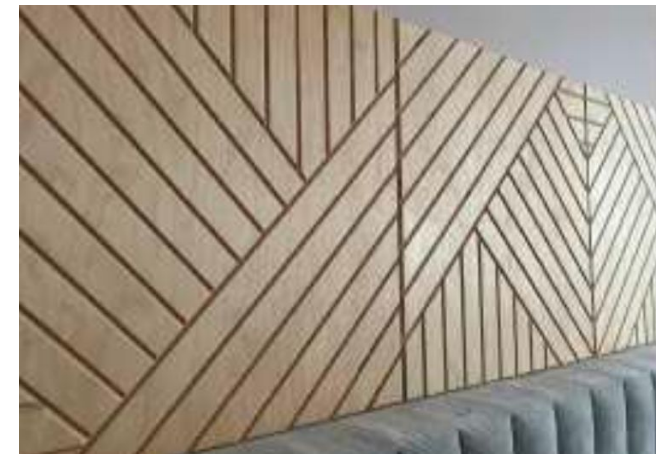


Figure 11: The proposed re-used timber acoustic feature wall will provide effective absorption provided that it has gaps between the slats and mineral wool absorption behind.

7.7 MEETING ROOMS AND OFFICES

The existing meeting rooms have ceilings which appear to be acoustically absorptive. We recommend any replacement ceiling provides Class A absorption over the entire ceiling area.

7.8 TOILETS AND DRESSING ROOMS

There is no requirement for acoustically absorptive ceilings in dressing rooms and toilets, but they would be acoustically preferable over plasterboard ceilings to help with privacy between adjacent rooms.



8 BUILDING SERVICES PLANT NOISE

8.1 NOISE EMISSIONS LIMITS (OUTSIDE THE SITE)

BS 4142 states that a rating sound level equal to or lower than the background noise level at the NSR constitutes a 'low impact'. In line with local policy, we propose to conservatively set the noise limits at '10 dB below background'.

The representative background sound levels at the NSR locations are based on the results from the noise logger at MP1. Therefore, **the building services plant noise emissions limits are 42, 40 and 35 dBL_{A,r} during daytime, evening and night time respectively.**

8.2 NOISE EMISSIONS LIMITS (INSIDE THE SITE)

Although not covered by the above statutory noise limits, it is also important that plant noise does not cause issues inside the existing building. The rooms which are most at risk of noise disturbance from external plant noise have been identified as follows:



Figure 12: Windows on existing building which could be affected by external plant noise.

At this stage we have assumed that these windows are meeting rooms or offices, and that the background sound levels in this location, facing the M4, would be at least as high as those at OP3, i.e. 53 dBL_{A90} (lowest measured level, during the evening). Rating sound levels equal to the background sound level would be unlikely to cause disturbance inside these rooms, therefore **the proposed rating sound limit outside these windows is 53 dBL_{A,r}.**

8.3 VENTILATION STRATEGY

We understand the proposed ventilation strategy for the refurbished/extended parts of the building involves full mechanical ventilation. This strategy should allow the noisy spaces within the building to operate with no open windows or doors required for ventilation, which is important given the relatively high environmental noise levels at the site.

8.4 VENTILATION SYSTEM DESIGN

The mechanical ventilation systems for the Auditorium will probably need to incorporate primary and secondary attenuators on the room side in order to meet the room criteria. It will also need to have sufficiently low air speeds to minimise regenerated noise levels through silencers and terminal components.

Ductwork should be installed to ensure a minimum of regenerated noise and laminar airflow within the system by incorporating:

- gradual bends;
- gradual changes in cross sectional area/long transition pieces, and;
- rectangular ductwork with a near unity aspect ratio.

As a general guide, ductwork should be sized in order to meet the guideline maximum airspeeds shown below:

IANL criterion L _{Aeq} , (dB)	Ducts leading to the room (m/s)	Terminal airspeeds (m/s)
30	3	2
40	5	3
45	6	3.5

Table 6: Guideline air velocity limits for ductwork

8.5 FAN COIL UNITS (FCUs)

We understand that the proposed heating and cooling strategy for the auditorium uses FCUs. This is an unconventional approach for auditoria because the FCUs typically need to be located close to the space they serve, therefore increasing the risk of noise from the FCUs being audible in the auditorium.

We have undertaken initial calculations for FCU selections provided by Hydrock with indicative selections for silencers on the intake/supply of the FCUs and the FCUs being ducted into the auditorium ceilings. The results show that the FCU noise levels are *just* over the proposed NR20 noise limit, due to the casing radiated noise: NR21 on the balcony and NR24 at ground floor level. The NR20 limit is deliberately onerous to allow for the cumulative effect of environmental noise break-in and down-duct noise from the AHU.

At this stage our advice is that FCUs can remain as a potential design solution, but **during Stage 4 Hydrock will need to provide a detailed design, including silencer and equipment selections which are capable of meeting the noise criteria.**

8.6 BUILDING SERVICES DISTRIBUTION

One of the most common causes of acoustic test failures is unnecessary and/or poorly sealed building services penetrations. Wherever possible, all building services distribution should be via corridors, not through acoustic partitions. This concept is illustrated in Figure 13 and applies to ventilation, pipework and electrical services.

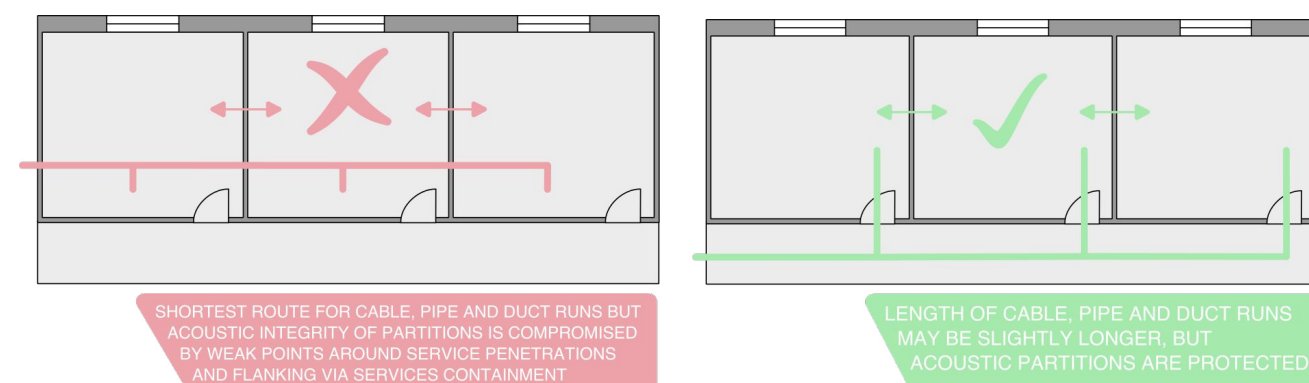


Figure 13: Services distribution should be via corridors, not passing through/over acoustic partitions.

8.7 SERVICE PENETRATIONS

If it is not possible to route services away from acoustic partitions, then acoustic service penetrations will be required and the following general guidance applies:

1. All penetrations should be formed with the minimum practicable clearance.
2. The remaining gap should be packed tightly with mineral wool and sealed using a collar of material with surface weight 9 kg/m² extending at least 50 mm past the edge of the penetration.
3. All interfaces should be sealed using a non-hardening flexible acoustic sealant.
4. If present, any lagging (acoustic or thermal) shall be removed from the section of duct penetrating the partition.
5. Soil and rainwater pipework routed through ceiling voids shall be avoided wherever possible. Where this is not possible, the pipework shall be routed via an acoustic enclosure with acoustic access panels for any rodding eyes.
6. If present, duct/pipe lagging (acoustic or thermal) should only be removed from the section of duct penetrating the element.
7. Pugging bags (e.g. clay/mortar/sand) should be used to fill larger gaps after the installation of electrical services such as cable trays, conduits etc. These should be rammed tightly to completely fill any excess gap.

8.8 FLEXIBLE CONNECTIONS

All ductwork, pipework and conduit should incorporate flexible connections as necessary where:

- connection is made to plant items e.g. at all inlets and outlets,
- they are necessary to prevent noise and vibration transmission to satisfy noise and vibration criteria, and
- connection is made to isolated structures or services components.

Flexible connections shall be installed between two on-axis pipe/duct/conduit sections and should not be used to make up for misalignment. If ducts/pipes/conduit do not coincide on-axis then they should be adjusted to meet this requirement. The flexible connection should be installed so that it is neither stretched nor compressed in comparison to its normal relaxed state.

8.9 PLUMBING AND PIPEWORK NOISE

All pipework running within or near to the Auditoria should be fixed on resilient hangers/mounts to reduce the risk of structure-borne noise being audible in the Hall. Any plumbing or pipework passing through the auditorium should be boxed out with at least 2 layers of plasterboard on an independent frame, with at least 25 mm mineral wool behind the plasterboard.

8.10 PLANT VIBRATION ISOLATION

To control vibration transmission through the building structure, it will be necessary to install vibration isolation to any plant equipment which generates significant levels of vibration (e.g. pumps, fans, condensers, etc).

All internal and external plant containing moving parts should be mounted on a heavy framework or plant base supported by anti-vibration mounts or resilient pads to reduce vibration transfer and structure-borne noise. The selection of appropriate anti-vibration mounts should be based on limiting noise transfer to a level at least 10 dB below the internal noise criteria in any adjacent rooms.

It is particularly important that any noisy or vibration generating plant items located in rooms adjacent to the auditoria, such as the rooftop AHU, are provided with effective anti-vibration mounts and are isolated from any structure or building element which could result in flanking transmission into the auditorium.

8.11 LIFT NOISE

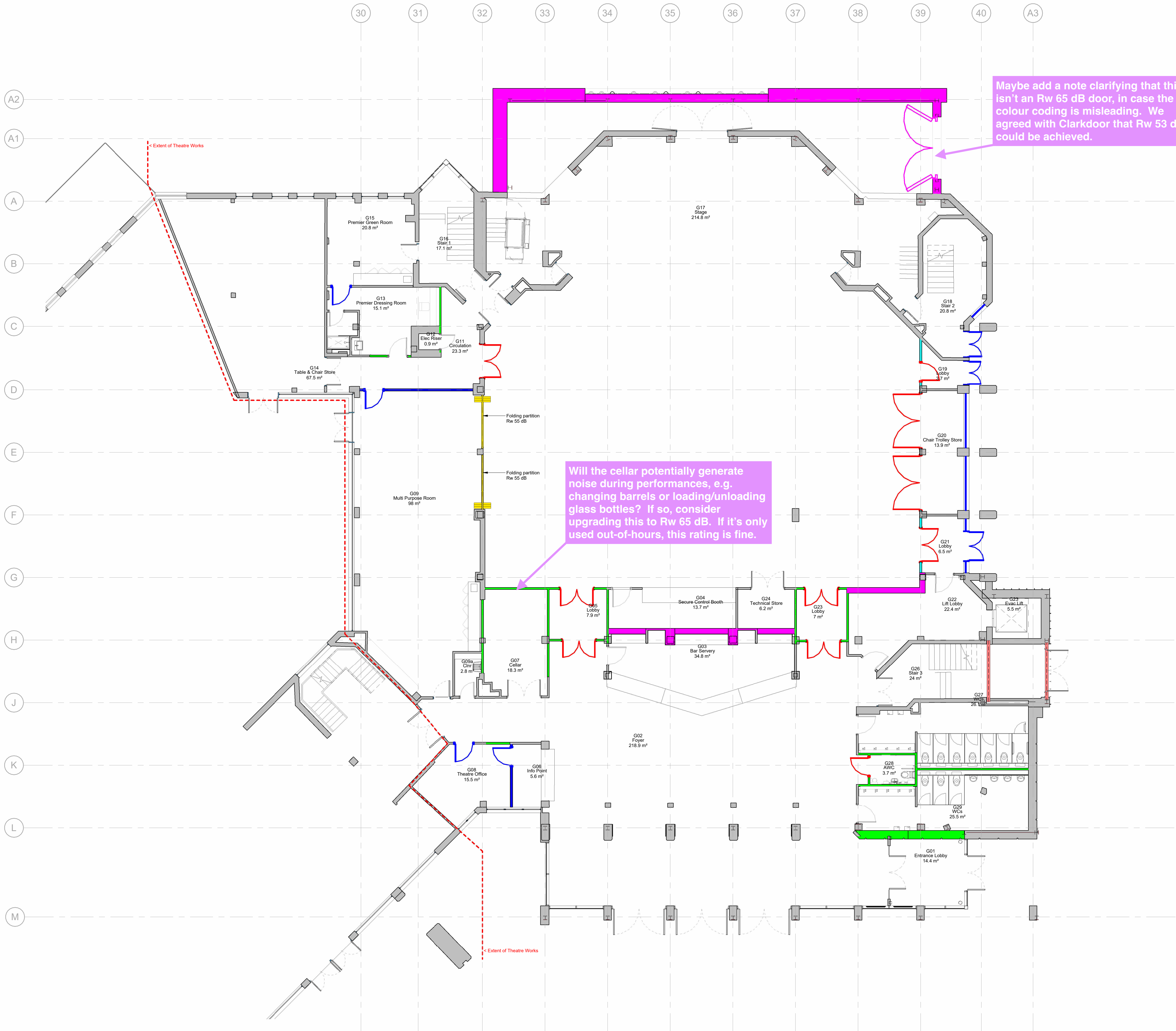
Criteria for noise and vibration levels of lifts are provided in CIBSE Guide D – Transportation Systems in Buildings (2010), and these are considered appropriate. The following is a summary of the criteria:

- Door noise, at 1.5m from the centre of the floor and 1m from the door face, should not exceed 65 dBA. Noise levels in the car at the rated speed in the cycle, should not exceed 55 dBA for lift speeds of 0.5-2.0 m/s and should not exceed 60 dBA for speeds of 2.0-7.0 m/s.
- If applicable, the sound reduction properties of the lift machine room construction, including doors, hatches, ventilation openings etc., should be adequate to prevent the escape of noise at values that exceed the acoustic design criteria for the surrounding areas.
- Maximum (RMS) acceleration level in any 1/3 octave band should not exceed 0.08 m/s² in the horizontal or vertical vibration frequency range 1-80 Hz.

Maximum (RMS) acceleration level in any 1/3 octave band should not exceed 0.1 m/s² in the vertical vibration frequency range 1-80 Hz during acceleration/deceleration and start/stop.



APPENDIX: ACOUSTIC MARK-UPS



Acoustic Strategy Key

Drawing to be read in conjunction with Formant's Acoustic Strategy Report.

Weighted Sound Reduction Index (Rw) of internal partitions capable of achieving the required in-situ sound insulation performance as cited within Formant's Acoustic Strategy Report.

- Rw 40 dB
- Rw 45 dB
- Rw 50 dB
- Rw 55 dB
- Rw 65 dB

- Doorset minimum weighted sound reduction index: 30 Rw (dB)
- Doorset minimum weighted sound reduction index: Rw 35 dB
- Doorset minimum weighted sound reduction index: Rw 40 dB
- Doorset minimum weighted sound reduction index: Rw 55 dB

Existing Internal Doorsets:
Condition survey report to be conducted to all required internal doorsets in order to establish the doorsets current fire and acoustic performance ratings.

Extent of replacement or remedial works to existing doorsets to be determined by specialist sub-contractor in order to achieve the requirements of the Fire and Acoustic strategy.

Existing Walls:
Acoustic ratings indicated are not verified. Acoustician to review construction record data and/or undertake onsite testing to verify walls will reach the proposed ratings.

FORMANT.

Acoustic comments
29 Aug 2024
By: PD

P01	(S4) Stage 3 Issue	19.08.24	BT	HT
Rev	Description	Date	Dr	App
original by	Author	date created	by	by
		07/23/24	Approved	Approver

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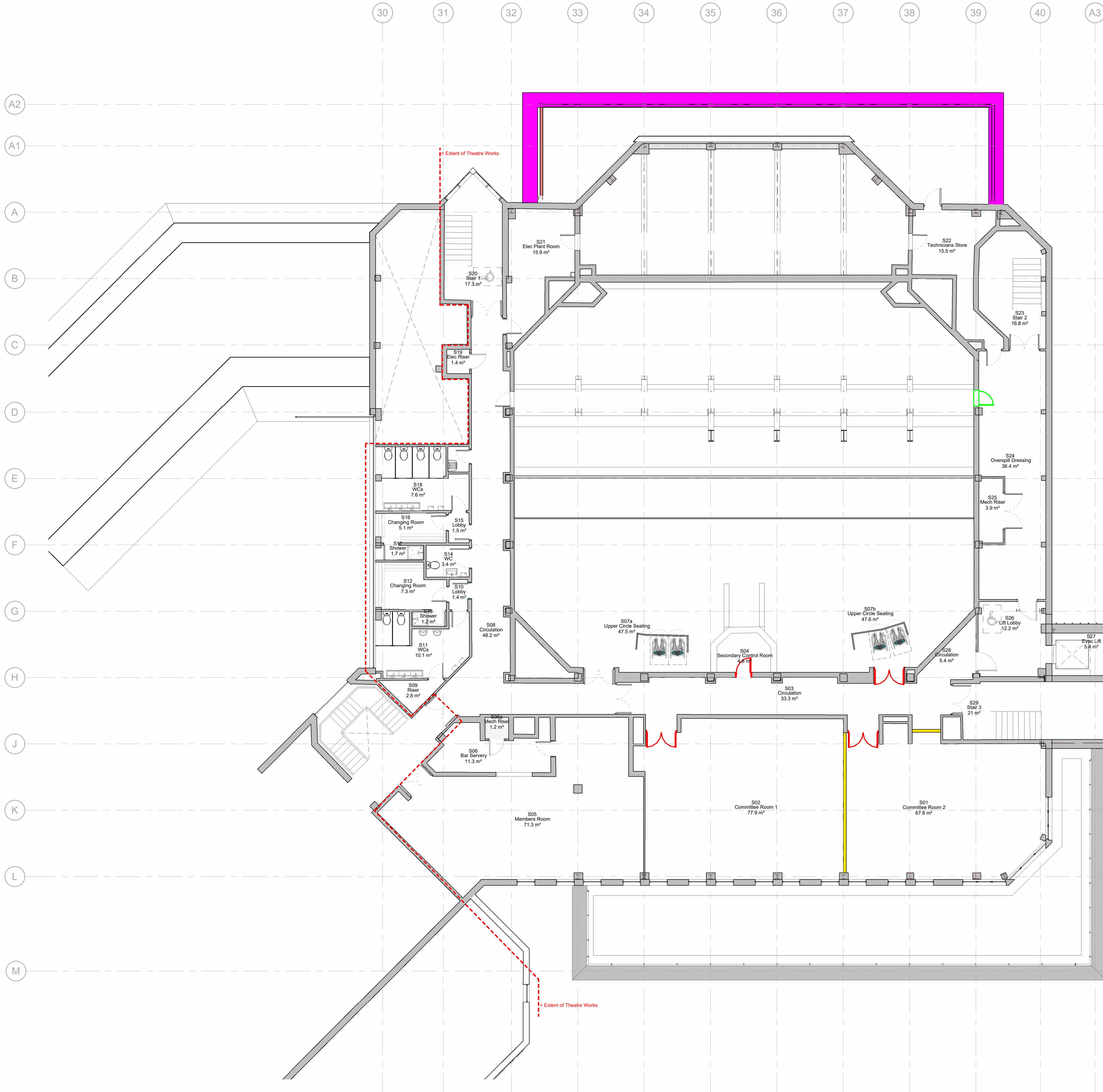
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client name	Morgan Sindall
project	Princess Royal Theatre
drawing	Acoustic Strategy - Ground Floor Plan
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plot date	
project number	2022.00734.000
scale	1 : 100 @A1
drawing number	26CC03-AHR-ZZ-00-DR-A-38100
rev	P01
issue status	S4

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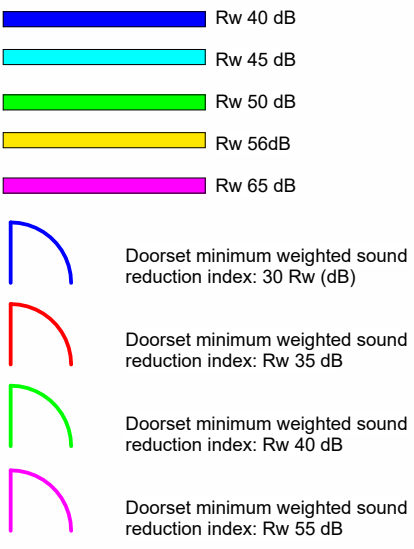
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Acoustic Strategy Key

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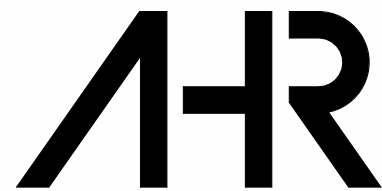
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Acoustic review
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By: PD

No comments

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client name	Morgan Sindall
project	Princess Royal Theatre
drawing	Acoustic Strategy - Second Floor Plan
computer file	110.32.1.110EM_Profile_Folder_redactor\princey\Documents\Revel_FireUse\FireUse\20240823\AHR-ZZ-22-03-A-2000_ArchModel_2ns.tammy.n1
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rev	P01
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