BUROHAPPOLD ENGINEERING

Phase 2 - UCL, Institute of Education

Stage 4 Acoustics Report

0035833

9 September 2022

Revision 01

Revision	Description	Issued by	Date	Checked
00	First issue	GD	06/09/22	ASK
01	Updated Section 5.8 with Planning Condition 4	GD	09/09/22	ASK

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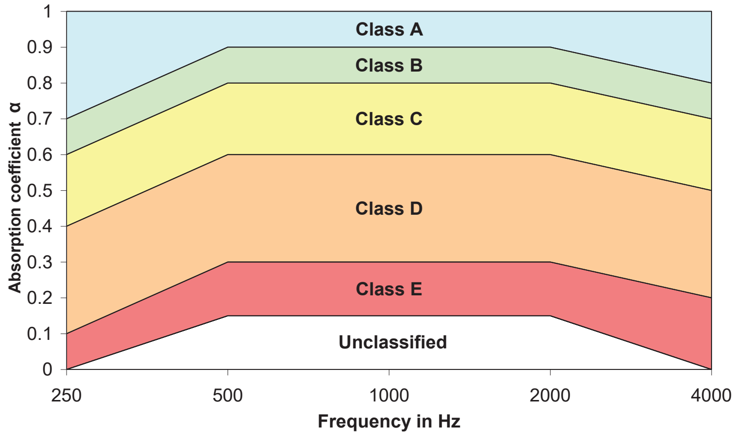
Glossary

Term	Definition
α (α_w)	Sound Absorption Coefficient (Weighted Sound Absorption Coefficient) is a measure of the effectiveness of materials as sound absorbers as defined in BS EN ISO 11654:1997. It is the ratio of the sound energy absorbed or transmitted (i.e. not reflected) by a surface to the total sound energy incident upon that surface. The value of the coefficient varies from 0 (perfect reflector) to 1 (perfect absorber).
A (A_T)	Absorption Area (Total Absorption Area) is equal to the product of multiplying the surface area of a construction (in m^2) and its Sound Absorption Coefficient (α).
Ambient Noise (as defined in BS 4142:2014+A1 2019)	Totally encompassing noise in a given situation at a given time; it is usually composed of noise from many sources, near and far.
Background Noise (as defined in BS 4142:2014+A1 2019)	A-weighted sound pressure level of the residual noise at the assessment position that is exceeded for 90% of a given time interval, T, measured using the Fast time weighting and quoted to the nearest whole number of decibels.
C_{tr}	Spectrum adaptation term calculated using traffic noise as described in BS EN ISO 717-1:2013. This term is provided with weighted single values such as $D_{nT,w}$ or R_w to match with particular requirements (building acoustic or traffic noise spectrum).
Decibel, dB	Decibel (dB) is a dimensionless unit commonly used to demonstrate sound levels. It is derived from the logarithm of the ratio between the measured level and the reference value. For sound pressure level (L_p) the reference value is $2x10^{-5}$ pascals. For sound power (L_w) reference value is $1x10^{-12}$ Watts.
$D_{n,f,w}$	The weighted transmission of sound energy from a source room to a receiving room via structural (vibrational) paths in the construction mainly, e.g. walls, floors, ceilings.
$D_{nT,w}$	The Weighted Standardised Level Difference ($D_{nT,w}$) is defined in BS EN ISO 140-4:1998 (superseded by BS EN ISO 16283-1:2014+A1:2017 but still cited in The Building Regulations) BS EN ISO 717-1:2013. This performance describes the installed site performance of the composite separating constructions, including the partition element performance, the flanking path transmission and the reception room reverberation time factors. $D_{nT,w}$ target leads to a selection of adequate construction elements and methods to build the partition that are rated using weighted sound reduction index R_w. It is typically standardised to a reverberation time (T_0) of 0.5 seconds. In the instance of testing in schools, T_0 is taken as the room's T_{mf}.
D_w	Weighted Level Difference: Single-number quantity that characterizes airborne sound insulation between rooms, but which is not adjusted to reference conditions
Flanking Noise	The transmission of sound around the perimeter or through holes within partitions (or barriers) that reduces the otherwise obtained sound transmission loss of a partition. Examples of flanking paths within buildings are ceiling plenum above partitions or raised floor cavities, ductwork, piping, and electrical conduit penetrations through partitions, back to back electrical boxes within partitions, window mullions, etc.
Frequency	Number of cycles per second, measured in hertz (Hz), related to sound pitch.

IANL	Indoor Ambient Noise Level. For schools Table 1 in BB93 (2015) specifies the upper limit for indoor ambient noise levels within teaching areas. The design criteria is set for a 30-minute average level (i.e. $L_{Aeq,30mins}$). However, where there is negligible change in the noise level, BB93 states that a much shorter time period (e.g. $L_{Aeq,5min}$) can be used. BB93 also states that for rooms identified having limits of $L_{eq,30min}$ 35 dB(A) or less, the noise should not regularly exceed $L_{1,30min}$ 55 dB(A).
$L_{90,T}$ ($L_{A90,T}$)	Sound pressure level exceeded for 90% of the measurement period. Referred to as background noise level.
$L_{Ar,T}$	Rating Noise Level (as defined in BS 4142:2014+A12019), the specific noise level plus any adjustment for the characteristic features of the noise.
$L_{eq,T}$ ($L_{Aeq,T}$)	The equivalent continuous noise level of a time-varying noise. It is the steady noise level which, over the period of time under consideration, contains the same amount of sound energy as the time-varying noise over the same period of time.
$L_{Fmax,T}$ ($L_{AFmax,T}$)	The maximum sound pressure level measured during the measurement period T using the fast time constant.
$L'_{nT,w}$	Weighted Standardized Impact Sound Pressure Level: a single-figure value of impact sound insulation performance. This European index is described in BS EN ISO 140-7:1998 (superseded by BS EN ISO 16283-2:2015 but still cited in The Building Regulations) and BS EN ISO 717-2:2013, used for comparing and rating floors and based on the values of L'_{nT} at different frequencies. L'_{nTw} target leads to a selection of adequate construction elements and methods to build the floor that are rated using weighted normalized impact sound pressure level $L_{n,w}$. The lower the $L'_{nT,w}$ the better the performance
$L_{n,w}$	Weighted Normalized Impact Sound Pressure Level: European single figure rating for transmission loss of impact sound through building elements as described in BS EN ISO 10140-3:2010+A1:2015 and BS EN ISO 717-2:2013. The lower the $L_{n,w}$ the better the performance.
L_p	Sound pressure level, in decibels, of a sound is 20 times the logarithm to the base of 10 of the ratio of the sound pressure to the reference pressure ($2x10^{-5}$ pascals). The reference pressure shall be explicitly stated and is defined by standard.
Noise Rating (NR)	Curves developed by the International Organization for Standardization (ISO) to determine the acceptable indoor environment for hearing preservation, speech communication and annoyance. These can be compared to NC curves and also can be approximated to equivalent dB(A) levels.
Reverberation Time (RT)	Time required for the steady sound pressure level in an enclosed space to decay by 60 dB, measured from the moment the sound source is switched off. Reverberation time is described in ISO 354:2003.
R_w (C, C_{tr})	Weighted Sound Reduction Index: Single-figure value of sound reduction according to BS EN ISO 10140-2:2010 used for rating partition systems, door-sets or glazing, based on the values of sound reduction index R at different frequencies. The higher the R_w the better the performance.
SEL (L_{AE})	Single Event Level: The sound level over one second which would have the same energy content as the whole event.
Sound absorption classes	Sound absorption performance characteristics are defined by a class. Below is a diagram of the different classes of absorption available, taken from BS EN ISO 11654:1997. The y-axis is the absorption coefficient of the material with one being total absorption and zero being no absorption. The x-axis is the frequency of the sound.

	
Specific Noise Level (as defined in BS 4142:2014+A1 2019)	The equivalent continuous A-weighted sound pressure level at the assessment position produced by the specific noise source over a given reference time interval.
T_{mf}	Mid Frequency Reverberation Time: Within BB93, the reverberation time criteria are set in terms of the averaged value of the 500 Hz, 1000 Hz and 2000 Hz frequency bands. The various levels for T_{mf} are specified within Table 6 of BB93 (2015) and are generally upper limits. Usually the specified mid-frequency reverberation times are for 'finished but unoccupied and unfurnished rooms'.
Vibration	Force which oscillates about some specified reference point. Vibration is commonly expressed in terms of frequency such as cycles per second (cps), Hertz (Hz), cycles per minute (cpm) or (rpm) and strokes per minute (spm). This is the number of oscillations which occurs in that time period. The amplitude is the magnitude or distance of travel of the force.
Weightings (as defined in BS EN 61672:2013):	A-Weighting: Frequency weighting devised to attempt to take into account the fact that human response to sound is not equally sensitive to all frequencies; it consists of an electronic filter in a sound level meter, which attempts to build in this variability into the indicated noise level reading so that it will correlate, approximately, with human response.). C-Weighting: One of the frequency weightings corresponding to the 100-phon contour and the closest to the linear or un-weighted value.

1 Introduction

Buro Happold have been appointed by University College London (UCL) Estates to provide acoustics consultancy on the proposed Phase 2 refurbishment works of the Institute of Education building, 20 Bedford Way, London.

The refurbishment scheme is understood to consist of open-plan offices, cellular offices, meeting rooms, social spaces, teaching spaces, meeting rooms, WCs and other associated spaces, located across Cores A, B and C of the existing building. It is understood that the client is proceeding on a Design and Build contract, with design responsibility since RIBA Stage 3 falling on the successful contractor, which is understood to be Overbury.

It is important that internal acoustic conditions are appropriate for their intended purpose, (which is understood to include quiet working and concentration, with occasional requirements for acoustic privacy). Furthermore, the operation of the development should be such that it is not unduly disturbing to nearby noise-sensitive receivers.

The purpose of this report at Stage 4 (Technical Design) is to provide sufficient information to see that planning requirements can be successfully achieved on-site. It should be noted that Stage 3 Acoustics Report dated 28th January 2020 forms the acoustic aspects of the Employer's Requirements.

For guidance, Figure 1-1 shows the locations of the Phase 2 refurbishment areas and core locations.

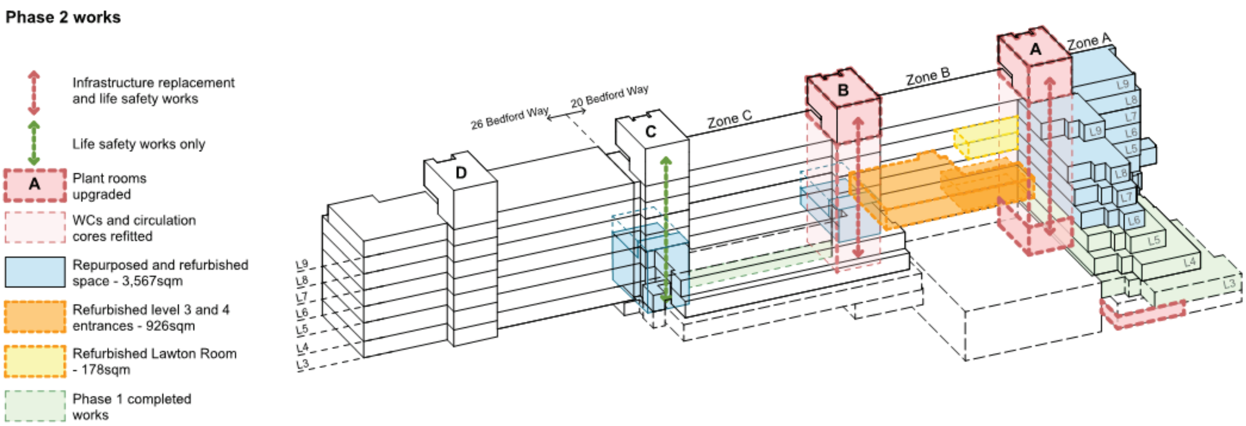


Figure 1-1: Drawing showing Phase 2 refurbishment areas and core locations

1.1 Content

This report concentrates on the following acoustic aspects of the design relevant to the RIBA Stage 4 of the scheme:

- Detailed glazing constructions;
- Detailed discussion of proposed ventilation strategy; and
- Detailed discussion of plant noise impact and required mitigation.

As per scheme-specific BREEAM requirements, the overall design of the development should comply with good practice design guides such as Building Bulletin 93 (2015): *Acoustic design of schools: performance standards* (BB93) as well as the UCL Design Brief.

1.2 BREEAM

Building Research Establishment's Environmental Assessment Method (BREEAM) is a method used to assess, rate and certify the sustainability of buildings. The objectives of BREEAM are:

- To provide market recognition of buildings with a low environmental impact;
- To ensure best environmental practice is incorporated in building planning, design, construction and operation;
- To define a robust, cost-effective performance standard surpassing that required by regulations;
- To challenge the market to provide innovative, cost effective solutions that minimise the environmental impact of buildings;
- To raise the awareness amongst owners, occupants, designers and operators of the benefits of buildings with a reduced life cycle impact on the environment; and
- To allow organisations to demonstrate progress towards corporate environmental objectives.

1.2.1 Available credits

It is understood that the building is to be assessed and rated according to BREEAM UK Refurbishment and Fit-out 2014 – High Education Building. Up to four BREEAM credits are available for Acoustic performance (Hea 05) and Reduction of noise pollution (Pol 05) depending on the building category.

It is understood that the development is targeting four credits under BREEAM Hea 05 'Acoustic Performance' and Pol 05 'Noise Pollution'.

1.2.2 BREEAM criteria

The aim of Hea 05 is:

> *"To ensure the building is capable of providing an appropriate acoustic environment to provide comfort for building users."*

The BREEAM credits available under Hea 05 Education buildings are summarised below:

Table 1-1 Hea 05 Education buildings (up to three credits)

First credit – Sound insulation		**Refer to**
Criteria	Achieve the performance standards set out in Section 1 of Building Bulletin 93: Acoustic design of schools: performance standards, February 2015 (BB93) relating to airborne sound insulation between spaces and impact sound insulation of floors.	Section 0 of this report
Second credit – Internal indoor ambient noise levels		**Refer to**
Criteria	Achieve the indoor ambient noise level standards set out within Section 1 of BB93 for all room types. For lightweight roofs and roof glazing, calculations using laboratory data with 'heavy' rain noise excitation as defined in BS EN ISO 140-18 are required (in accordance with the guidance in BB93) for teaching/learning spaces to demonstrate that the reverberant sound pressure level in these rooms are not more than 25 dB above the appropriate limits presented within Section 1 of BB93, table 1.	Section 4 of this report
Third credit – Reverberation		**Refer to**
Criteria	Acoustic environment (Control of reverberation, sound absorption and speech transmission index (STI)): **Teaching and study spaces:** achieve the requirements relating to reverberation time for teaching and study spaces set out within table 6 in Section 1 of BB93. **Open plan teaching spaces:** achieve the performance requirements relating to speech transmission index (STI) set out within Section 1.8 of BB93 . **Corridor and stairwells:** for those that give direct access to teaching and study spaces, achieve the performance requirements relating to sound absorption.	Section 0 of this report

It should be noted that there is a testing requirement to achieve credits for Hea 05. The acoustic testing programme should be carried out pre-completion of the refurbishment by a compliant test body in accordance with BB93 requirements and the ANC Good Practice Guide.

The aim of Pol 05 is:

"To reduce the likelihood of noise arising from fixed installations on the new development affecting nearby noise-sensitive buildings."

The criteria for achieving Pol 05 are as follows:

1. Where there are, or will be, no noise-sensitive areas or buildings within 800m radius of the assessed site.
2. OR
3. Alternatively, where the building does have noise-sensitive areas or buildings within 800m radius of the site, one credit can be awarded as follows:
    a. Where a noise impact assessment in compliance with BS 7445 has been carried out and the following noise levels measured/determined:
        i. Existing background noise levels at the nearest or most exposed noise-sensitive development to the proposed development or at a location where background conditions can be argued to be similar.
        ii. The rating noise level resulting from the new noise source (see CN4).
4. The noise impact assessment must be carried out by a suitably qualified acoustic consultant holding a recognised acoustic qualification and membership of an appropriate professional body (see Relevant definitions in the Additional Information section).
5. The noise level from the proposed site/building, as measured in the locality of the nearest or most exposed noise-sensitive development, is a difference no greater than +5dB during the day (07:00 to 23:00) and +3dB at night (23:00 to 07:00) compared to the background noise level.
6. Where the noise source(s) from the proposed site/building is greater than the levels described in criterion 4.

Compliance with the Pol 05 first credit is demonstrated in Section 5 of this report.

1.2.3 BREEAM suitably qualified acoustician (SQA)

This report has been prepared by Gareth Davies, who is a full member of the Institute of Acoustics (IOA), holds the IOA Diploma qualification, and has more than three years of relevant experience (within the last five years), and is therefore considered a SQA consultant for BREEAM purposes.

1.3 Camden Council Requirements - Planning Notice

Pre-commencement Planning Condition 4 of Phase 2B for the development states the following:

> *Prior to commencement of the relevant works, details shall be submitted to and approved in writing by the Council, of the external noise level emitted from plant/ machinery/ equipment and mitigation measures as appropriate. The measures shall ensure that noise levels at a point 1 metre external to sensitive facades shall be at least 10dB(A) less than the existing background measurement (LA90), expressed in dB(A) when all plant/equipment (or any part of it) is in operation unless the plant/equipment hereby permitted will have a noise that has a distinguishable, discrete continuous note (whine, hiss, screech, hum) and/or if there are distinct impulses (bangs, clicks, clatters, thumps), then the noise levels from that piece of plant/equipment at any sensitive façade shall be at least 15dB(A) below the LA90, expressed in dB(A).*

As such, it is understood that Camden Council requires noise emissions from newly introduced fixed plant to not exceed 10 dB below the lowest measured background noise level at a point 1 metre outside any window of the nearest noise sensitive receiver.

Furthermore, if the fixed plant contains tones or is intermitted, the fixed plant noise emissions shall not exceed 15 dB below the lowest measured background noise level at a point 1 metre outside any window of the nearest noise sensitive receiver.

It should be noted that the Council targets are more onerous than the BREEAM Pol 05 criteria. Therefore, the Pol 05 credit can be awarded by default.

1.4 Reference Codes and Standards

This acoustic design report is informed by the following list of codes and standards:

- **Acoustics of Schools: a Design Guide: 2015** – Provide supporting guidance and recommendations on the acoustic design of new and refurbished schools.
- **BREEAM UK New Construction 2014 – Non-Domestic Buildings Technical Manual SD5076: 5.0 – 2014**. Provides an environmental performance standard against which non-domestic refurbishment and fit-out projects in the UK can be assessed, rated and certified.
    - **Hea 05 acoustic performance (3 credits available)** – To ensure the building's acoustic performance including sound insulation meet the appropriate standards for its purposes.
        - First credit – Sound insulation
        - Second credit – Indoor ambient noise levels
        - Third credit – Reverberation
    - **Pol 05 Reduction of noise pollution (1 credit available)** – To reduce the likely impacts of noise arising from existing or newly specified fixed installations affecting nearby noise-sensitive buildings.
- **Building Bulletin 93 February (BB93): 2015 – Acoustic Design of Schools: Performance standards** provides a regulatory framework for the acoustic design of schools. Sections of the criteria contained within BB93 provide guidance that is typically considered appropriate in the acoustic design of university buildings.
- Charted Institution of Building Services Engineering's (CIBSE) published document **CIBSE Guide A: 2016 – Environmental design**. Used as a reference for designing low energy sustainable buildings utilising the latest research and best practice.
- **UCL Engineering, Maintenance and Infrastructure: 2017 – Design Guidance for Mechanical, Electrical and Public Health Service**, provides design criteria for internal noise levels for internal building services within UCL premises.
- **UCL: 2016 – Learning Space Guidelines v2.0** provides guidelines for those designing facilities and environments in UCL's learning spaces.

1.5 Reference to Specific Products or Manufacturers

Rather than repetitively include the phrase *"or equal approved product, to be discussed with Buro Happold before procurement"* or similar, all references to specific products or manufacturers within this document should be taken to mean that any other product or process which provides an equal performance value and can be built/installed/constructed such that the same level of acoustic performance is achieved, is acceptable, following formal approval by Buro Happold.

It should be noted that it may also be necessary to consider the requirements of other design team members and the end-users, when considering alternative specifications. Buro Happold has no vested interest in any specific product or manufacturer.

2 Site and External Noise Survey

2.1 Introduction

Buro Happold conducted external noise surveys on the 4th October, 10th October and 8th December 2016 within the vicinity of the development site.

Surveys were undertaken in order to:

- Capture the noise impact from surrounding environmental noise sources (e.g. roads) on the proposed façades. This allows the specification of external building envelope attenuation (i.e. glazing and ventilation) to see that internal ambient noise levels within the various spaces can be compliant with pertinent criteria; and
- To capture the existing background noise levels at nearby noise-sensitive (i.e. residential/hospital ward) receptors. This allows the specification of limiting noise levels for any externally located (or external terminations of) services plant, to see that the installation will not unduly increase existing noise levels in the vicinity of the site in line with pertinent criteria.

2.2 Instrumentation

The acoustic survey was conducted using the instrumentation described in Table 2-1 below.

Table 2-1 Noise Survey Instrumentation

Description	Model No.	Serial No.
Handheld sound analyser	BandK 2250	3008216
Preamplifier	ZC 0032	22669
Condenser Microphone	BandK 4189	2983647
Brüel Kjær Acoustic Calibrator	BandK 4231	2438725
Handheld sound analyser	01dB Solo	203726
Preamplifier	PRE21S	14038
Condenser Microphone	MCE212	91389

All instrumentation had been laboratory calibrated (UKAS accredited) and certified within the last two years and traceable to National Standards. The instrumentation was field calibrated before and after the completion of the noise survey. No adjustments for instrumentation drift during the measurement period were required.

2.3 Weather

Weather details for the undertaken surveys are detailed below:

- 4th October 2016 – approx. 14-18°C, sunny with passing clouds and westerly winds between 6-8 metres/second (m/s);
- 10th October 2016 – approx. 7-13°C, sunny with passing clouds and southerly winds between 1-5 m/s; and
- 8th December 2016 – approx. 12-13°C, sunny with passing clouds and northerly winds between 2-4 m/s.

2.4 Measurement Methodology

The noise survey methodology undertaken provides a comprehensive and complete picture of how noise levels vary around the site throughout various times of the day and night. Measurement locations are detailed below and marked on an annotated aerial image in Figure 2-1**.**

- **Location 1** – Short term (manned) noise measurement, located on the eastern side of the institute on Bedford Way at approximately 1.5 metres above ground level;
- **Location 2** – Short term (manned) noise measurement, located on the southern side of the institute on Russell Square at approximately 1.5 metres above ground level;
- **Location 3** – Short term (manned) noise measurement, located on the western side of the institute on Thornaugh Street at approximately 1.5 metres above ground level;
- **Location 4** – Short term (manned) noise measurement, located on the northern side of the institute on Gordon Square at approximately 1.5 metres above ground level; and
- **Location 5** – Short term (manned) noise measurement, located near the centre of the western side of the institute 1.5 metres above ground level.

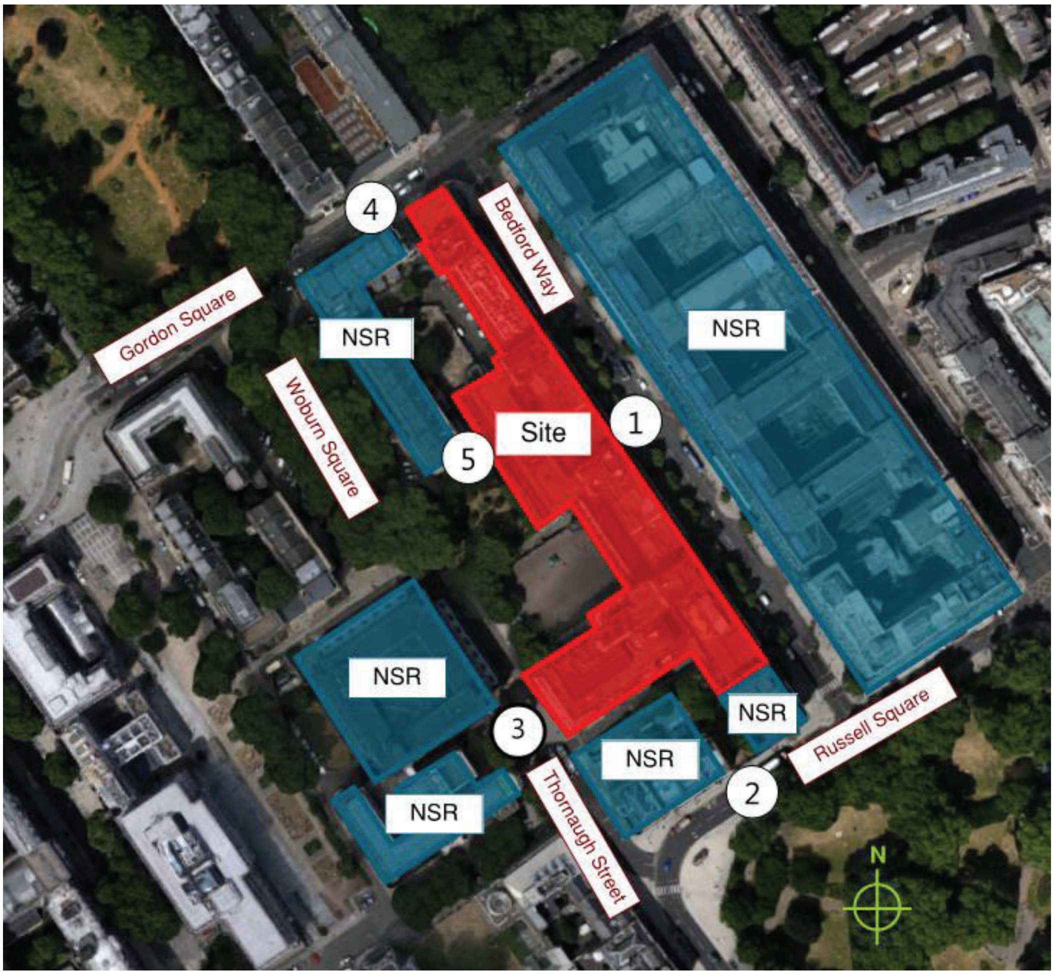


Figure 2-1: Site plan showing noise monitoring locations and noise-sensitive receivers (NSRs)

Terminology used to describe the measured noise levels are as follows:

- **$L_{Aeq,15mins}$ dB(A)** – the average A-weighted sound pressure level within a 15-minute period. Typically thought of as the average ambient noise level at a particular time, and likely to be due to a combination of various noise sources, near and far;
- **$L_{AF,max}$ dB(A)** – the maximum instantaneous A-weighted sound pressure level measured during a 15-minute period. Typically corresponding to a short-duration event with a very high sound pressure level, for example motorbike passing by, car horn etc; and
- **$L_{A90,15mins}$ dB(A)** – the A-weighted sound pressure level exceeded for 90% of the measurement period i.e. a level which would be perceived as a constant, background noise level. Typically, largely unaffected by local traffic pass-by or by transient events. More usually attributable to constantly-running building services plant or distant road traffic. What you would hear when there is no local traffic present (or other readily-identifiable noise source).

The 'design level' values in the tables below were derived from the long and short-term measurements undertaken at locations illustrated in the figure above. Each descriptor was calculated as follows:

- **Existing Ambient $L_{Aeq,T}$** – **logarithmic average** of the measured $L_{Aeq,15minute}$ values, measured during representative daytime periods;
- **Maximum $L_{AF,max}$** – is the **logarithmic average** measured $L_{AF,max}$ value, sampled over 15-minute periods during representative daytime periods;
- **Background $L_{A90,15min}$** – is the **minimum** measured $L_{A90,15minute}$ values, measured during representative, daytime periods.

2.5 Survey Results

Table 2-2: Noise survey results

Noise measurements (4th and 10th Oct 2016) (dB)						
Period	**Start time**	**End time**	**$L_{Aeq,T}$**	**$L_{AF,max}$**	**$L_{A90,T}$**	**Comments**
Location 1						
Day	04/10/2016 15:24	04/10/2016 15:40	66	78	57	Medium traffic on the front road, students walking / talking
	04/10/2016 16:40	04/10/2016 16:55	67	90	59	
	10/10/2016 17:40	10/10/2016 17:55	66	89	60	Peak time, large number of pedestrians and cars; however, traffic jam meant cars were at a standstill most of the time.
Design level			**66**	**88**	**57**	
Location 2						
Day	04/10/2016 15:57	04/10/2016 16:12	67	84	59	Traffic from Russell Square, buses and cars. Students talking / walking
	10/10/2016 17:58	10/10/2016 18:13	65	83	59	High traffic, however at a standstill most of the time.
Design level			**66**	**84**	**59**	
Location 3						
Day	04/10/2016 16:13	04/10/2016 16:28	58	77	53	No circulation, calm, few students walking / talking
	10/10/2016 18:34	10/10/2016 18:49	50	66	47	Very calm, pedestrians and occasional cyclists.

Noise measurements (4th and 10th Oct 2016) (dB)						
Period	**Start time**	**End time**	$L_{Aeq,T}$	$L_{AF,max}$	$L_{A90,T}$	**Comments**
Design level			**56**	**74**	**47**	
Location 4						
Day	04/10/2016 16:29	04/10/2016 16:44	66	85	60	Medium traffic, students talking / walking
	10/10/2016 18:16	10/10/2016 18:31	66	84	61	High traffic, however mostly stopped at traffic lights.
Design level			**66**	**85**	**60**	
Noise measurements (8th December 2016) (dB)						
Period	**Start time**	**End time**	$L_{Aeq,T}$	$L_{AF,max}$	$L_{A90,T}$	**Comments**
Location 5						
Day	16:38	16:53	48	59	46	No individual distinguishable noise sources were noted during the survey and the noise climate was subjectively noted to be quiet. Any noise from the adjacent construction site was excluded.
	16:53	17:08	48	65	46	
	17:08	17:23	48	60	46	
	17:23	17:38	48	58	46	
Design level			**48**	**61**	**46**	

Figure 2-2 shows the design noise levels, arranged around the site to correspond with the geographical location of each measurement:

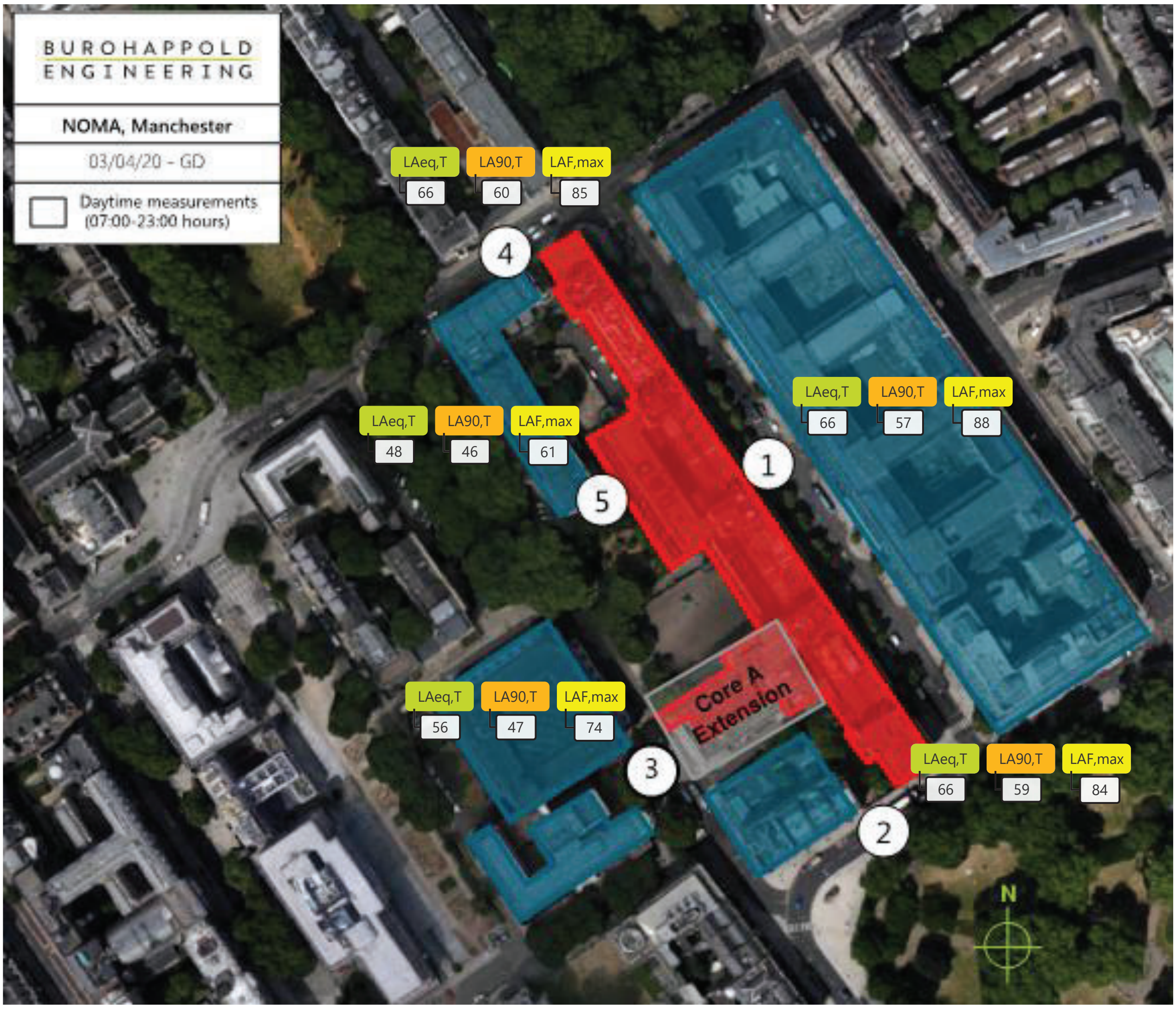


Figure 2-2 Design noise levels at each location

2.6 Discussion

As can be seen from the results above, elevations that are immediately adjacent to Bedford Way, Russell Square and Gordon Square experience noise levels of up to $L_{Aeq,T}$ 66 dB(A). However, there is a considerable disparity to the 'rear' elevations, shielded from Bedford Way, Russell Square and Gordon Square by the building itself and all other façades, with these quieter elevations experiencing a noise impact of $L_{Aeq,T}$ 48 and 56 dB(A) at Locations 5 and 3 respectively.

3 Modelling

3.1 Introduction

To assess the noise propagation across the façades of the Institute of Education, a noise model has been produced using CadnaA v2018 acoustic modelling software. The noise model has been constructed based on detailed Google Earth mapping data and architectural drawings. Local roads were added into the model to simulate noise sources that were measured during the on-site noise surveys. Furthermore, the bar terrace at Level 3 on Wing A (Core A) has been modelled to predict the likely impact of a full capacity terrace on nearby façades.

The model predicts and maps the noise impact on the façades of the institute, considering factors such as distance attenuation, natural and man-made barrier attenuation, reflections and source directivity.

The constructed noise model has been calibrated based upon the results obtained during the attended surveys to represent the noise climate as close as possible to the current one on site.

3.2 Limitations

The assessment has been based on the results produced through a noise modelling exercise, which provides predictions on the likely future noise levels. In order to increase the reliability of the results, the models have been calibrated to the noise levels measured on site. However, this does not guarantee full accuracy of the predicted noise levels. Typically, an uncertainty within a range of approximately +/- 3 dB could be expected from computer noise modelling software. However, this uncertainty has been controlled as far as practicable by cross-referencing the levels of predicted noise impact against the spot measurements captured on site.

3.3 Results

The following noise maps show how noise is predicted to impact the proposed elevations during daytime hours (07:00 – 23:00 hours).

Figure 3-2 to Figure 3-5 illustrate the predicted noise levels incident on the façades of the development during the daytime.

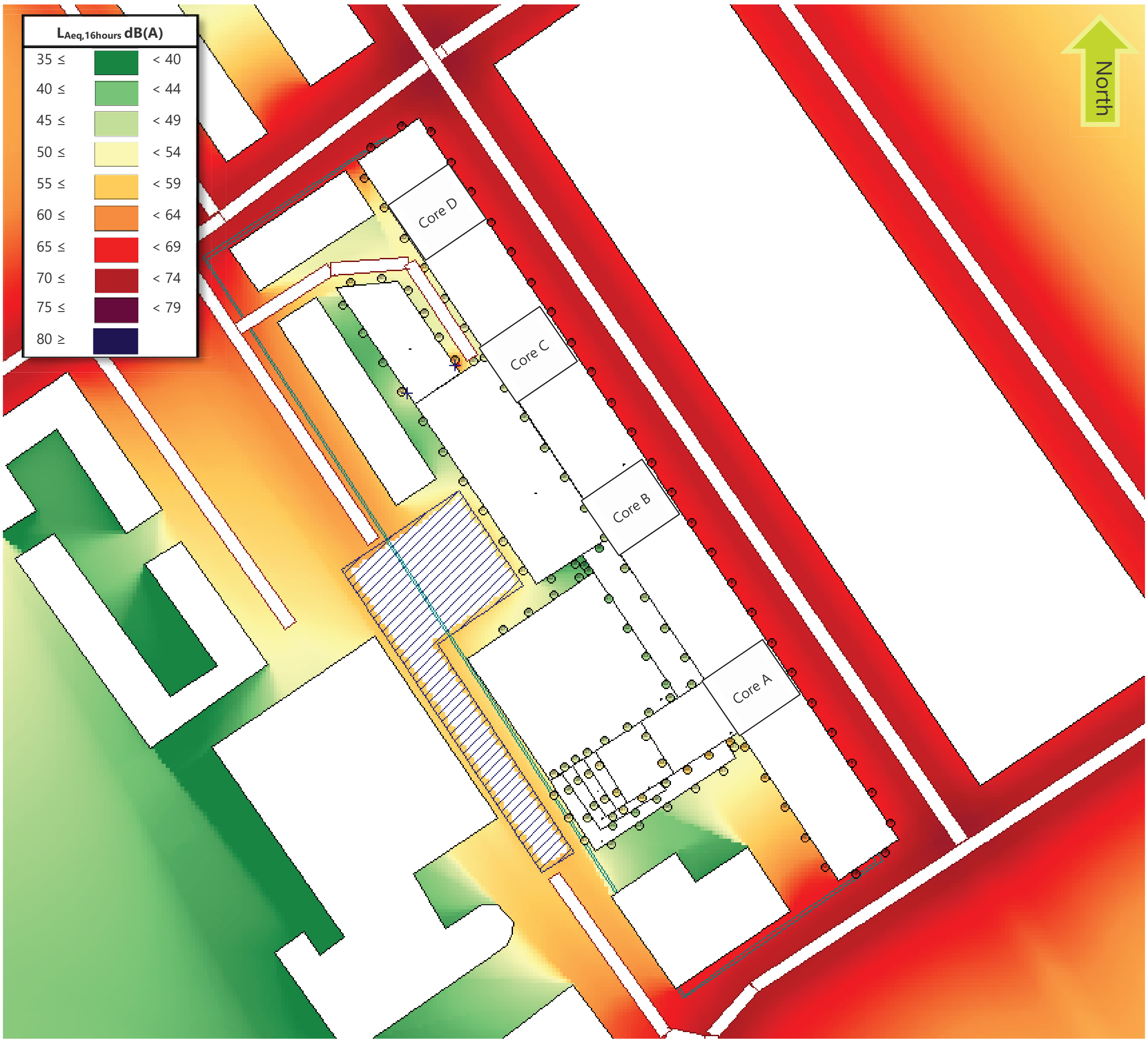


Figure 3-1: Plan view of predicted daytime site wide noise levels ($L_{Aeq,T}$ dB(A))

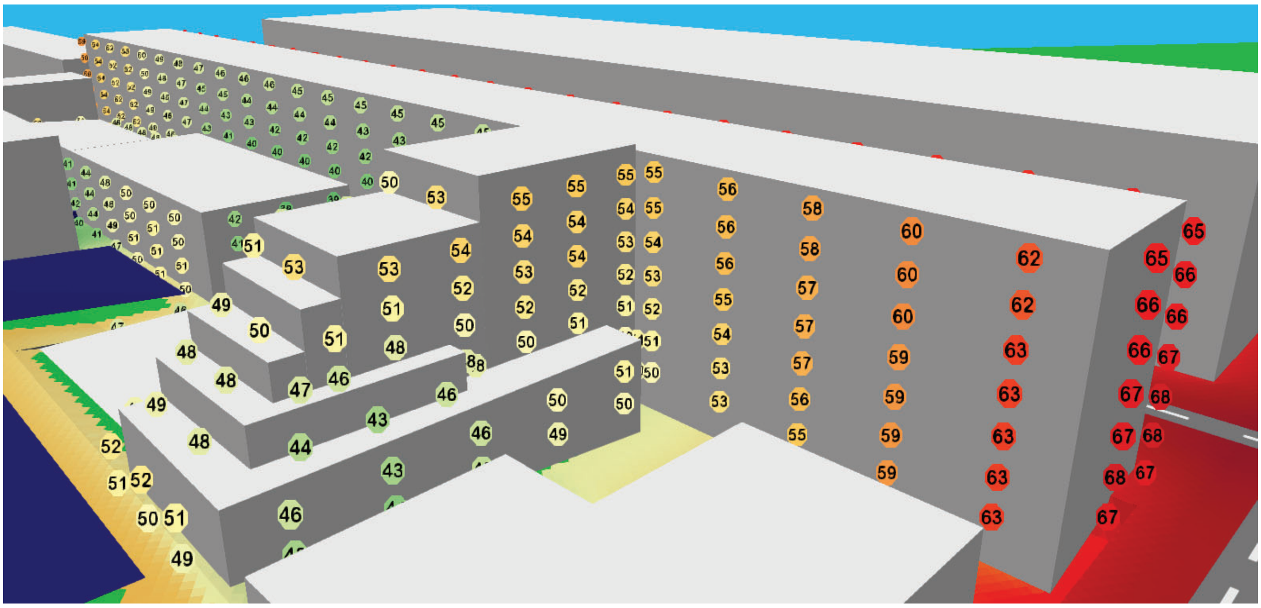


Figure 3-2: 3D view of predicted daytime site wide noise levels ($L_{Aeq,T}$ dB(A)) south and west elevations

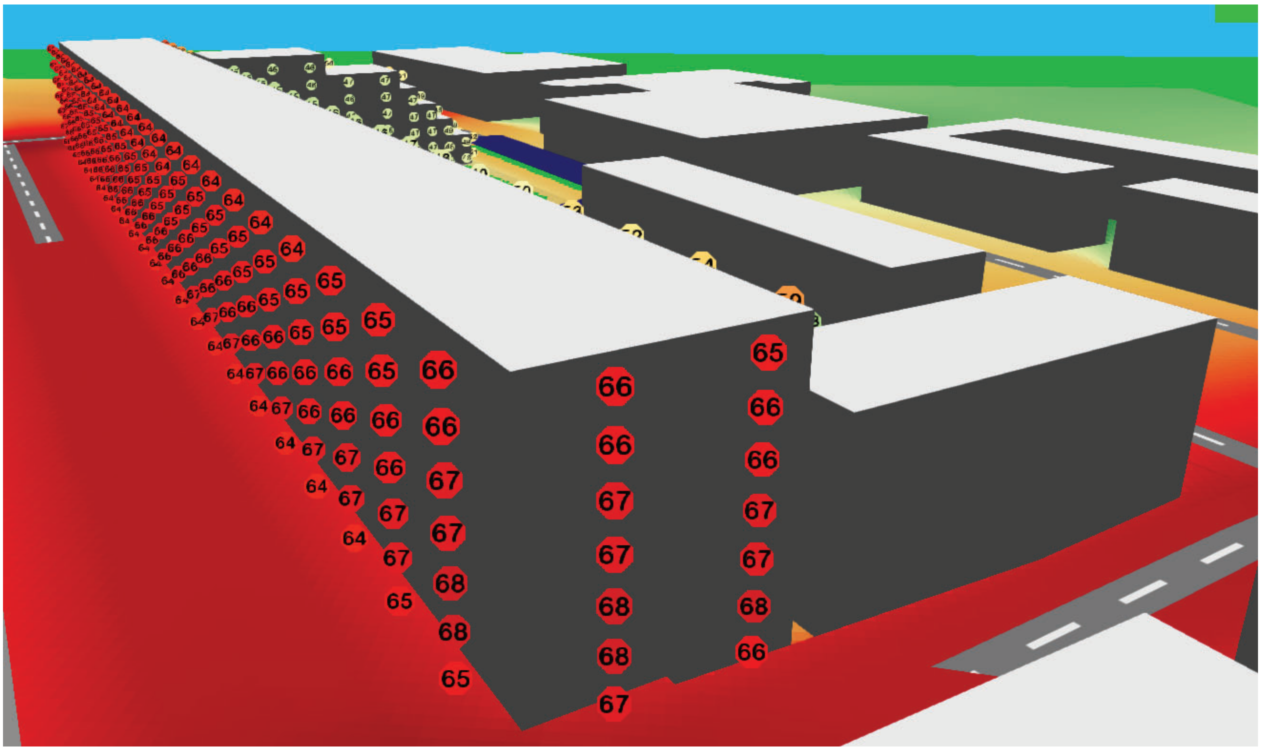


Figure 3-3: 3D view of predicted daytime site wide noise levels ($L_{Aeq,T}$ dB(A)) north and east elevations

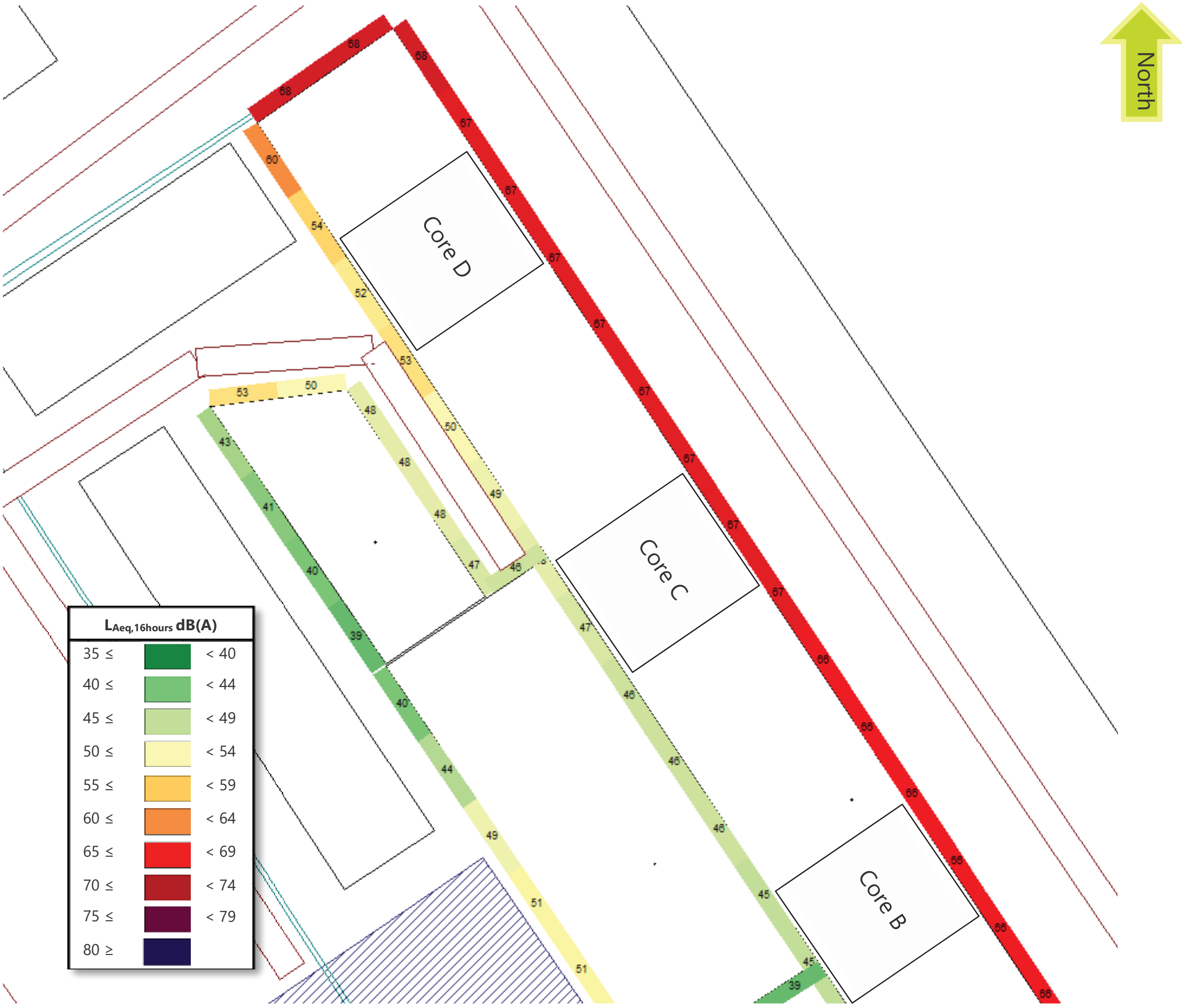


Figure 3-4: Predicted highest daytime Cores B to D, Institute of Education façade incident noise levels ($L_{Aeq,T}$ dB(A))

Figure 3-5: Predicted highest daytime Cores A to B, Institute of Education façade incident noise levels ($L_{Aeq,T}$ dB(A))

3.4 Bar Terrace

A terrace associated with the bar on Level 4 of the Core A extension has a seating capacity of approximately 126 people. The noise break-out from the terrace has been modelled.

In a full capacity scenario, up to 200 people could be expected to be using the terrace (e.g. during lunchtime or after hours). Sources representing noise from people on the Level 4 bar terrace were added to the model. It was assumed that 50% of people are listening and 50% are talking with a raised voice. The estimated number of users have been split into groups of 4No. totalling 200No. people with only half talking at any one time. Each of these groups of people will be simulated as a point source with a total noise level corresponding to 4No. people.

As detailed in Acoustics of Schools: a Design Guide (2015) a raised voice at 1 m is taken to produce a level of $L_{Aeq,T}$ 67 dB(A) at 1 m from the speaker. A spectrum, from 125 Hz – 8000 Hz, corresponding to this broadband sound pressure level was used in the modelling, as shown in Table 3-1, together with the equivalent levels for 4No. people talking, as input into the acoustic simulation.

Table 3-1: Raised voice sound pressure level spectrum

Description	Sound pressure level – dB re 20 µPa at each octave band centre frequency - Hz							Total (dB(A))
	125	250	500	1000	2000	4000	8000	
SPL raised voice at 1 m [dB] – Single person	51	62	66	62	57	51	43	67
SPL raised voice at 1 m [dB] – 4No. people speaking	57	68	72	68	63	57	49	73

The representative sources were dispersed as evenly as possible throughout the terrace in the model. The locations of groups of people are marked with an '+' in Figure 3-6.

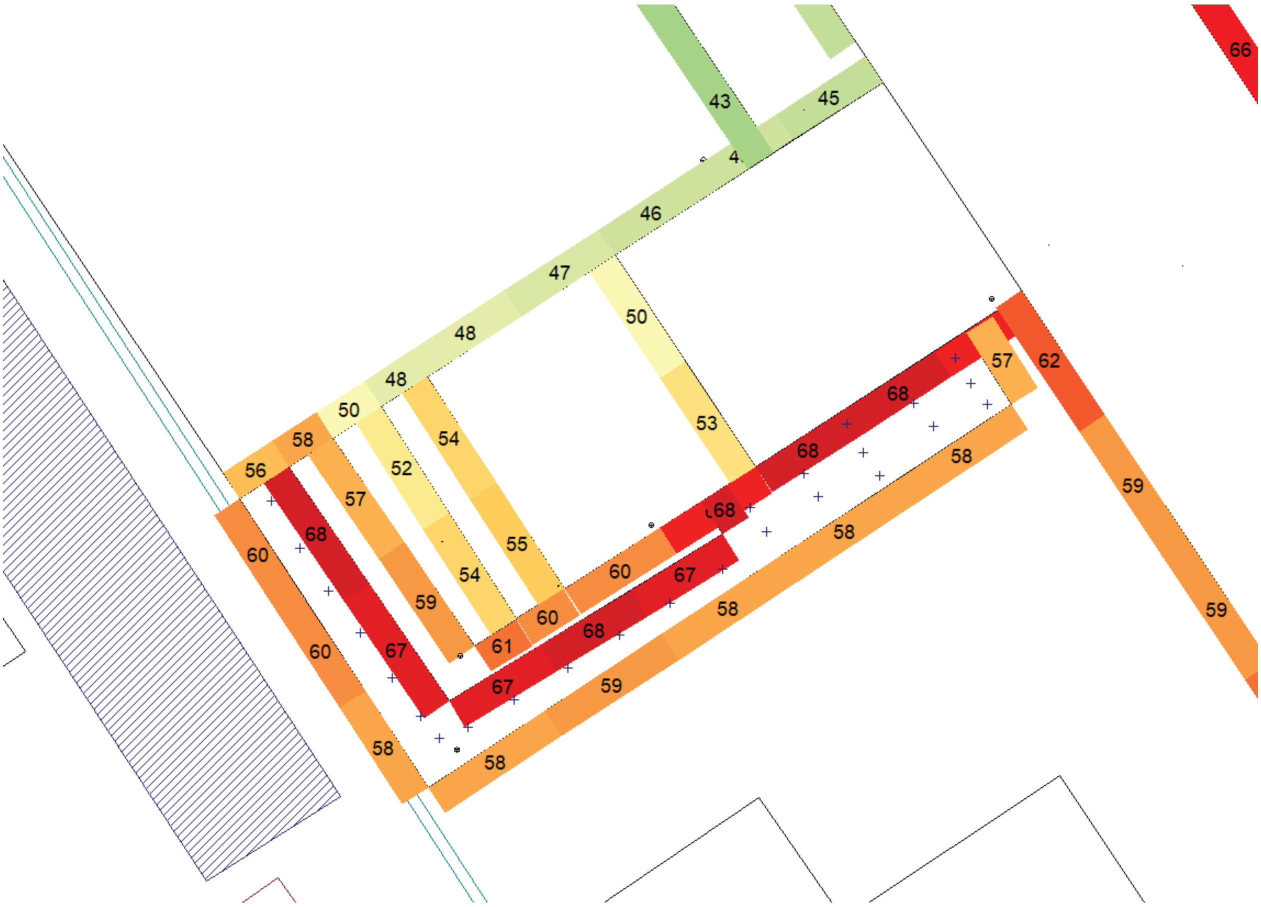


Figure 3-6: Daytime $L_{Aeq,T}$ noise levels with bar terrace at full capacity – south and west elevations

3.5 Discussion

As can be seen from predicted noise levels presented in Figure 3-4 and Figure 3-5 the elevations adjacent to Bedford Way, Gordon Square and Russell Square roads of the institute are likely to be exposed to high levels of traffic noise, up to approximately 68 $L_{Aeq,T}$ dB(A) during daytime hours. Moderate noise levels, up to approximately 55 $L_{Aeq,T}$ dB(A), are predicted where elevations are at least partially screened from the Bedford Way, Gordon Square and Russell Square roads.

Two bar terrace scenarios were modelled. The first scenario assumed an empty bar terrace with the main noise sources being the nearby roads. The second scenario added 200No. people (100No. talking with a raised voice) to the model to simulate a full bar terrace. In a full capacity bar scenario, maximum levels of $L_{Aeq,T}$ 68 dB(A) are predicted on nearby façades.

The results from the modelling will help inform the ventilation and glazing strategy calculations in Section 4.

4 Façade Acoustic Design and Noise Break-In

4.1 Introduction

The indoor ambient noise level (IANL) should be controlled to within acceptable levels in order to provide a good learning, teaching and working environment.

The IANL is made up of contributions from external noise sources such as traffic, aircraft and external plant noise and internal building services noise. The aim is to acoustically design the building such that the cumulative noise from external and internal noise sources does not exceed the IANL requirements.

4.2 Acoustic Criteria – Internal Ambient Noise Levels

BB93 refurbishment values will be used as guidance for setting out the targets for indoor ambient noise levels within the different spaces of the development. As discussed in Section 1.2, this generates the award of a BREEAM credit under Hea 05.

The objective of the performance standards set out in Section 1.1 *Indoor Ambient Noise Levels in Unoccupied Spaces* of BB93 is:

- Clear communication of speech between teacher and student,
- Clear communication between students, and
- Learning and study activities.

The table below presents acceptable noise intrusion requirements for each specific room type. It should be noted that these values are also in-line with UCL Learning Spaces Guidelines.

Table 4-1: Target IANLs per room type – refurbishment (source: BB93)

Room type	Target IANL $L_{Aeq,\ 30min}$
Lecture room / Classroom	≤ 40 dB
Open plan resource / breakout area	≤ 45 dB
Circulation spaces not intended for teaching or learning / Café	≤ 50 dB
Office / Meeting room	≤ 45 dB
Kitchen / Corridor / Stairwells / Toilets	≤ 55 dB

It is worth noting that BB93 states the following with regards to discrete noise events:

> In order to protect students from regular discrete noise events, eg, aircraft or trains, indoor ambient noise levels should not exceed 60 dB $L_{A1,\ 30mins}$. This is achieved by default for spaces with IANLs up to 40 dB $L_{Aeq,\ 30min}$, but requires assessment in spaces with higher IANL limits, eg, 45 and 50 dB.

Figure 4-1: Discrete noise events IANL requirements (source: BB93)

4.3 Ventilation Strategy

It is understood that all areas of Phase 2 development will be mechanically ventilated via centralised air handling units (AHUs). Therefore, there is no requirement for operable windows to provide background ventilation. This means that the IANL will primarily be a product of the internal building services, and the level of noise break-in through a sealed façade (notably via the glazing system). Guidelines for internal services noise within various spaces are given in Section 0. The acoustic sound insulation performance of the façade is discussed in the following sections.

4.4 Façade Design Noise Levels

The façade design noise levels are based on the noise mapping calculations outlined above and rationalised to simplify the façade sound insulation requirements across each building elevation. The façade design noise levels have been broken down into "conditions" which represent a range of noise levels, with the higher façade noise level being used to calculate the façade sound insulation requirements.

It should be noted that a typical octave-band spectrum measured on-site was used and adjusted to match the broadband design noise levels. The figure below details the façade design noise levels across each elevation.

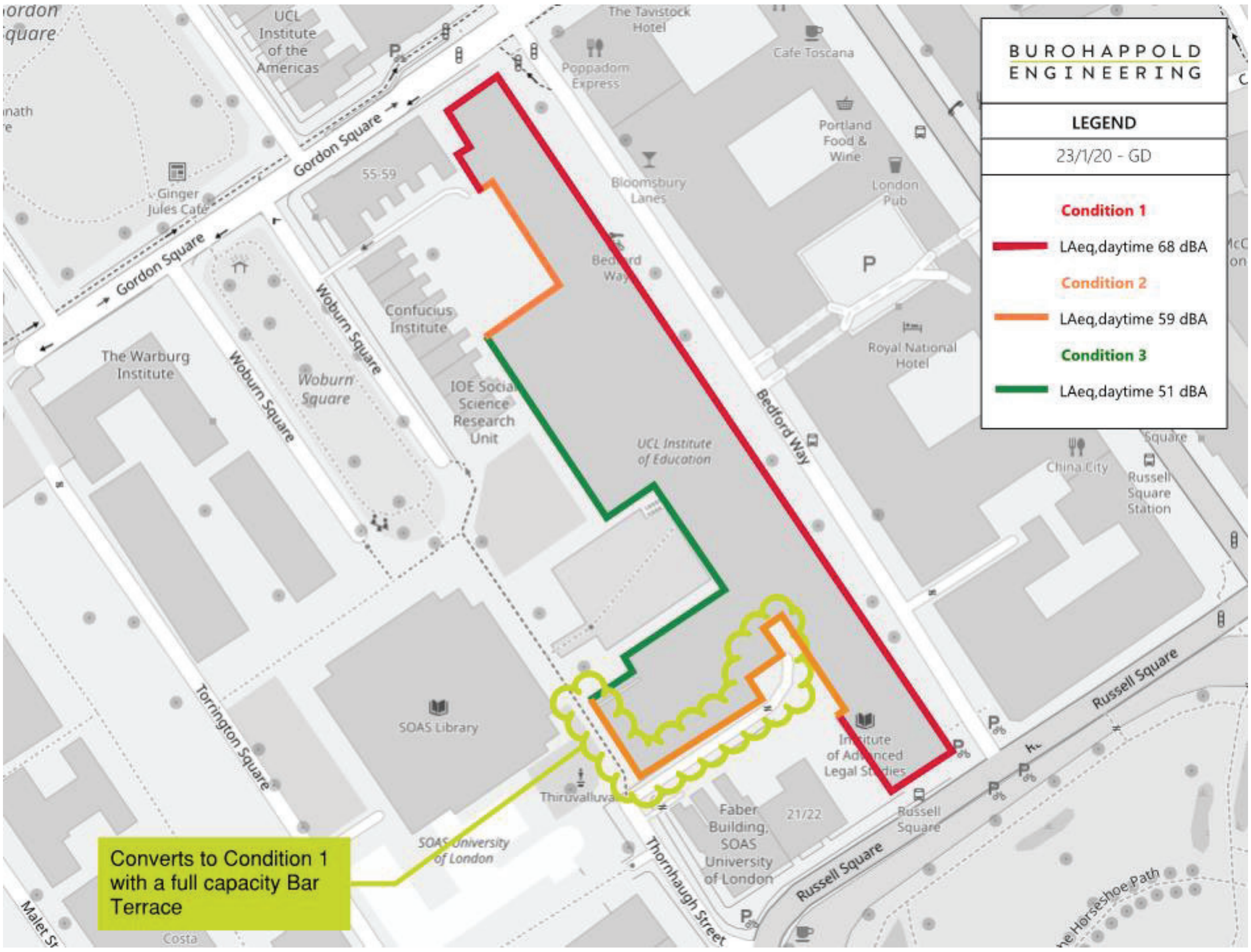


Figure 4-2: Façade design noise levels

4.5 Calculation Basis

As outlined in the previous section, mechanical ventilation has been specified to provide background ventilation in all areas of Phase 2 of the development.

Mechanical ventilation, by its nature, is effective at preventing the ingress of environmental noise, due to the lack of need for un-ducted/un-attenuated openings in the external elevation required by natural systems (i.e. open windows and trickle vents). On that basis, the level of external noise break-in through the systems is likely to be negligible. Duct noise break-out into internal areas via the façade inlet/outlet terminations will be considered such that the noise path is negligible in comparison to the path through the façade and its elements (masonry and glazed).

In-line with the above, it is expected that the weakest elements of the external elevation will be the glazing systems. The specification of these elements will be the primary factor in determining the internal ambient noise level within each area due to noise ingress from outside. Calculation procedures follow the “more rigorous calculation method” outlined in BS 8233:2014 as shown below.

$$L_{eq,2} = L_{eq,ff} + 10\log_{10}\left(\frac{A_0}{S}10^{\frac{-D_{ne}}{10}} + \frac{S_{wi}}{S}10^{\frac{-R_{wi}}{10}} + \frac{S_{ew}}{S}10^{\frac{-R_{ew}}{10}} + \frac{S_{rr}}{S}10^{\frac{-R_{rr}}{10}}\right) + 10\log_{10}\left(\frac{S}{A}\right) + 3$$

Where:

Sf	*is the total façade area in square metres (m2) of the room in question;*
Swi	*is the area in square metres (m2) of the windows of the room;*
Sew	*is the area in square metres (m2) of the external wall of the room;*
Srr	*is the area is square metres (m2) of the ceiling of the room;*
S	*is the total area in square metres (m2) of elements through which sound enters the room, i.e. Sf + Srr;*
Dn,e	*is the insulation of the trickle ventilator measured according to BS EN ISO 10140;*
Rwi	*is the sound reduction index (octave band value) of the window;*
Rew	*is the sound reduction index (octave band value) of the external wall;*
Rrr	*is the sound reduction index (octave band value) of the roof/ceiling;*
A	*is the equivalent absorption area of the receiving room being considered; and*
3	*is a correction factor.*

4.6 Calculation Assumptions

The façade sound insulation requirements have been calculated using the design noise levels shown in Figure 4-2, and the indoor ambient noise levels targets outlined below under each condition. These room types are considered to be the most stringent scenarios whereby the most stringent acceptable IANL, smallest room volume and greatest façade glazed area is considered.

The following dimensions and information per condition (see Figure 4-2) have been used for the calculations based on what are understood to be typical space dimensions (see Figure 4-3) from the latest layouts from Architon architects:

Condition 1:

- IANL ≤ $L_{Aeq,T}$ 40 dB(A) for a classroom based on BB93 refurbishment criteria;
- 50 m^2 floor area;
- Room height 3 m;
- 8 m^2 (total) façade area;
- 5 m^2 of glazing within the façade;
- Mechanical ventilation; and
- 0.8 s reverberation time for a classroom based on BB93 new build criteria.

An assessment of the Level 3 entrance on Bedford Way has also been undertaken as the 'pavilion elevation' features existing 100 % curtain wall glazing.

- IANL ≤ $L_{Aeq,T}$ 50 dB(A) for an atrium / circulation space based on BB93 refurbishment criteria;
- 100 m^2 floor area;
- Room height 5 m (double height);
- 50 m^2 (total) façade area;
- 50 m^2 of glazing within the façade;
- Mechanical ventilation; and
- 1.5 s reverberation time for a circulation space, based on BB93 new build criteria.

Condition 2:

It is understood that only large (>100 m^2) open plan 'Shared Hubs' (offices) are bordered by Condition 2 facades. In order to provide a reasonable prediction with regards likely impact of external noise intrusion on users, a 10 m x 10 m area bordering the façade has been used in calculations, i.e. users are within 10 m of the nearest façade.

- IANL ≤ $L_{Aeq,T}$ 45 dB(A) for an office based on BB93 refurbishment criteria;
- 100 m^2 floor area;
- Room height 3 m;
- 30 m^2 (total) façade area;
- 19 m^2 of glazing within the façade;
- Mechanical ventilation; and
- 1.0 s reverberation time for an office based on BB93 new build criteria

Condition 3:

- IANL ≤ $L_{Aeq,T}$ 45 dB(A) for an office based on BB93 refurbishment criteria;
- 55 m^2 floor area;
- Room height 3 m;
- 8 m^2 (total) façade area;
- 5 m^2 of glazing within the façade;
- Mechanical ventilation; and
- 1.0 s reverberation time for an office based on BB93 new build criteria

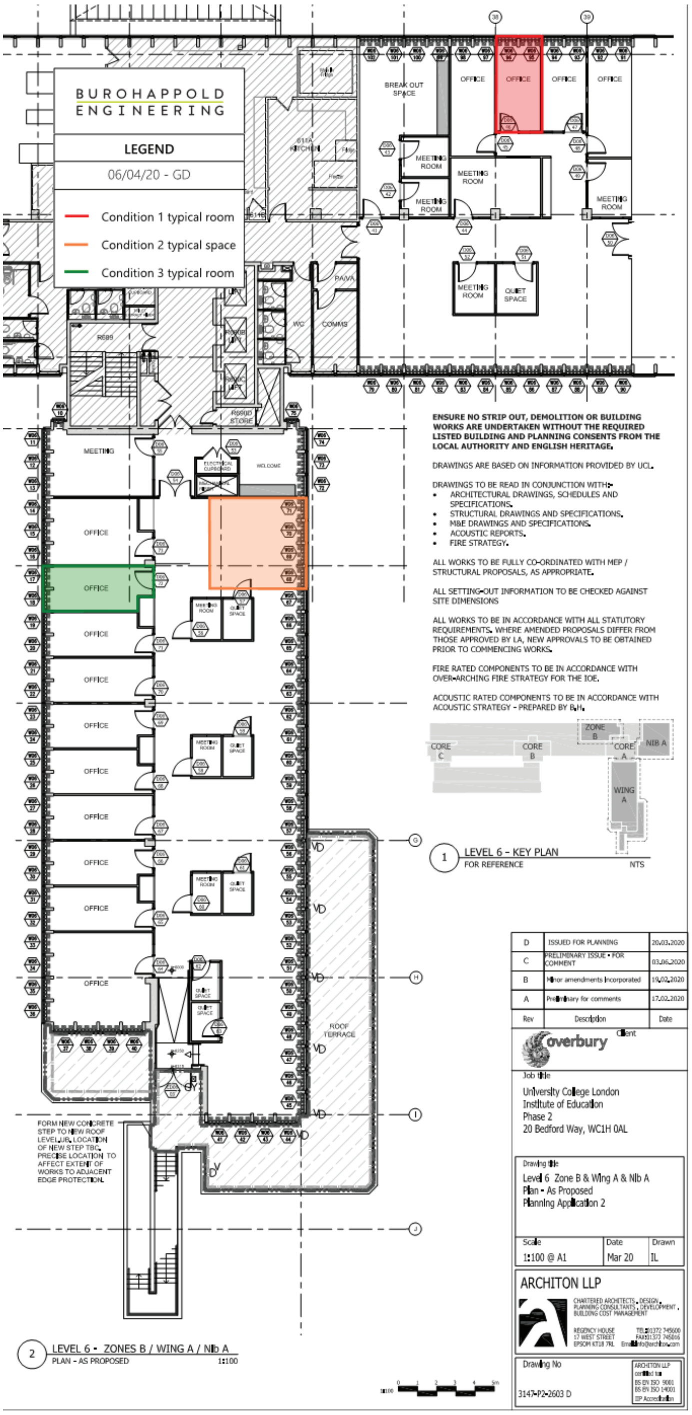


Figure 4-3 Rooms used in noise break-in calculations (Level 6, Phase 2)

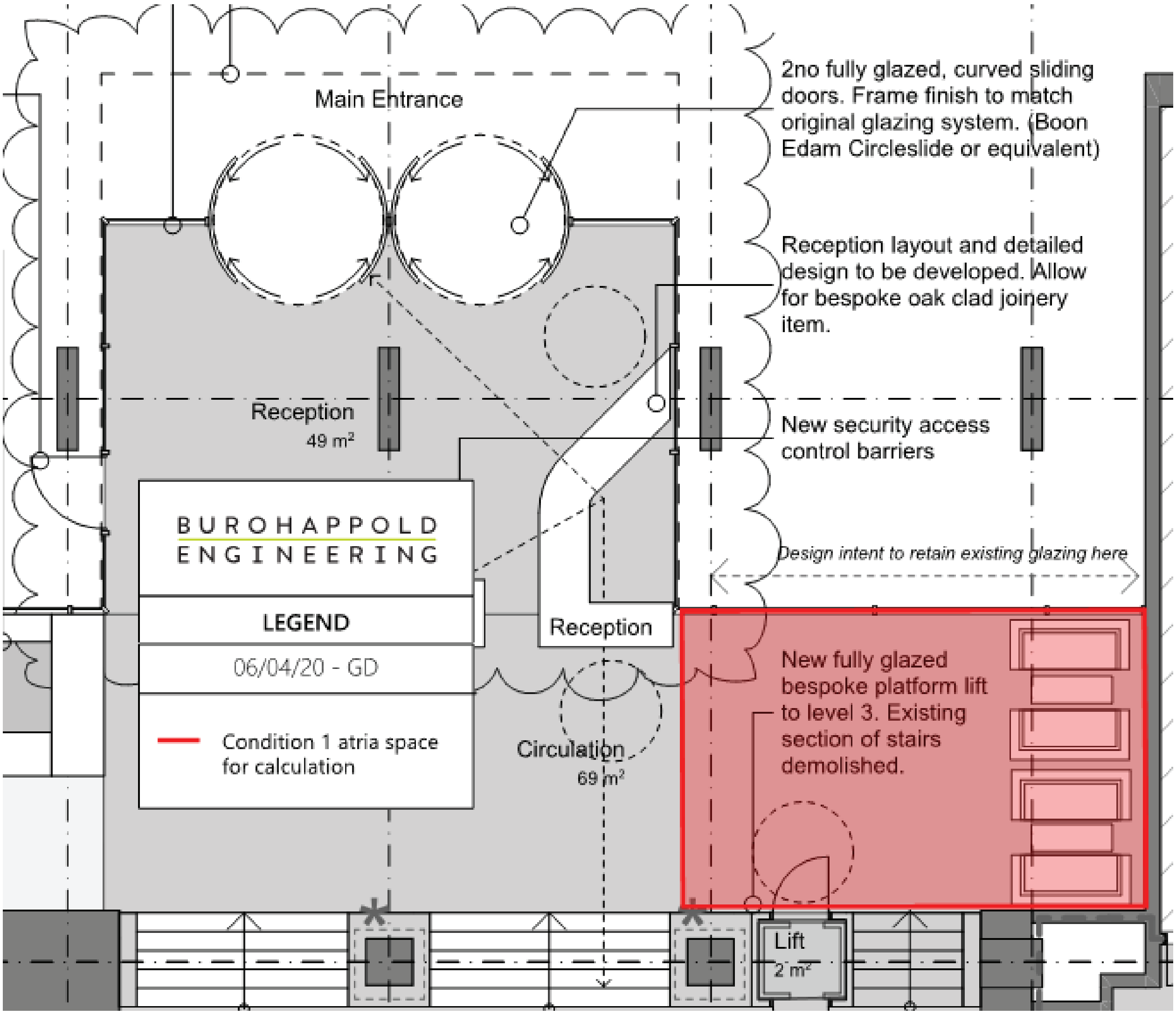


Figure 4-4: Atria space used in noise break-in calculations (Level 3, Phase 2)

4.7 Glazing Requirements

Detailed example calculations are shown in Appendix A. The table below summarises the calculations and gives the required façade glazing (including framing) sound insulation requirements across each condition (see Figure 4-2). To achieve the IANL criteria, the sound reduction at each octave band centre frequency shall be equal to or greater than that shown in Table 4-2.

Table 4-2 Façade glazing requirements

<table>
<tr><th rowspan="2">Condition</th><th colspan="6">Sound reduction (dB)
at each octave band centre frequencies (Hz)</th><th rowspan="2">$R_w + C_{tr}$ – dB</th><th rowspan="2">Example glazing Construction[1]</th></tr>
<tr><th>125</th><th>250</th><th>500</th><th>1K</th><th>2k</th><th>4k</th></tr>
<tr><td>Condition 1</td><td>20</td><td>18</td><td>28</td><td>38</td><td>34</td><td>38</td><td>27</td><td>6 mm glass / 20 mm air gap / 6 mm glass</td></tr>
<tr><td>Condition 1 – Pavilion Entrance</td><td>20</td><td>22</td><td>28</td><td>33</td><td>34</td><td>28</td><td>25</td><td>4 mm glass</td></tr>
<tr><td>Condition 2</td><td rowspan="2">21</td><td rowspan="2">17</td><td rowspan="2">25</td><td rowspan="2">35</td><td rowspan="2">37</td><td rowspan="2">31</td><td rowspan="2">25</td><td rowspan="2">4 mm glass / 20 mm air gap / 4 mm glass</td></tr>
<tr><td>Condition 3</td></tr>
</table>

It should be noted that glazed external doors are located on the building envelope to access terraces and other external spaces. These doorsets should also be capable of achieving the relevant sound reduction values at each octave band centre frequency shown in Table 4-2.

Figure 4-5: Wing A roof terrace external door (Level 7, Phase 2)

[1] These are example configurations for guidance purposes only. The priority when undertaking glazing selections is to match or exceed the specified octave band data.

4.7.1 Previous Phases

It is understood that the façades of the Phase 2 refurbishment currently include a relatively new double-glazed window system that will largely be retained. It is expected, in-line with in-situ test results for previous phases of the IoE refurbishment, that the existing glazing should provide an adequate level of sound reduction already.

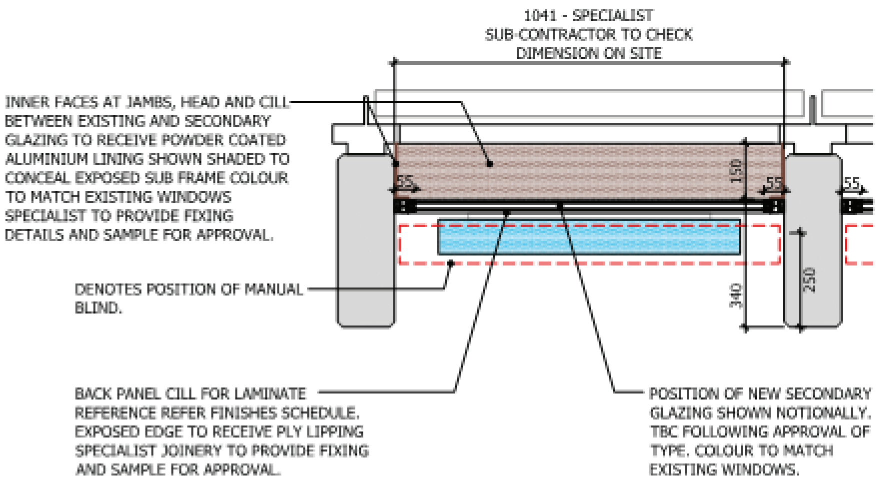


Figure 4-6: Outline secondary glazing strategy

4.7.1.1 Pavilion Entrance

It is understood that the existing glazing is to be retained as part of the Pavilion Entrance on Level 3. Based on the calculations and specifications given above, existing single glazing (including framing) is likely to see that IANLs are less than $L_{Aeq,T}$ 50 dB(A) in the atria / circulation spaces.

4.8 Roof Terraces

It is understood that refurbishment of the terraces on Level 6, 7, 8 and 9 is to be undertaken as part of the Phase 2 works, see Appendix B for the extent and location of these areas. Architon LLP has provided details of these proposals as detailed below:

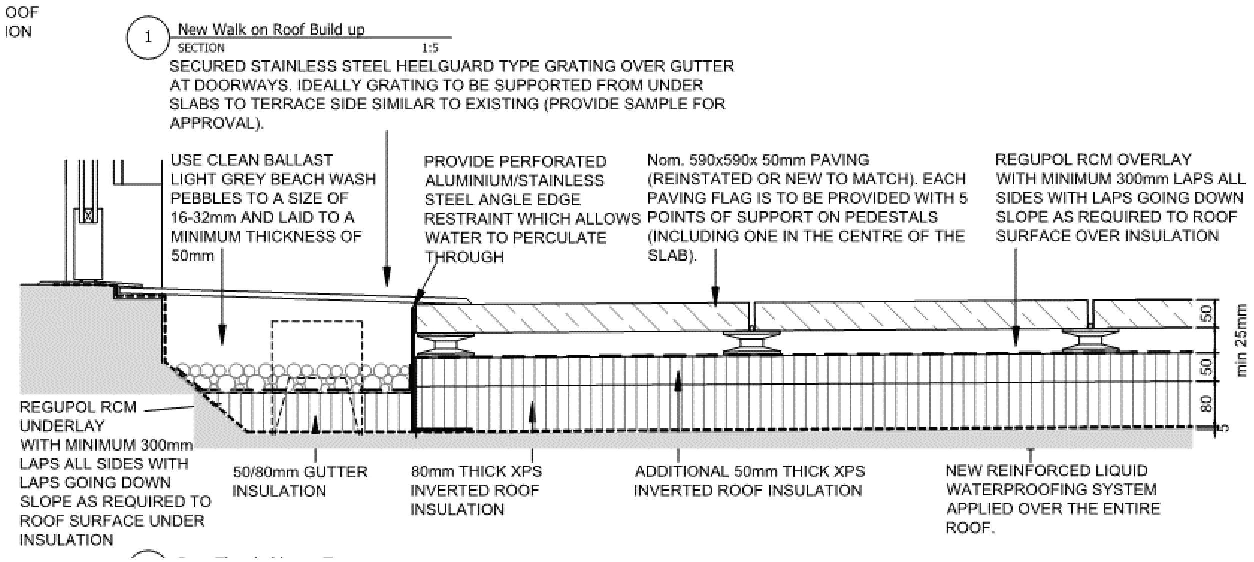


Figure 4-7: Outline secondary glazing strategy

Furthermore, investigation of the Revit model (IOE-ACM-00-ZZ-M3-SE-00001), supplied by Aecom and based on historical drawings of the building (circa. 1972), indicates that the primary structure includes 300 - 355 mm deep concrete roof areas.

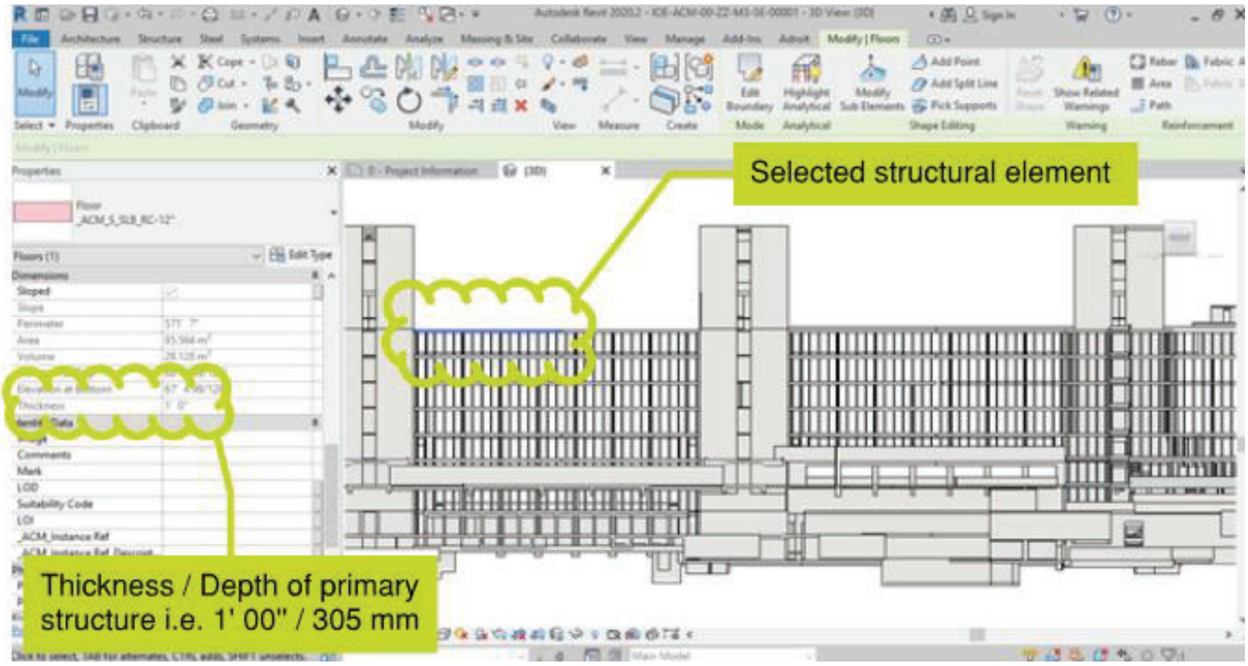


Figure 4-8: Revit model structural roof dimensions - Level 10

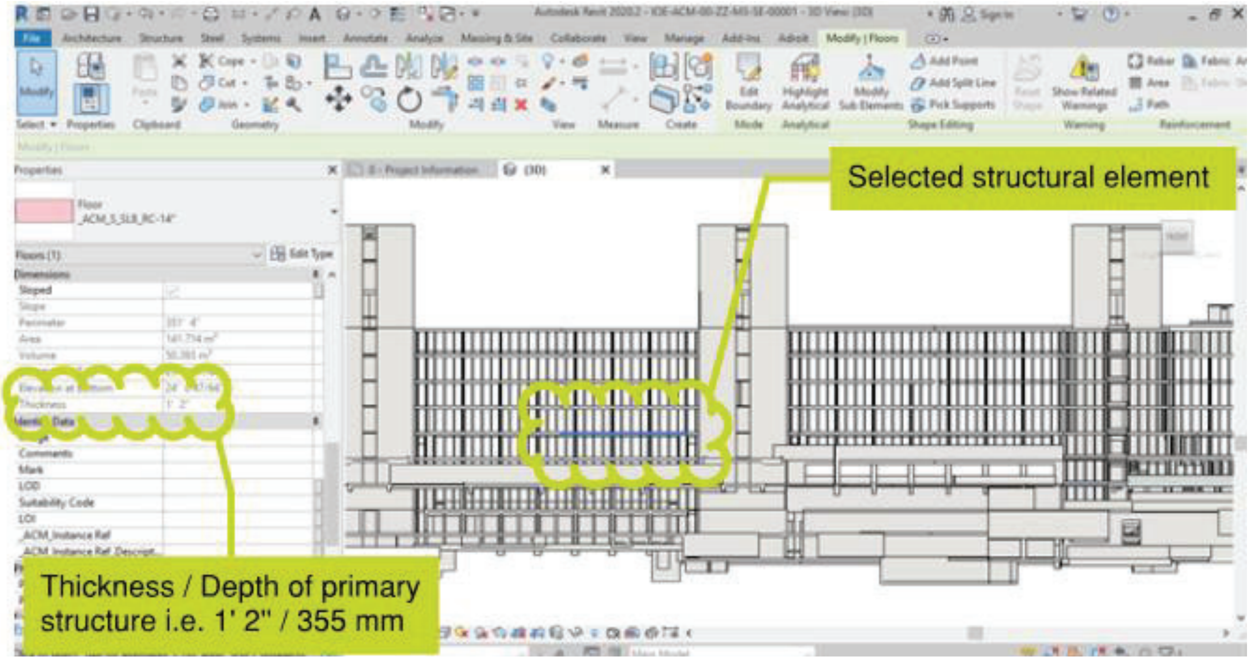


Figure 4-9: Revit model structural roof dimensions - Level 6

The existing floor build up is understood to be hollow pot concrete blocks (no information of the superficial mass Kg/m^2 is available) with 50 mm screed supported by concrete / steel beams and concrete columns. It is also understood that where the slab is damaged, cement particle board is to be fixed to the soffit in these areas as per Phase 1 refurbishment works.

In-line with the above it is expected that the proposed refurbished terraces are to consist of the following:

- 50 mm paving flag on pedestals
- 25 mm void
- 130 mm thermal insulation
- 50 mm concrete screed
- 255-305 mm hollow pot concrete blocks

4.8.1 Environmental noise break-in

The significant mass associated with the proposed roof terrace construction including the existing concrete roof should mean that environmental noise break-in through the roof terrace construction is negligible, particularly when compared to the level of noise ingress via the glazing systems.

4.8.2 Airborne noise transfer

Should the roof terrace areas be significantly populated by users such as the Level 4 terrace (Section 3.4) the significant mass associated with the proposed roof terrace construction including the existing concrete roof should mean that airborne noise transfer through the roof terrace construction is negligible, particularly when compared to the level of noise ingress via the glazing systems.

4.8.3 Rain noise

The mass associated with the roof terraces is also expected to provide more than sufficient protection against rain noise impacts.

4.8.4 Impact Noise

The mass associated with the roof terraces is also expected to provide more than sufficient protection against impact noise such as footfall.

5 Plant Noise Break-Out

5.1 Introduction

Any newly introduced external plant associated with the refurbishment works should be controlled to demonstrate that the Council requirements are achieved and that the noise impact upon existing noise-sensitive receivers is mitigated to within accepted limits.

This section of the report outlines Camden Council's mechanical plant noise limits, which are derived from the lowest background sound level measured at a location representative of the nearest noise sensitive receiver, and the approach to achieving these.

5.2 Design Criteria

5.2.1 Operational plant

Target values to limit the impact of noise break-out from noise-generating plant at nearby NSRs are detailed in Camden Councils guidelines shown in Section 1.3.

The design criteria are reproduced below for reference.

- The cumulative noise level for plant is at least 10 dB below the lowest background noise level ($L_{,A90,15mins}$ dB(A)) for the proposed operating period; and
- The cumulative noise level for plant is at least 15 dB below the lowest background noise level ($L_{,A90,15mins}$ dB(A)) for the proposed operating period should plant be identified as having "acoustic features" (e.g. intermittency, tonal characteristics, and impulsivity).

Individual plant items may need to be designed to a lower limit such that the overall total achieves the stated criteria above.

Since the requirements of the Local Authority with regards to limiting plant noise are more stringent, BREEAM criteria Pol 05 can automatically be met when the local planning requirements are satisfied.

5.2.2 Emergency plant

The following conditions are proposed for Emergency Plant in-line with the Camden Local Plan 2017 requirements shown in Figure 5-1:

- The testing of equipment is not to take place between the hours of 18:00 and 08:00 on any day, and not at any time on Sundays, Bank Holidays or after 13:00 hours on a Saturday;
- The duration of the testing to be commensurate with the test requirements and not to exceed one hour; and
- The acoustic design and control of the fixed plant and equipment to meet a criterion of a rating level, measured or calculated at 1m from the façade of the nearest noise sensitive premises, of not more than 10 dB above the existing background noise level ($L_{A90,15mins}$) as provided in Table 5-1.

6.100 Emergency equipment such as generators which are only to be used for short periods of time will be required to meet the noise criteria of no more than 10dB above the background level (L90 15 minutes). During standby periods, emergency equipment will be required to meet the usual criteria for plant and machinery. Conditions to this effect may be imposed in instances where emergency equipment forms part of the application.

Figure 5-1: Emergency plant criteria (source: Camden Local Plan 2017)

5.3 Noise Sensitive Receivers

The following noise-sensitive receivers (NSRs) have been identified; these have been marked in blue on the annotated aerial image in Figure 5-2 below:

- Hotel rooms located adjacent to the eastern boundary of the IoE building on Bedford Way;
- Commercial and academic buildings adjacent to the southern boundary of the IoE building on Russell Square; and
- Residential, commercial and academic buildings located adjacent to the western boundary of the IoE building on Thornaugh Street and Woburn Square.

Figure 5-2: Site plan showing noise monitoring locations and noise-sensitive receiver (NSRs)

5.4 Plant Noise Limits at the Nearest NSRs

Camden Council requires the noise level of mechanical plant, $L_{Aeq.T}$ dB(A), to be at least 10 dB below the lowest background sound level ($L_{A90,15min}$) when assessed at the nearest NSR.

Furthermore, the Camden Local Plan: 2017 states that plant identified as having "acoustic features" (e.g. intermittency, tonal characteristics, and impulsivity) should have an equivalent noise level ($L_{Aeq.T}$ dB(A)) at least 15 dB below the lowest background noise level.

Based on the measured background sound levels taken during daytime hours (see Section 2.5), and in-line with design criteria (Section 1.3), limiting plant noise levels at the nearby noise sensitive receivers have been set in the table below. It is understood that the proposed mechanical plant and equipment will only be operating during the daytime period (07:00 – 23:00); therefore, only the daytime period is assessed.

Table 5-1: Limiting daytime (07:00 to 23:00 hours) plant noise levels at the nearest NSRs

Lowest measured existing background noise level ($L_{A90,15mins}$ dB(A))	Cumulative plant noise limits from the proposed development: Max. $L_{Aeq,T}$ dB(A) @ 1 m from affected façade	
	Plant without acoustic characteristics	Plant with acoustic characteristics
Location 1 – Bedford Way		
57	47	42
Location 2 – Russell Square		
59	49	44
Location 3 – Thornaugh Street		
47	37	32
Location 4 – Gordon Square		
60	50	45
Location 5 – Woburn Square		
46	36	31

Should any plant operating at night be considered at later stages, the assessment is to be completed for that period in a similar manner. For clarity, this means establishing the night-time background noise level $L_{A90,15mins}$, and setting the cumulative noise limit, $L_{Aeq,T}$ dB(A), in-line with the design criteria detailed above for all new plant as measured at the nearest NSR in terms of $L_{Aeq,T}$.

5.5 Plant Noise Limits at IoE Facades

This section sets out external plant noise limits at the nearest window on the IoE building as it is important to protect users of the IoE building, and to see that noise disturbance from plant noise is minimised.

The following equation gives an approximation of the likely level of noise break-in through a façade with an open window, which is considered a worst-case scenario for the IoE building:

- External noise level – 15 dB = internal noise level

Based on the target internal ambient noise level (IANL) refurbishment criteria of ≤ $L_{Aeq,T}$ 40 dB(A), the limiting level at 1 metre outside of an open window of the IoE building from fixed mechanical plant is:

- $L_{Aeq,T}$ 40 dB(A) + 15 dB = plant noise limit of **$L_{Aeq,T}$ 55 dB(A)**

In addition, based on the target internal ambient noise level (IANL) refurbishment criteria of ≤ $L_{Aeq,T}$ 40 dB(A) and Emergency Plant relaxations proposed in Section 5.2.2, the limiting level at 1 metre outside of an open window of the IoE building from Emergency plant is:

- $L_{Aeq,T}$ 40 dB(A) + 15 dB + 10 dB = Emergency plant noise limit of **$L_{Aeq,T}$ 65 dB(A)**

5.6 Plant Assessment – Noise Break Out

The following proposals have been outlined by Long and Partners as part of the Mechanical, Electrical and Plumbing (MEP) refurbishment programme.

5.6.1 Operating Hours

It is understood that all proposed plant associated with Phase 2 of the refurbishment is to operate between 07:00 and 23:00 hours.[2]

5.6.2 Level 1 and 2 – Plant Room 5/8

Replacement of an AHU unit in the existing Plant Room 5/8 has been proposed as part of the Phase 2 refurbishment. This plant room is located between Cores B and C on the east boundary of the building at Levels 1 and 2. Appendix C shows the extent, location and noise data of the proposed plant refurbishment.

It is understood that the AHU will be ducted to the atmosphere within the air shaft at Level 1 and at higher levels. It is understood that all terminations are no less than 30m from the nearest NSR.

It is expected that Local Authority criteria should be achieved, based on the proposals outlined in Appendix C and the proposed in-duct attenuators as shown below.

Attenuator Schedule

Ref.	Description	Type and Model Code	Dimensions (mm)			Insertion Loss (dB)								Vol (m^3/s)	PL (Pa)	Qty	Noise Criteria	Features
			W	H	L	63	125	250	500	1k	2k	4k	8k					
ATPR3-01	L1 PR3 AHU-PR3-01BINT Atmosphere side	Rectangular SG01H/3C/L/S	1200	650	1800	8	11	20	41	55	39	24	18	2.03	19	1	45dB(A) at 1m	Horizontal elements.
ATPR3-02	L1 PR3 COMMON EXH Atmosphere side	Rectangular SG01V/3C/L/S	1700	1125	2100	11	16	27	51	55	55	37	28	4.06	25	1	45dB(A) at 1m	
ATPR3-03	L1 PR3 AHU-PR3-01AINT Atmosphere side	Rectangular SG01V/3C/L/S	1200	650	1200	6	9	16	32	46	32	21	16	2.03	25	1	45dB(A) at 1m	
ATPR3-04	L1 PR3 COMMON EXT Room side	Rectangular SG02H/2C/L/S	1800	675	1800	8	10	19	39	55	36	21	16	4.06	25	1	NR30 at 2.5m	Unit delivered in 2 sections, split in length. Horizontal elements. Medium pressure rating (+1000/-750Pa).
ATPR3-05	L1 PR3 AHU-PR3-01BSUP Room side	Rectangular SG01H/3C/L/S	1500	925	1050	7	12	22	41	44	33	24	19	2.03	25	1	NR30 at 1.5m	Horizontal elements.
ATPR3-06	L1 PR3 AHU-PR3-01ASUP Room side	Rectangular SG01V/3C/L/S	1200	800	1800	10	14	24	45	55	51	32	25	2.03	24	1	NR30 at 1.5m	
PR5-8/01	L1&2 PR5/8 AHU-03 EXH Atmosphere side	Rectangular SG01V/3C/L/S	800	800	900	4	6	12	25	26	18	13	10	1.89	19	1	50dB(A) at 1m	
PR5-8/02	L1&2 PR5/8 AHU-03 INT Atmosphere side	Rectangular SG01V/3C/L/S	800	800	600	2	4	9	18	18	12	10	9	1.89	18	1	50dB(A) at 1m	

Figure 5-3: Proposed in-duct attenuators to atmosphere for AHU-5/8-03 outlined in red (source: CAICE Design)

[2] Confirmed, in a meeting on 12 March 2020, by Jaime Welch (Overbury) and Nathan Hanson (Long and Partners).

5.6.3 Level 5 – Condensers

4No. external condensers have been proposed at Core B on the east boundary of the building at Level 5 as part of the Phase 2 refurbishment. Appendix D shows the extent, location and noise data (broadband only) of the proposed external condensers.

Due to the proximity, less than a metre, to the IoE Meeting Room and Office windows (see Figure 5-4), the criteria at the development itself ($L_{Aeq,T}$ ≤ 55 dB) is the determinant of the limiting noise levels for the condensers.

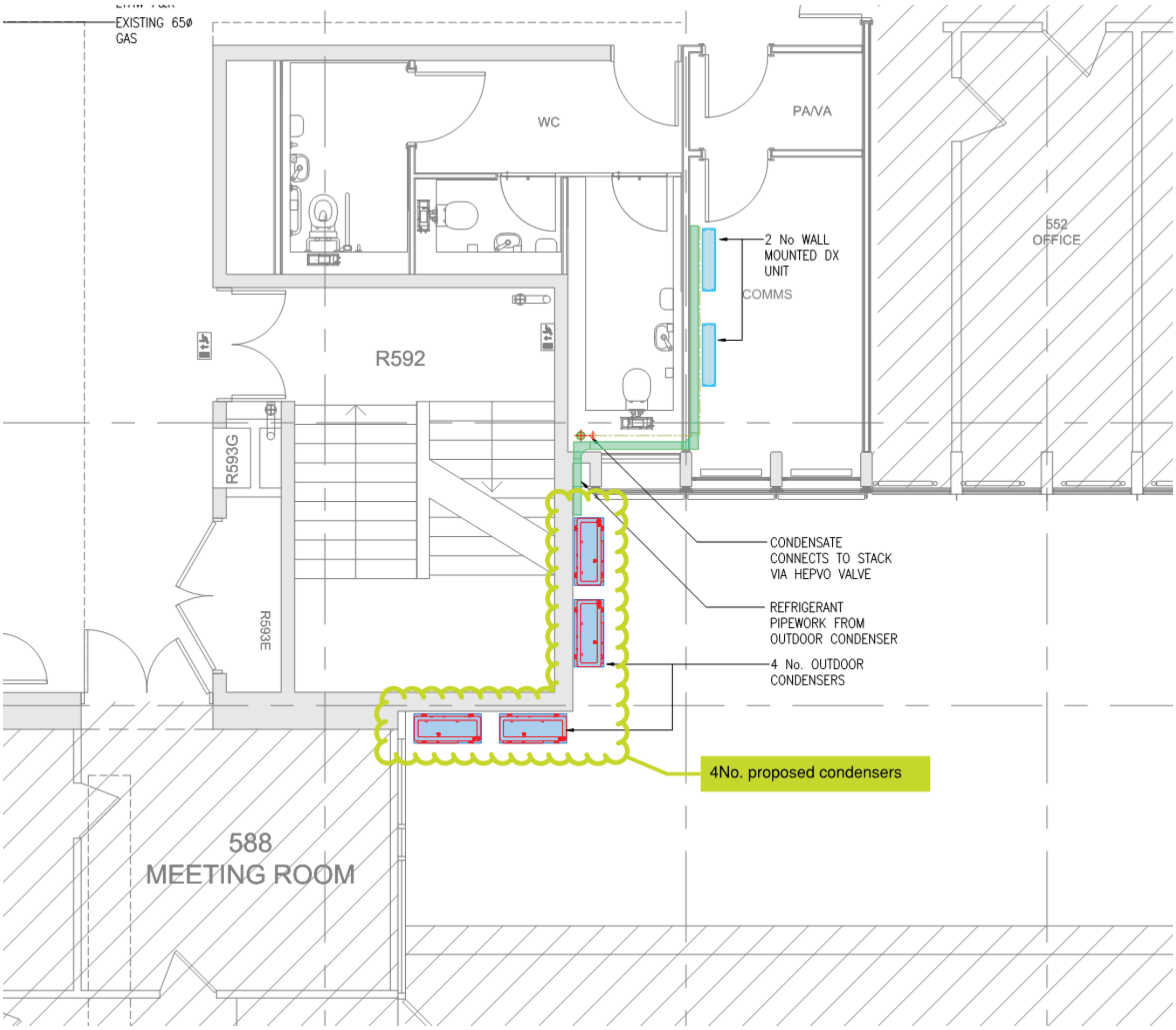


Figure 5-4 Proposed condenser locations showing proximity to own windows

The proposed condensers are expected to achieve the target criteria based on the following assumptions:

- A hemispherical limiting plant noise level of ≤ $L_{Aeq,T}$ 49 dB(A) at 1m from each condenser unit
- There are no acoustic characteristics applicable to the plant e.g. tonality, impulsivity etc.
- The plant is sat on the floor against 2No. reflecting surfaces; and
- The distance between condensers and receiver is 1 m.

It is expected that Local Authority criteria should be achieved by default, based on the recommendations above as the nearest noise sensitive windows at neighbouring residential properties are approximately 47 m away from the proposed plant, and also screened.

5.6.4 Level 8 – AHU unit

A new plant room containing an AHU unit has been proposed as part of the Phase 2 refurbishment. This plant room is to be located at Wing A, Core A on the south boundary of the building at Level 8. shows the extent, location and noise data of the proposed plant refurbishment.

It is understood that the AHU will be naturally ventilated by louvres on the south façade of Wing A; as shown in the following figures:

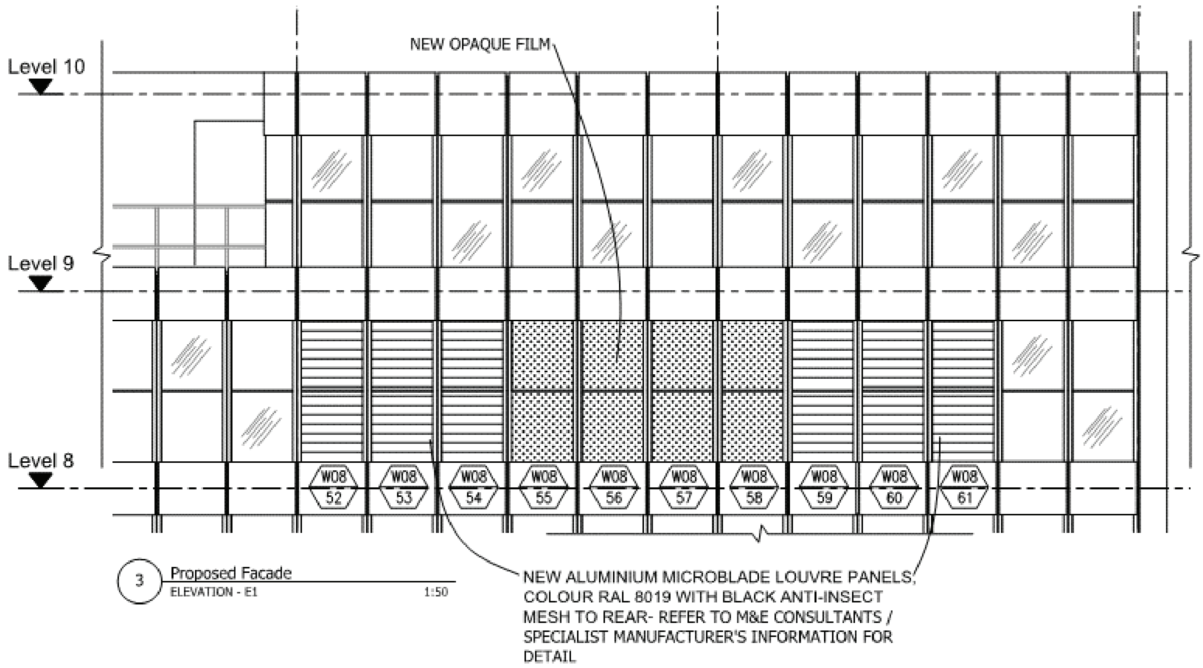


Figure 5-5 South elevation of the proposed plant room at Level 8 showing louvre locations

Due to the close proximity (less than 1m), of the Meeting Room and Office windows to the proposed AHU unit louvres (see Figure 5-4), the target at the IoE façade itself is the determining factor for limiting noise levels for the new plant. As discussed in the sections above, the cumulative external plant noise levels impacting the IoE itself should be ≤ $L_{Aeq,T}$ 55 dB(A).

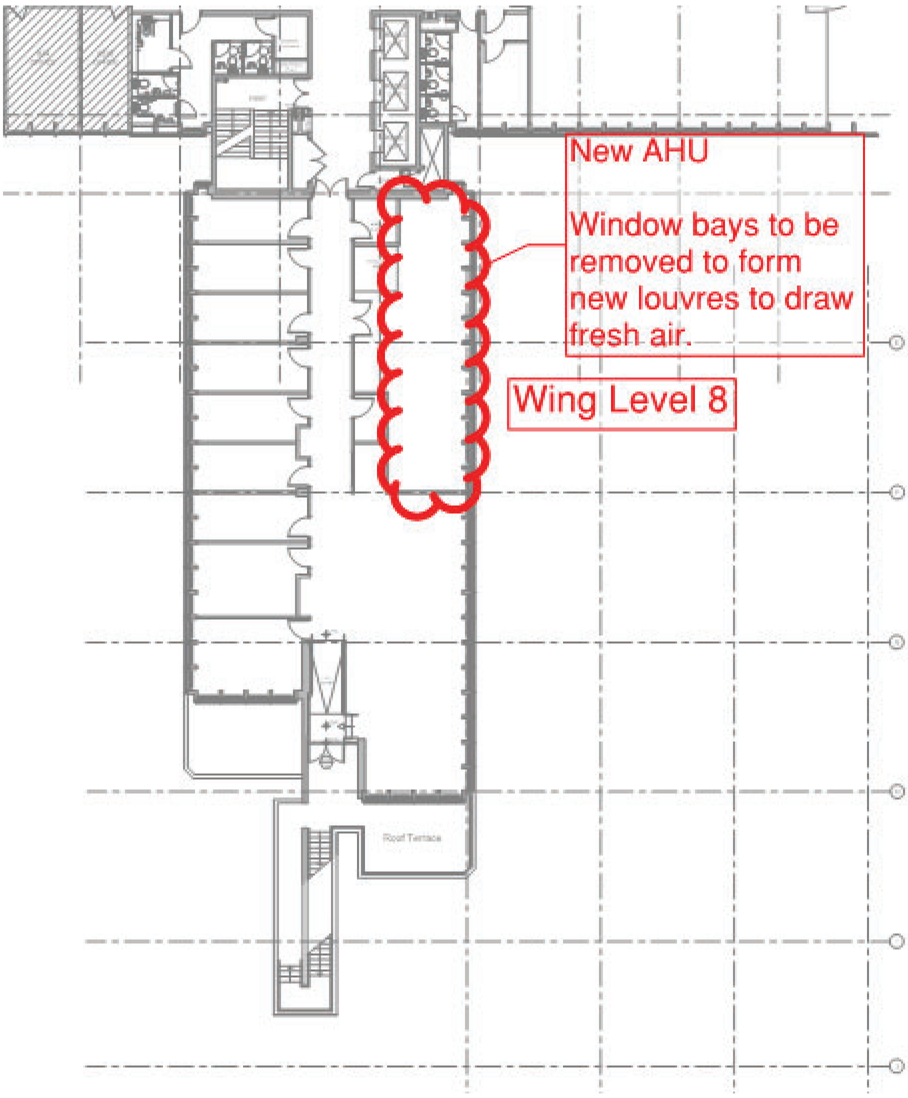


Figure 5-6 Proposed plant room at Level 8 location on plan

It is expected that Local Authority and IoE own window criteria should be achieved, based on the proposals outlined in Appendix C, and the proposed in-duct attenuators as shown below.

ATWL8-01	L8 PR2 AHU-PR8-1 EXH Atmosphere side	Rectangular SG01V/3C/L/S	2050	910	2400	13	18	31	55	55	55	42	32	3.21	18	1	[illegible]
ATWL8-02	L8 PR2 AHU-PR8-1 INT Atmosphere side	Rectangular SG01V/3C/L/S	2050	1010	2100	14	20	32	54	55	55	48	37	3.21	36	1	[illegible]

Figure 5-7 Atmospheric in-duct attenuation specifications – Level 8 AHU Unit (source: CAICE Design)

Furthermore, noise break-out via the proposed acoustic louvres on the south façade of Wing A (as shown in the figures) should have the following insertion loss performance to see that ≤ $L_{Aeq,T}$ 55 dB(A) is achieved at 1 m from the buildings own window.

Acoustic Data	dB in each Octave Band Centre Frequency (Hz)							
	63	125	250	500	1k	2k	4k	8k
Sound reduction index	4	4	6	8	11	11	11	10
Weighted sound reduction index (Rw)	11							
Static insertion loss	3	4	6	10	12	13	13	14
Regenerated sound power level at 1m/s face velocity	48	41	34	35	30	22	13	12
Regenerated sound power level at 2m/s face velocity	66	58	51	51	50	47	41	28

Figure 5-8 Proposed Caice SS150 acoustic louvres insertion loss performance outlined in red – Level 08 (source: CAICE Design)

It is expected that Local Authority criteria should be achieved by default, based on the recommendations above as the nearest noise sensitive windows at neighbouring residential properties are approximately 50 m away from the proposed plant.

5.6.5 Level 12 (Roof) – Chillers

As part of the Phase 2 refurbishment, the plant room at Level 12 of Core A of the building is to house 2No. chillers. It is understood that the roof of the existing plant room is to be removed, thus creating a semi exposed rooftop plant area. Appendix F shows the extent, location and noise data of the proposed plant refurbishment. There are understood to be existing acoustic louvres in the following locations:

- West wall – it is understood these are to be filled e.g. by installing a fully sealed 140 mm blockwork in-fills, specifying blocks of minimum density: 1350 kg/m^2
- East wall – understood to be fitted with 3.0 m x 1.2 m acoustic louvres (x 2)

Furthermore, Planning Notice 2019/6386/P for Phase 2A of the development, dated 2 March 2020 states:

> 5 The chiller unit within Core A hereby approved shall not project higher that the existing roof.
>
> Reason: In order to safeguard the special architectural and historic interest of the building and this part of the conservation area in accordance with the requirements of policies D1 and D2 of the Camden Local Plan 2017.

Figure 5-9: Camden Council planning notice for Phase 2A of the development

The nearest noise sensitive receptors are windows located at the Royal National Hotel on Bedford Way approximately 22 m to the east. The nearest IoE windows are approximately 6 m below which are understood to be teaching spaces.

The calculations consider the following assumptions:

- Spectral noise data for EWAD 500 and EWAD 700 chillers;
- 2No. 3 m x 1.2 m acoustic louvres on the east plant wall;
- The plant is located at a separation distance of 0.5 m from the existing louvre / walls;
- Source height of approx. 24 m, barrier height of 24 m and receiver height of 22 m;
- The plant is sat on the floor and semi-enclosed subject to an approximate reflection correction of + 6 dB;
- The existing louvres on the west wall are understood to be filled e.g. by installing a fully sealed 140 mm blockwork in-fills, specifying blocks of minimum density: 1350 kg/m^2;
- The existing louvres (x 2) on the east wall are proposed to have the following insertion losses installed as per the proposed Caice SH150 product:

Performance

Acoustic Data	dB in each Octave Band Centre Frequency (Hz)							
	63	125	250	500	1k	2k	4k	8k
Sound reduction index	5	5	7	9	13	13	13	12
Weighted sound reduction index (Rw)	13							
Static insertion loss	4	5	7	12	16	16	16	18
Regenerated sound power level at 1m/s face velocity	53	47	38	36	33	29	18	12
Regenerated sound power level at 2m/s face velocity	70	65	58	53	51	51	45	35

Figure 5-10 Proposed Caice SH150 acoustic louvres insertion loss performance outlined in red – east wall (source: CAICE Design)

- The distance between the chillers and nearest NSR is 26 m to the east and screened by the plant room walls; and
- The distance between the chillers and nearest own windows is 6 m and screened by the plant room walls.

In addition, proposals indicate that exhaust air from the Level 11 AHU unit is to terminate in the Level 12 plant room. As a result, cumulative noise levels have been taken into account including AHU noise and are contained in the Level 11 Plant Room assessment found in 5.6.6.

It is expected that Local Authority and IoE own window criteria should be achieved for the proposed chillers at Level 12 (roof plant). Recommendations have been based on the details above and should be updated should plant be reselected and / or layouts altered.

5.6.6 Level 11 – Plant Room 2

As part of the Phase 2 refurbishment, the plant room at Level 11 of Core A of the building is to house a new AHU unit, Toilet Extract Fan and Emergency Generator. Appendix G shows the extent, location and noise data of the proposed plant refurbishment. It is understood that plant will be naturally ventilated by the following all-weather (non-acoustic) louvres:

- West wall – approx. 3.5 m x 2.1 m
- East wall – approx. 3.2 m x 1.1 m (x 2)

Due to the close proximity (less than 3m), of the Meeting Room and Office windows to the proposed terminations / existing louvres (see Figure 5-11), the target at the IoE façade itself is the determining factor for limiting noise levels for the new plant. As discussed in the sections above, the cumulative external plant noise levels impacting the IoE itself should be ≤ $L_{Aeq,T}$ 55 dB(A), and ≤ $L_{Aeq,T}$ 65 dB(A) for Emergency Plant.

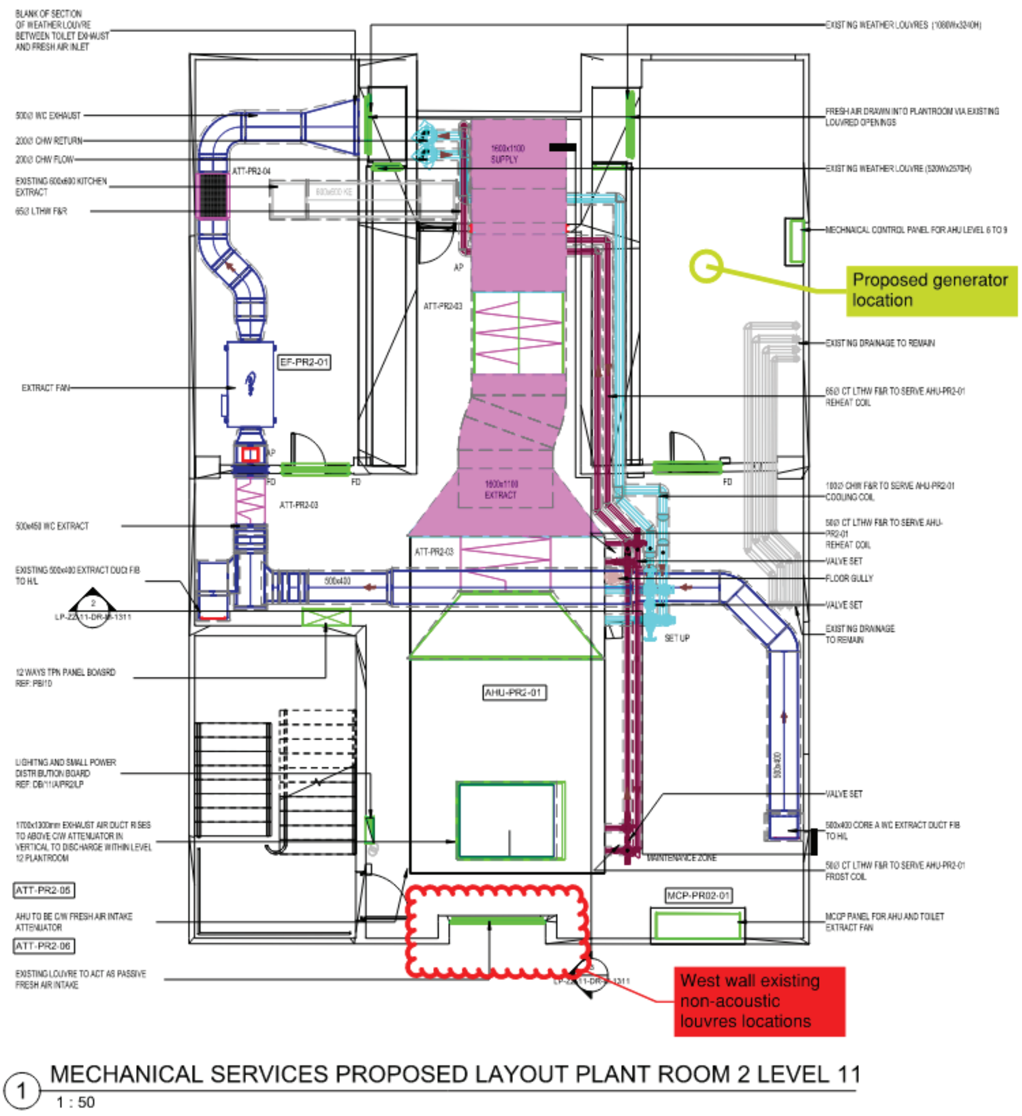


Figure 5-11: Proposed Plant Room 2 at Level 11 existing louvres and proposed generator locations

It is expected that Local Authority criteria should be achieved, based on the proposals outlined in Appendix G and the proposed in-duct attenuators as shown below.

Ref.	Description	Type and Model Code	Dimensions (mm) W	H	L	Insertion Loss (dB) 63	125	250	500	1k	2k	4k	8k	Vol (m^3/s)	PL (Pa)	Qty	Noise Criteria	Features
ATPR1/04	L12 PR2 GEN SUPPLY	Rectangular SG02V/2C/L/S	1500	1800	2400	17	24	38	55	55	55	55	46	2.74	25	1	-	Unit delivered in 2 sections, split in length. Medium pressure rating (+1000/-750Pa).
ATPR1-05	L12 PR2 GEN EXHAUST	Rectangular SG02V/2C/L/S	1500	1800	2400	13	19	37	55	55	47	29	21	5.49	25	1	-	Unit delivered in 2 sections, split in length. Medium pressure rating (+1000/-750Pa).
ATPR1-01	L11 PR2 EF-PR1-01 SYS Room side	Rectangular LG01H/3C/L/S	800	500	600	2	3	5	9	12	8	5	3	1.14	10	1	NR40 at 1.5m	Horizontal elements.
ATPR1-02	L11 PR2 EF-PR1-01 EXH Atmosphere side	Rectangular LG01H/3C/L/S	800	500	600	2	3	5	9	12	8	5	3	1.14	10	1	45dB(A) at 5m	Horizontal elements.
ATPR2-01	L11 PR2 EF-PR2-01 EXT Room side	Rectangular LG01H/3C/L/S	500	450	600	1	2	5	9	11	8	5	5	1.03	19	1	NR40 at 1.5m	Horizontal elements.
ATPR2-02	L11 PR2 EF-PR2-01 EXH Atmosphere side	Rectangular SG01H/3C/L/S	775	625	1050	6	9	17	36	40	31	21	16	1.03	25	1	45dB(A) at 1m	Horizontal elements.
ATPR2-03	L11 PR2 AHU-PR2-01EXT Room side	Modular MG04H/2C/L/S	3420	1345	2100	10	12	23	46	55	46	27	20	12.09	21	1	NR45 at 7m	Horizontal elements. Unit delivered in 4 sections, split 2 in width and 2 in length. Medium pressure rating (+1000/-750Pa).
ATPR2-04	L11 PR2 AHU-PR2-01SUP Room side	Modular MG04H/2C/L/S	3420	1345	1800	8	11	20	41	55	39	24	18	12.09	20	1	NR35 at 1.5m	Horizontal elements. Unit delivered in 4 sections, split 2 in width and 2 in length. Medium pressure rating (+1000/-750Pa).
ATPR2-05	L11 PR2 AHU-PR2-01EXH Atmosphere side	Modular MG02H/3C/L/S	2050	1345	2100	9	12	22	45	55	42	24	18	12.09	48	1	50dB(A) at 5m	Horizontal elements. Unit delivered in 2 sections, split 2 in width.
ATPR2-06	INTEGRAL TO AHU		0	0	0	0	0	0	0	0	0	0	0	0.00	0	1	-	

Figure 5-12: Proposed in-duct attenuators to atmosphere for AHU-PR2-01 and EF-PR2-01 outlined in red (source: Caice Design)

Furthermore, noise break-out via the proposed acoustic louvres on the west wall (as labelled in red in Figure 5-11) should have the following insertion loss performance to see that ≤ $L_{Aeq,T}$ 55 dB(A) is achieved at 1 m from the buildings own window. It is assumed that each space within the plant room has been adequately sound insulated e.g. > Rw 25 dB door, > Rw 35 dB wall for internal plant room partitions.

Acoustic Data	dB in each Octave Band Centre Frequency (Hz)							
	63	125	250	500	1k	2k	4k	8k
Sound reduction index	7	8	13	23	37	33	29	29
Weighted sound reduction index (Rw)	25							
Static insertion loss	6	8	13	23	38	32	32	32
Regenerated sound power level at 1m/s face velocity	54	46	37	32	28	24	15	12
Regenerated sound power level at 2m/s face velocity	71	66	57	50	47	46	41	30

Figure 5-13 Proposed Caice CS600 acoustic louvres insertion loss performance outlined in red – Level 11 (source: CAICE Design)

It is expected that Local Authority criteria should be achieved by default, based on the recommendations above as the nearest noise sensitive windows at neighbouring residential properties are approximately 26 m away from the proposed plant.

5.6.2 Level 1 – Plant Room 3

Replacement of an AHU unit in the existing Plant Room 3 has been proposed as part of the Phase 2 refurbishment. This plant room is located on the south boundary of the building at Level 1. Appendix H shows the extent, location and noise data of the proposed plant refurbishment.

It is understood that the AHU will be ducted to the atmosphere within the existing fresh air plenum at Level 1 and at high level. It is understood that the plenum is approximately 40m and screened from the nearest NSR. Locations of high level terminations were not known at the time of writing yet it is expected that a worst case assessment has been undertaken.

Due to the close proximity (less than 1m), of the buildings own windows to the proposed AHU unit louvres the target at the IoE façade itself is the determining factor for limiting noise levels for the new plant. As discussed in the sections above, the cumulative external plant noise levels impacting the IoE itself should be ≤ $L_{Aeq,T}$ 55 dB(A), and ≤ $L_{Aeq,T}$ 65 dB(A) for Emergency Plant.

It is expected that Local Authority criteria should be achieved, based on the proposals outlined in Appendix H and the proposed in-duct attenuators as shown below.

			Dimensions (mm)			Insertion Loss (dB)												
Ref.	Description	Type and Model Code	W	H	L	63	125	250	500	1k	2k	4k	8k	Vol (m^3/s)	PL (Pa)	Qty	Noise Criteria	Features
ATPR3-01	L1 PR3 AHU-PR3-01BINT Atmosphere side	Rectangular SG01H/3C/L/S	1200	650	1800	8	11	20	41	55	39	24	18	2.03	19	1	45dB(A) at 1m	Horizontal elements.
ATPR3-02	L1 PR3 COMMON EXH Atmosphere side	Rectangular SG01V/3C/L/S	1700	1125	2100	11	16	27	51	55	55	37	28	4.06	25	1	45dB(A) at 1m	
ATPR3-03	L1 PR3 AHU-PR3-01AINT Atmosphere side	Rectangular SG01V/3C/L/S	1200	650	1200	6	9	16	32	46	32	21	16	2.03	25	1	45dB(A) at 1m	

Figure 5-14: Proposed in-duct attenuators to atmosphere for AHU-PR3-01A/B outlined in red (source: CAICE Design)

5.7 Plant Assessment - Noise transfer into the IoE building Itself

5.7.1 Criteria

Mitigation measures should be considered to see that transfer of noise through the soffit and walls of the proposed plant rooms and into adjacent teaching / office spaces is suitably minimised to protect future users of the adjacent spaces. As such, the targets reproduced below are considered to be suitable for noise transfer from the proposed plant:

Table 5-2: Maximum acceptable noise levels for plant room noise transfer

Room Type	Maximum Acceptable Noise Level from Plant Room Noise Transfer
Lecture room	NR 25-30
Seminar room, classroom	NR 25-35
Circulation spaces not intended for teaching or learning	NR 35-45
Cellular office, meeting room	NR 35
Open plan office	NR 40
Open plan resource / breakout area, kitchen	NR 45
Toilet, corridors, stairwells	NR 35-45

5.7.2 Strategy

It is not anticipated that further assessment of noise transfer would be required, assuming the design process is thorough e.g. appropriate vibration isolation to the plant and that the proposed concrete slab roof / partition is adequate. However, it should be noted, current specifications are based on assumed worst-case levels of ≤ $L_{Aeq,T}$ 80 dB(A) within plant rooms (based on the First Action Level stipulated in the Noise at Work Regulations) and achieving the appropriate level shown in Table 5-2 within affected adjacencies.

The following plant rooms ought to be considered with regards noise transfer into adjacent spaces. Plant Room 5/8 is incorporated into the IoE building at Levels 1 and 2, which is located directly below Post Graduate Research (PGR) and Teaching spaces at Level 3. Furthermore, the proposed Level 8 plant room is surrounded by office spaces both horizontally and vertically.

However, on the basis that noise complaints are not currently forthcoming regards noise transfer into noise-sensitive places, it is anticipated that the current in-situ constructions are likely to be sufficient to reduce the potential for noise disturbance in adjacent areas.

5.8 Discussion

An acoustic survey was conducted in the vicinity of the development site to assess the existing noise climate. Analysis of the lowest measured background sound levels has been undertaken.

Pre-commencement Planning Condition 4 of Phase 2B for the development states the following:

> *Prior to commencement of the relevant works, details shall be submitted to and approved in writing by the Council, of the external noise level emitted from plant/ machinery/ equipment and mitigation measures as appropriate. The measures shall ensure that noise levels at a point 1 metre external to sensitive facades shall be at least 10dB(A) less than the existing background measurement (LA90), expressed in dB(A) when all plant/equipment (or any part of it) is in operation unless the plant/equipment hereby permitted will have a noise that has a distinguishable, discrete continuous note (whine, hiss, screech, hum) and/or if there are distinct impulses (bangs, clicks, clatters, thumps), then the noise levels from that piece of plant/equipment at any sensitive façade shall be at least 15dB(A) below the LA90, expressed in dB(A).*

In accordance with Camden Council requirements, new plant noise emissions shall be at least 10 dB less than the existing background measurement, and emergency plant must not exceed existing background noise level by more than 10 dB.

It is expected that noise from plant can be controlled to satisfy Local Authority criteria by selecting low noise plant items and use of noise mitigation measures as proposed and detailed above.

Appendix A Example Noise Break-In Calculations

FAÇADE BREAK-IN CALCULATION

Project Name	UCL Institute of Education	BUROHAPPOLD ENGINEERING
Room or space	Atria - Condition 1	
Date	06/04/20	

ROOM CONSTANT & FAÇADE AREA

Façade area (incl. window)	*50.0 m2*	**Area of the external wall**	0 m2
Area of the louver	*0.0 m2*		
Area of the windows	*50.0 m2*		
Area of the roof/ceiling	*100.0 m2*	**Area of exposed envelope**	####
Room Depth (x)	*10.0 m*		
Room Width (y)	*10.0 m*	**Room Volume**	####
Ceiling height (z)	*5.0 m*		

Room reverberation time (s)

Tmf	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
1.5	1.5	1.5	1.5	1.5	1.5	1.5

DISTANCE ATTENUATION CALCULATION

Distance correction	*No*	**Calculated Distance Attenuation**	-
Type of distance correction	*Line source*		
Distance from source to microphone	-		
Distance from source to receiver	-		

FREE FIELD LEVELS AT 1m FROM THE NOISE SENSITIVE FAÇADE

		dB(A)	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
LAeq	Free Field Leq in octave bands (dB)	67	73	66	64	63	59	53
	Resultant Free-Field Leq with distance attenuation (dB(A))	67	73	66	64	63	59	53

		dB(A)	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
LAmax (if applicable)	Free Field Lfmax in octave bands	-	-	-	-	-	-	-
	Resultant Free-Field LAmax with distance	-	-	-	-	-	-	-

SOUND REDUCTION PROPERTIES OF BUILDING ELEMENTS

		125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	R_w	R_w+C_{Tr} (dB)
Window (R_w)	*Manual*	20	22	28	33	34	28	0	0
Louver (Rw)	*No Louver*	0	0	0	0	0	0	0	0
External wall Construction (Rw)	*Typical external wall construction*	46	44	46	54	62	67	52	49
Roof Construction (Rw)	*Typical roof construction*	99	99	99	99	99	99	99	99

			125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	$D_{n,ew}$ (dB)
Trickle Vent ($D_{n,e,w}$)	*No Vent*	0 Units	200	200	200	200	200	200	-

CALCULATED INTERNAL LAeq AND LAF,max LEVELS

	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
Calculated LAeq in the receiver room (dB)	56	47	39	33	28	28
Calculated LAFmax in the receiver room (dB)	-	-	-	-	-	-

L_{Aeq} (125-4000Hz)	L_{Amax} (125-4000Hz)
44 dB(A)	**-**

FAÇADE BREAK-IN CALCULATION

Project Name	UCL Institute of Education	BUROHAPPOLD ENGINEERING
Room or space	Classroom - Condition 1	
Date	06/04/20	

ROOM CONSTANT & FAÇADE AREA

Façade area (incl. window)	*8.0 m2*	**Area of the external wall**	3 m2
Area of the louver	*0.0 m2*		
Area of the windows	*5.0 m2*		
Area of the roof/ceiling	*50.0 m2*	**Area of exposed envelope**	58 m2
Room Depth (x)	*10.0 m*		
Room Width (y)	*5.0 m*	**Room Volume**	####
Ceiling height (z)	*3.0 m*		

Room reverberation time (s)

Tmf	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
0.8	0.8	0.8	0.8	0.8	0.8	0.8

DISTANCE ATTENUATION CALCULATION

Distance correction	*No*	**Calculated Distance Attenuation**	-
Type of distance correction	*Line source*		
Distance from source to microphone	-		
Distance from source to receiver	-		

FREE FIELD LEVELS AT 1m FROM THE NOISE SENSITIVE FAÇADE

		dB(A)	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
LAeq	Free Field Leq in octave bands (dB)	67	73	66	64	63	59	53
	Resultant Free-Field Leq with distance attenuation (dB(A))	67	73	66	64	63	59	53
LAmax (if applicable)	Free Field Lfmax in octave bands	89	91	87	85	85	81	76
	Resultant Free-Field LAmax with distance	89	91	87	85	85	81	76

SOUND REDUCTION PROPERTIES OF BUILDING ELEMENTS

			125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	R_w	R_w+C_{Tr} (dB)
Window (R_w)	*Rw+Ctr 27dB BS12354 6/20/6*		20	18	28	38	34	38	31	27
Louver (Rw)	*No Louver*		0	0	0	0	0	0	0	0
External wall Construction (Rw)	*Typical external wall construction*		46	44	46	54	62	67	52	49
Roof Construction (Rw)	*Typical roof construction*		99	99	99	99	99	99	99	99
			125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	$D_{n,ew}$ (dB)	
Trickle Vent ($D_{n,e,w}$)	*No Vent*	0 Units	200	200	200	200	200	200	-	

CALCULATED INTERNAL LAeq AND LAF,max LEVELS

	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
Calculated LAeq in the receiver room (dB)	48	43	31	20	20	10
Calculated LAFmax in the receiver room (dB)	63	61	49	39	39	30

L_{Aeq} (125-4000Hz)	L_{Amax} (125-4000Hz)
37 dB(A)	**55 dB(A)**