150 HOLBORN

STAGE 05 SUBMISSION - Z2_RESIDENTIAL BUILDING

ACOUSTIC DESIGN REPORT

150-PWA-Z2-XX-RP-A6_REV C01

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DARPLUS

SANDY BROWN

SANDY BROWN

Consultants in Acoustics, Noise & Vibration

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150 Holborn, London EC1

Stage 4 acoustic design report (residential)

55 Charterhouse Street, London EC1M 6HA
68 Sackville Street, Manchester M1 3NJ
2 Walker Street, Edinburgh EH3 7LA
87 Caroline Street, Birmingham B3 1UP

T: +44 (0)20 7549 3500
T: +44 (0)161 771 2020
T: +44 (0)131 235 2020
T: +44 (0)121 227 5020

post@sandybrown.com
www.sandybrown.com

Sandy Brown Associates LLP
Registered in England & Wales No. OC 307504

Registered Office: 55 Charterhouse Street, London EC1M 6HA

Version	Date	Comments	Author	Reviewer
A	2 May 18		Sam Daintree	Philip Owen

Summary

Sandy Brown has been commissioned to provide acoustic advice in relation to the proposed mixed use commercial led development at 150 Holborn, London EC1.

The report summarises the design criteria to be adopted for the residential use spaces in the proposed building. The design criteria are based upon the Camden Council requirements, Building Regulations and other relevant design standards.

These include noise ingress/egress, sound insulation, room acoustics and building services noise & vibration. On the basis of these, the report considers the following:

- Acoustic design criteria
- Building envelope acoustic performance requirements
- Internal sound insulation requirements for separating floors, walls & doors
- Reverberation and noise control
- Building services noise & vibration control.

This report sets out the adopted acoustic design criteria and the documented design measures.

Contents

1 Introduction

Sandy Brown has been commissioned to provide acoustic advice in relation to the proposed mixed use commercial led development at 150 Holborn, London EC1.

This report summarises the acoustic design strategy for the residential areas of the building.

Guidance on relevant acoustic terminology is given in Appendix A.

1.1 Description of development

The site location in relation to its surroundings is shown in Figure 1.

Figure 1 Site map (courtesy of Google Earth Pro)

The site is located at 150 Holborn, which is bound by Gray's Inn Road to the west, Brooke Street to the east and Holborn to the south.

The site is in the London Borough of Camden (LBC), with the boundary of the City of London (CoL) on the southern side of Holborn.

The residential element of 150 Holborn is located on the Brooke Street facing elevation of the site. The residential comprises a total of 13 units, a total of 1,332 m^2 (14,338 ft^2) Gross Internal Area (GIA), arranged over 7 floors plus basement level.

The basement level consists primarily of plant facilities.

The main entrance is off of Brooke Street and comprises a residential reception lounge, cycle storage for 22 bicycles and refuse facilities.

Floors 1 to 6 form the residential accommodation, providing 3 x studios, 3 x 1 bed units, 5 x 2 bed units and 2x 3 bed duplexes on the top two floors.

The residential core provides lift access to all units and will also provide a separated fire exit staircase.

The residential facades are highlighted in Figure 2 with yellow (Brooke Street) and purple (courtyard).

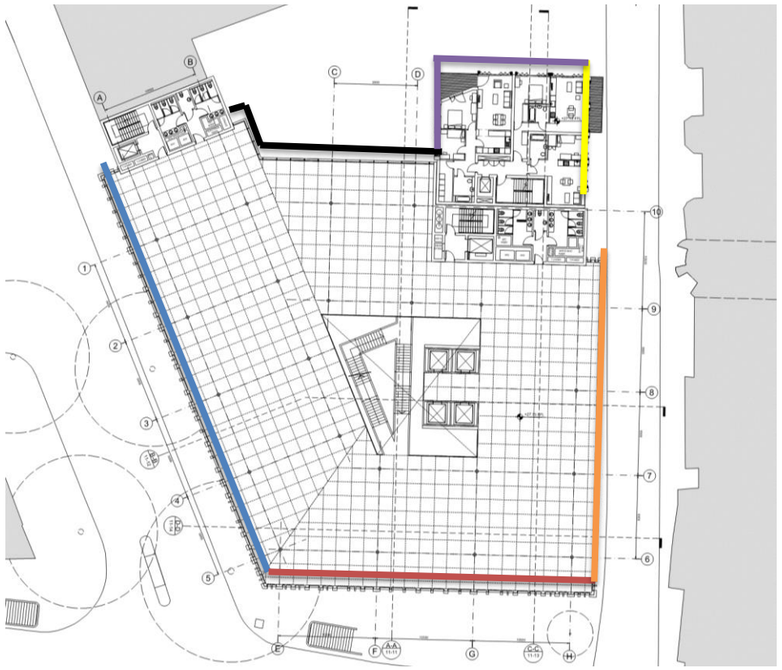

Figure 2 Proposed 150 Holborn development

2 Key acoustic design requirements

The key acoustic design requirements can broadly be summarised as follows:

- Building envelope: The control of intrusive noise (from environmental sources including road traffic and building services plant on other nearby buildings) via the building envelope to acceptable levels within internal spaces

  The control of vertical sound transmission between floors and horizontal flanking sound transmission between adjacent spaces on the same floor

  The control of noise breakout from spaces which contain plant/equipment or other noisy activities

  The control of self-noise associated with thermal movement of the cladding system and/or airflow movement across it

- Sound insulation: Internal walls, floors, ceilings and doors will need to adequately reduce sound transmission

  Impact sound transmission through floors will also need to be considered in specific locations as will airborne/structure-borne sound transmission from plant

- Acoustic quality: The acoustic environment within each space will need to be compatible with the proposed usage, in particular the control of reverberation and noise build-up

- Building services: Noise & vibration from building services plant and systems (including maintenance equipment) will need to be controlled by suitable attenuation and isolation measures, both inside and outside the development.

Each of these is discussed in more detail in the following sections.

3 Schedule of acoustic criteria

In establishing the appropriate criteria, reference has been made to the following design documentation and standards:

- 15374-R13-D *Stage 3 acoustic design report*, produced by Sandy Brown
- BS 8233:2014 *Guidance on sound insulation and noise reduction for buildings* (BS 8233)
- World Health Organisation (WHO) *Guidelines for community noise (2000)*
- Development Policy 28 (DP28), *Noise and vibration,* London Borough of Camden (2010)
- Approved Document E 2003 Edition (including 2004 and 2010 amendments) of The Building Regulations 2000 (ADE2003)
- Code for Sustainable Homes (CfSH)
- The Chartered Institute of Building Services Engineers (CIBSE) Guide A 2015 Environmental criteria for design
- BS 6472- 1: 2008 *Guide to evaluation of human exposure to vibration in buildings. Vibration sources other than blasting*
- The Construction (Design and Management) Regulations 2015

3.1 Adopted acoustic design standards

The adopted acoustic design standards are detailed in Table 1.

Table 1 Schedule of acoustic criteria

Acoustic consideration	Affected element	Acoustic criteria	Relevant codes and standards	Comments
ENVIRONMENTAL NOISE/PLANNING CONDITIONS				
Internal noise limits: *Appropriate internal noise limits must be applied to control noise break in from the external environment*	Building envelope to residential units (including cladding, glazing and ventilation)	Living room (07:00–23:00) - $L_{Aeq,16hr}$ 35 dB Bedroom (07:00–23:00) - $L_{Aeq,16hr}$ 35 dB Bedroom (23:00–07:00) - $L_{Aeq,8hr}$ 30 dB.	BS 8233:2014	-
		Bedroom (23:00-07:00) - L_{AFmax} 45 dB should not be exceeded more than 10-15 times a night	WHO guidelines	-
External noise limits: *Noise from building services plant etc needs to be limited to minimise disturbance to existing (and new) noise sensitive premises in the vicinity of the development, and new noise sensitive premises within the development*	Building services design	Weekday/Weekend: • Daytime $L_{Aeq,T}$ (0700-1900) ○ Brooke St - 50/46 dB ○ Holborn - 57/53 dB ○ Gray's Inn Rd - 56/53 dB • Evening $L_{Aeq,T}$ (1900-2300) ○ Brooke St - 49/45 dB ○ Holborn - 56/53 dB ○ Gray's Inn Rd - 54/53 dB • Night $L_{Aeq,T}$ (2300-0700) ○ Brooke St - 42/41 dB ○ Holborn - 49/47 dB ○ Gray's Inn Rd - 51/50 dB	Camden Council DP28	If the proposed plant noise contains attention catching features (such as tonal elements, whines, whistles, bangs etc), the plant should be designed to achieve a limit 5 dB below those presented.
SOUND INSULATION				
Party walls and floors between residential and non-residential spaces - airborne *Appropriate levels of airborne sound insulation are required to minimise sound transfer horizontally and vertically between residential and non-residential units*	Party floors separating ground floor spaces (plant, stores, circulation) and first floor apartments	Minimum $D_{nT,w}$ + C_{tr} of 50 dB	ADE2003 (E1) CfSH	Performance of 5 dB better than ADE is considered suitable as the ground floor spaces are not expected to be noisy.

Acoustic consideration	Affected element	Acoustic criteria	Relevant codes and standards	Comments
Party walls and floors between apartments – airborne *Appropriate levels of airborne sound insulation are required to minimise sound transfer between horizontally and vertically adjacent apartments*	Party walls and floors (and associated detailing)	Minimum $D_{nT,w}$ + C_{tr} of 50 dB to achieve 5 dB better than ADE2003 for CfSH credits	ADE2003 (E1) CfSH	Building Regulations requirements are absolute minimum to receive Building Control sign-off. The 5 dB improvement is the design target for all party walls Pre-completion testing to demonstrate compliance with adopted standard will be required.
Party floors – impact *Appropriate levels of impact sound insulation are required to mitigate disturbance to below from impact sources such as footfall and chairs scraping etc*	Party floors (and associated detailing)	Maximum $L_{nT,w}$ of 57 dB to achieve 5 dB better than ADE2003 for CfSH credits	ADE2003 (E1) CfSH	Building Regulations requirements are absolute minimum to receive Building Control sign-off, and is the required standard for the majority of apartments. Pre-completion testing to demonstrate compliance with adopted standard will be required.
Internal walls/floors – airborne *Appropriate levels of airborne sound insulation are required for internal walls to mitigate disturbance within apartments*	Internal walls and floors within dwellings.	Minimum R_w of 40 dB	ADE2003 (E2)	This requirement strictly only applies to internal floors, and internal walls which separate a bedroom or a room with a WC from other rooms within dwellings. It does not apply to walls with doors in, or to walls which separate an en-suite from the bedroom with which it is associated. This requirement is only a laboratory requirement, and does not require on-site testing.
Plant room *Walls between plant rooms and non-residential areas do not require the same standard as other walls*	Basement plant room walls	-	-	140 mm solid masonry (block or brickwork with a minimum density of 1400 kg/m^3) is deemed to be compliant with this requirement
Lift shafts *Walls between lift shafts and habitable rooms require higher levels of sound insulation and protection against structure-borne noise to minimise disturbance*	Lift shaft walls	Lift shaft walls to bedrooms and living rooms should incorporate an independent wall lining mounted on independent studs ie, not tied back to the lift shaft wall (2 x 12.5mm SoundBloc + 25 mm insulation)	BS 8233:2014	Lifts often generate vibration which can cause issues with re-radiated 'structure-borne' noise in adjacent spaces. As such, an independent wall lining is required to living rooms and bedroom walls to mitigate the transmission of structural noise from lifts into sensitive spaces.
Recesses into party walls *Appropriate detailing must be applied to ensure recessed fittings do not undermine the sound insulation of party walls*	Party walls	Recessed sockets and switches etc should be avoided in party walls	-	Recessed sockets and switches etc should not be located in party walls formed using drywalls. Where this is unavoidable, they must be boxed in to the rear with a suitable enclosure, and must not be back to back (ie sockets on opposite sides of the wall should not be located within the same stud bay).

Acoustic consideration	Affected element	Acoustic criteria	Relevant codes and standards	Comments
Riser walls *Appropriate level of sound insulation between dwellings and risers in order to maintain the sound insulation between dwellings and to minimise disturbance from riser noise*	Riser shafts adjacent to dwellings or linking dwellings vertically (open riser shafts)	R_w 45 dB	-	Not applicable
Services enclosures *Services which penetrate party walls or floors need to be appropriately detailed to ensure above requirements are achieved, and to minimise disturbance from water noise etc.*	Water services pipework adjacent to habitable spaces (often affects soil stacks etc)	Pipe must be lagged (see Section 8.9), and enclosed with board material (minimum mass per unit area of boarding equivalent to 20 kg/m^2) Pipework cannot be located within party walls or supported from drywalls.	ADE2003	Careful detailing of all services will be required such that flanking sound transmission routes do not undermine the on-site performance of party walls and floors etc. Minimum mass requirement for boarding takes into account requirement for enhanced sound insulation between apartments.
Apartment doors *Apartment doors need to provide adequate sound insulation to mitigate disturbance from noise in common areas outside*	Apartment entrance doors	Entrance doors to apartments should have an acoustic rating of R_w 29 dB	ADE2003	The minimum requirement of ADE2003 is R_w 29 dB and enhancements are not required for CfSH or other credits. Acoustic requirements should be taken into account when selecting apartment doors (and doors seals), to ensure an appropriate acoustic performance is achieved.
Non-residential doors *Non-residential doors need to provide adequate sound insulation to mitigate transfer of noise around the building*	All other doors that are recommended to achieve an acoustic separation performance	Riser doors- R_w 35 dB	-	-
ROOM ACOUSTICS				
Reverberation in common areas *Reverberation in common areas needs to be controlled to minimise flanking sound transmission via common corridors, and to provide an appropriate acoustic environment*	Corridors, hallways, stairwells and entrance halls which give direct access to flats or rooms for residential purposes	Method A or Method B (as defined in ADE2003 section 7)	ADE2003 (E3)	Method B has been adopted. Please see Section 6.1 for more details.
BUILDING SERVICES NOISE				
Internal noise limits in residential areas *Internal noise limits from building services need to be applied to minimise disturbance to occupants*	Building services design	Bedroom – NR25 Studios – NR28 Living rooms – NR30 Bathrooms (en-suite) – NR30 Bathrooms (separate) – NR35 Kitchens NR40 (normal), NR45 (cooker hood low), NR55 (cooker hood high))	CIBSE BS 8233	Noise limits in bedroom, studios and living rooms are provided when apartment MEP services are operating cumulatively and under background/residual duties. Noise limits apply to all building services operating simultaneously with the exception of cooker hoods.

Acoustic consideration	Affected element	Acoustic criteria	Relevant codes and standards	Comments
Internal noise limits in non-residential areas *Internal noise limits from building services need to be applied to minimise disturbance to occupants*	Building services design	Circulation areas/foyers – NR40 Entrance/reception – NR45 BOH spaces (stores) NR50 Basement plant rooms – NR75 (80 dBA)	CIBSE Noise at Work Regulations	Octave band sound pressure limits apply to the mid-level plant room. The basement plant room noise limit includes octave band limits of 85 dB in the 63 Hz and 125 Hz octave bands. Lower limits may be applicable in the plant rooms that are naturally ventilated (ie UKPN) in order to meet the noise emission criteria
VIBRATION LIMITS				
Internal vibration limits *Internal vibration from building services need to be applied to minimise disturbance to occupants*	Building services design	Maximum permissible vibration amplitudes should not: Exceed a Vibration Dose Value (VDV) of 0.1 $m/s^{1.75}$ any occupiable residential space Exceed 0.01 m/s^2 or be of a magnitude which causes the maximum noise criteria to be exceeded.	BS 6472 Part 1: 2008	-
Re-radiated ground borne noise levels Re-radiated ground borne noise levels caused by trains need to be applied to minimise disturbance to occupants	Building foundations	Must not exceed: L_{ASmax} 35 dB inside dwellings	Camden Council DP28	-

4 Building envelope acoustic design

The key design considerations associated with the building envelope are as follows:

- Airborne sound insulation (noise ingress) – to control intrusive noise from external sources including road traffic, rail, aircraft and building services plant
- Airborne sound insulation (noise egress) – to control breakout from noisy internal areas such as plant rooms to the development itself, commercial space, public areas around it and nearby sensitive premises in accordance with the requirements of the Local Authority
- Horizontal flanking sound transmission – to control sound transmission from one space to another where internal walls connect to the building envelope to form two rooms or spaces
- Vertical flanking sound transmission – to control sound transmission from one space to another vertically where floors meet the building envelope.

Other design issues such as controlling noise from rainfall on any lightweight elements of cladding and minimising audible attention-catching noise due to thermal or air movement will also need to be considered as the design progresses.

Please refer to the acoustic cladding specification provided in Appendix C.

5 Internal sound insulation

5.1 Floors

5.1.1 General

The two principal acoustic performance requirements for floors are:

- The reduction of airborne sound from one floor to another (eg voices, domestic appliances, amplified sound or building services plant)
- The reduction in impact sound from one floor to another (eg footsteps).

The airborne sound insulation performance of the separating floors is primarily determined by the mass per unit area of the structural floor slab in combination with the floor finish build-up and suspended ceiling below.

The impact sound insulation performance of the separating floors is primarily determined by mass and by the reduction through resilient elements such as soft floor finishes (eg carpet) or resilient interlayers (eg isolation layer under screeds).

5.1.2 Party floors

The principles of the party floor construction from an acoustic perspective broadly comprise the following elements:

- 15mm floor finish (engineered timber floor)
- 55 mm screed (minimum density 1100 kg/m^3)
- 20 mm insulation (PIR or similar)
- 5 mm acoustic resilient layer (to be rated to achieve ΔL_w 18 dB or better)
- 225 mm solid normal weight concrete floor slab (2350-2400 kg/m^3)
- 130-235 mm ceiling zone, incorporating a suspended plasterboard ceiling (12.5 mm plasterboard) with surface mounted light fittings, small ventilation openings, etc.

The proposed party floor meets the minimum standard of construction capable of achieving the sound insulation requirements.

A resilient flanking strip would be required around the perimeter of the floated floor and flanking sound transmission via the cladding will need to be adequately controlled.

5.1.3 Internal floors within apartments

Internal floors within apartments comprise the same build-up as party floors.

5.1.4 Party floor perimeter junction details

Figure 3 shows the party floor interface with the facade. The cladding is discontinuous between vertically adjacent apartments, which is compatible with the flanking performance requirements set out in the cladding specification in Appendix C.

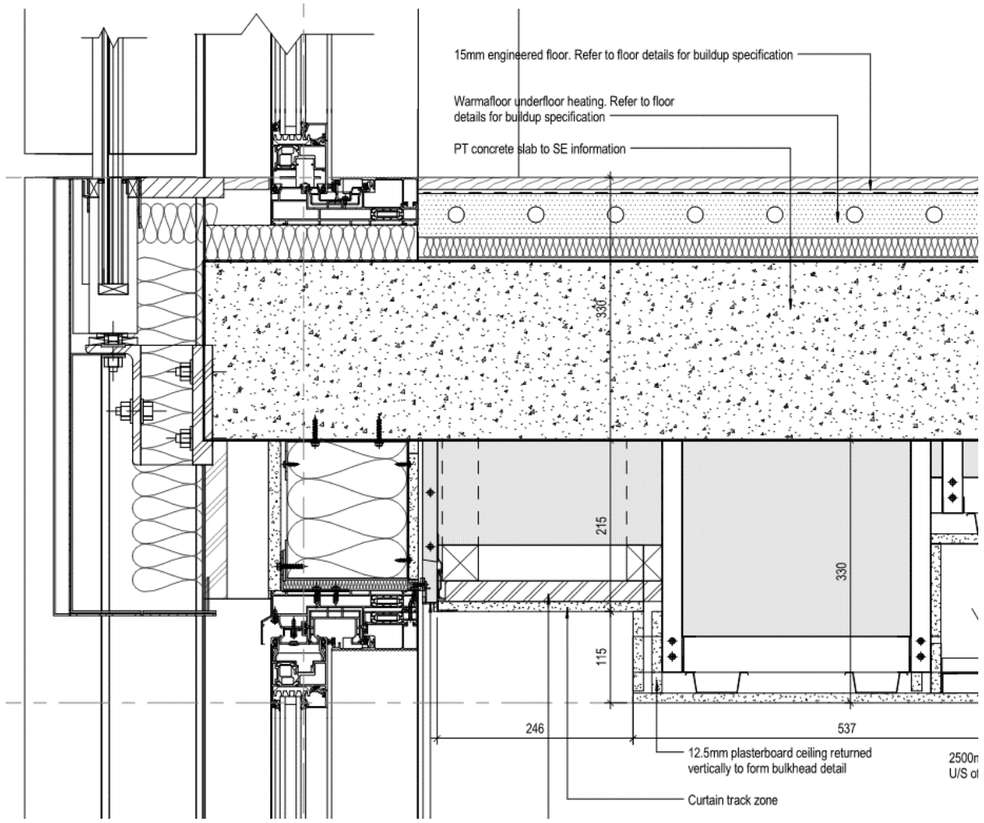

Figure 3 Party floor junction with facade

5.2 Walls

5.2.1 General

The two principal acoustic performance requirements for walls are:

- The reduction of airborne sound from one space to another (eg voices, domestic appliances, amplified sound, etc)
- The reduction is impact/structure-borne sound (eg cupboard doors banging, the use of switches/sockets, etc).

The airborne sound insulation performance of the separating walls is determined by a range of factors including their mass, isolation, cavity depths, insulation type & thickness, etc.

The resistance to impact/structure-borne transmission is influenced by the above factors but primarily by the degree of isolation between the elements which make-up the wall.

Appendix B contains marked up drawings of the information contained in Section 5.2.

5.2.2 Party walls

The performance requirement set out for separating walls in Table 1 relates to that between completed apartments. However, manufacturers' test data (such as that provided in the British Gypsum White Book or equivalent), states sound insulation performances when measured in an acoustic laboratory under ideal conditions.

The elemental sound insulation performance of the party walls needs to take into account other factors such as:

- Potential reductions in performance between laboratory and site bearing in mind workmanship
- Flanking sound transmission via adjacent elements such as the cladding, floors and other walls.

A typical laboratory performance requirement for a drywall which is capable of achieving ADE2003 + 5 dB on site would be $R_w + C_{tr}$ 59 dB.

5.2.3 Selected party wall system

Figure 4 illustrates the adopted drywall party walls. The drywalls consist of 2 layers of 15 mm SoundBloc (or similar) plasterboard each side of twin 50 mm studs, with 100 mm mineral wool included in the cavity. The overall width is 300-360 mm.

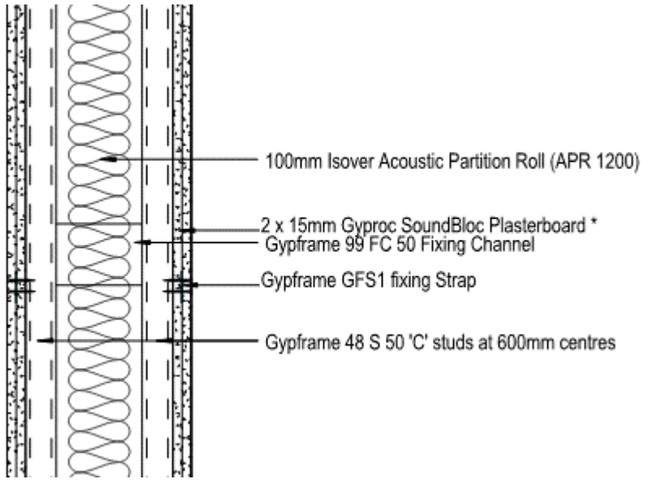

Figure 4 Drywall party wall

Where columns are located within party walls, the detail shown in Figure 5 is to be adopted. Mineral fibre insulation with a thickness of 25 mm is to be installed around the columns, and the party wall studs are not to be in contact with the column.

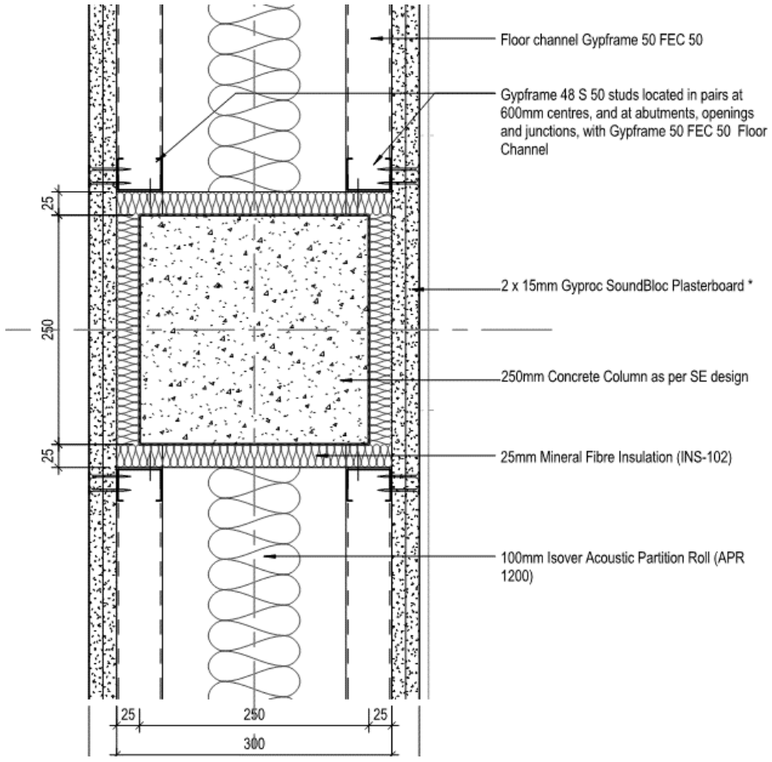

Figure 5 Column within party wall detail

5.2.4 Internal walls within apartments

The laboratory sound insulation performance requirement of internal walls is R_w 40 dB.

This can be achieved with 1 x 12.5 mm SoundBloc plasterboard (or similar) each side of a 70 mm 'C' stud at 600 mm centres. The wall adopted is illustrated in Figure 6.

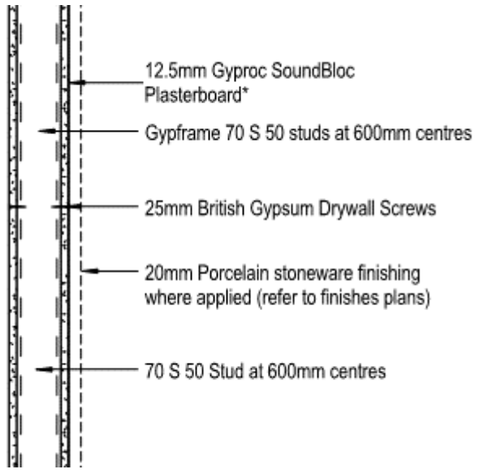

Figure 6 Internal wall proposal

5.2.5 Stairwells

The adopted stairwell wall lining consists of the following on each side of the 250 mm concrete:

- Boarding of 2 x 12.5 mm WallBoard or equivalent
- Installed on 25 mm Gypliner set out at 600 mm centres.

Where the wall forms a party wall separation, mineral fibre insulation should be included in the void behind the lining to maintain the airborne sound insulation performance.

5.2.6 Independent wall linings

It is imperative that independent wall linings are used where apartments are adjacent to lift shafts and MEP risers.

The current drawings indicate the build-up shown in Figure 7. This should be amended such that there is a gap of at least 15 mm between the stud and the concrete wall (ie 250 mm concrete, 15 mm gap, 60 mm stud with 25 mm mineral fibre insulation, 2 layers of 12.5 mm SoundBloc or equivalent).

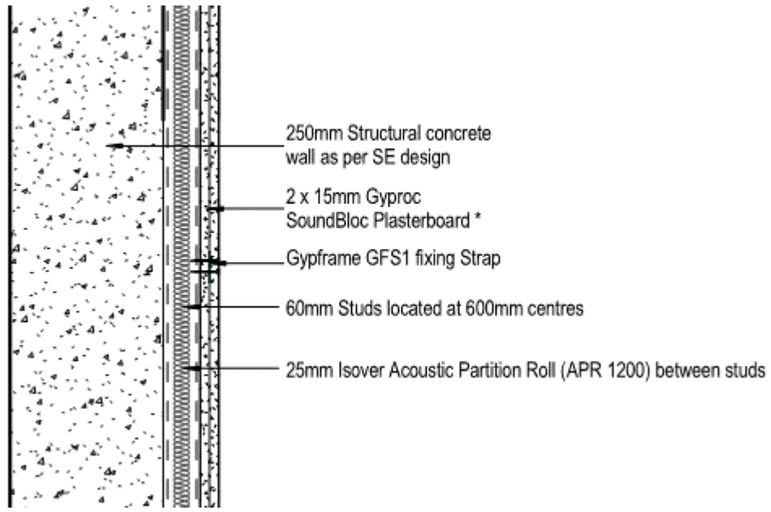

Figure 7 Proposed lining to lift shafts and MEP risers adjacent to apartments

5.2.7 Water services pipework risers

Water services pipework is not to be located within party walls due to the considerable risk associated with re-radiated noise.

Where water services pipework is located within risers adjacent to apartments they will be appropriately lagged, with the riser wall consisting of 2 x 15 mm FireLine (or equivalent) and independently supported.

The pipes need to be fixed to the concrete shaft through resilient clips and will not come into contact with the plasterboard layers.

5.2.8 MEP cupboards

The walls separating MEP cupboards from habitable spaces should be the same as those described in Section 5.2.4 and full height, to contain the noise radiated from the casing of MVHR units located within .

The MEP cupboards are to be either ventilated by the MVHR unit or through undercut doors. The use of undercut doors is to be assessed with respect to the other noise control provisions required to control the MVHR unit casing breakout noise.

Where MEP cupboards are adjacent to party walls it will be necessary to resilient support any moving/vibratory equipment from the party wall due to the considerable risk of structural borne noise transfer into the adjacent apartment.

For further discussion on the MVHR design refer to Section 8.3.2.

5.2.9 Basement walls

The majority of basement walls will consist of 140 mm medium density blockwork (1400-1450 kg/m^3), which has a sound insulation of R_w 45-50 dB. This degree of sound insulation is considered acceptable in all locations and is recommended for all basement plant rooms.

100 mm blockwork (1200 – 1250 kg/m^3) can be adopted to stores and other basement rooms that are non-noise sensitive or do not contain building services plant.

5.2.10 Ground floor walls

The majority of ground floor walls will consist of 140 mm medium density blockwork (1400-1450 kg/m^3), which has a sound insulation of R_w 45-50 dB. This degree of sound insulation is considered acceptable in all locations.

100 mm blockwork (1200 – 1250 kg/m^3) can be adopted to stores and other rooms that are non-noise sensitive or do not contain building services plant.

The UKPN substation has walls comprising 215 mm thick brickwork.

5.2.11 Party wall perimeter junction details

Robust junction details between the party walls and perimeter cladding/columns will be required.

Examples of the type of details that will require development are shown in Figure 8 and Figure 9.

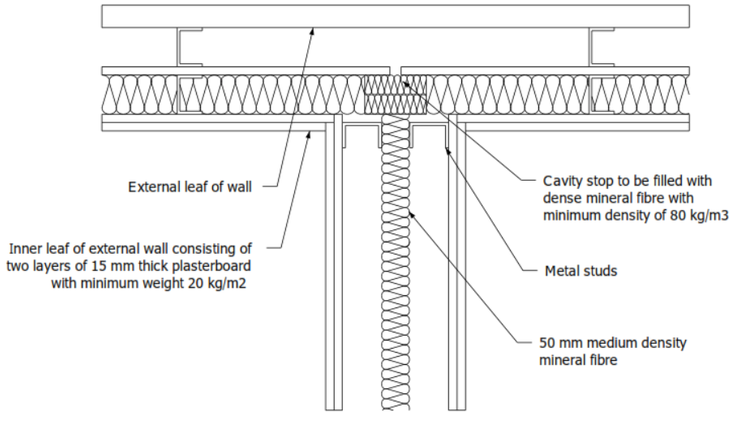

Figure 8 Indicative party wall junction with external cladding

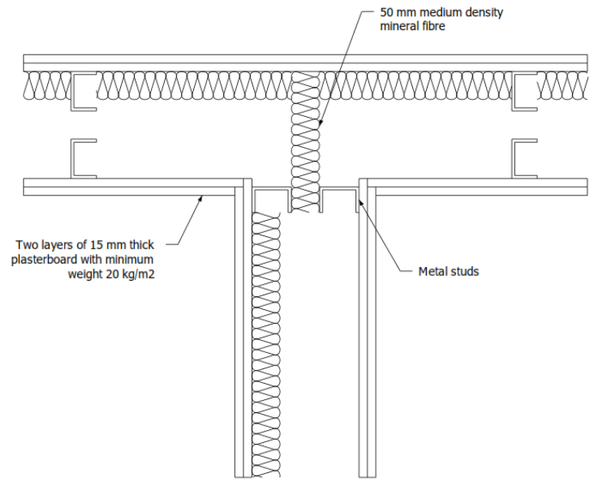

Figure 9 Indicative party wall junction with adjacent party wall

5.2.12 Recessed fixtures & fittings

The recessing of fixtures & fittings (sockets, switches, AV/TV plates, etc) into party walls can cause weaknesses acoustically, particularly in lightweight walls. Penetrations should be staggered from one another such that they are offset by at least one stud bay (600 mm). Where it is essential that penetrations are to be located closer together than this or even back-to-back, providing they incorporate putty pads (www.hilti.co.uk), it should be feasible to maintain the sound insulation of the party walls subject to their number and size.

5.3 Doors

5.3.1 Entrance doors to apartments

Entrance doors are specified to achieve R_w 29 dB, to comply with the minimum requirements of ADE2003.

5.3.2 Doorsets to other spaces

As per the requirements of Table 1, the sound insulation provided by the doors to other spaces are as follows:

- Riser doors - R_w 35 dB.

6 Acoustic finishes

6.1 Requirement E3

Requirement E3 states that the common internal parts of buildings which contain apartments shall be designed and constructed in such a way that as to prevent more reverberation around the common areas as is reasonable. Requirement E3 corridors which gives direct access to apartments.

ADE2003 provides two methods of complying with Requirement E3 ie, Method A and Method B. Method B has been applied with the adoption of SAS System 330 1511 perforated metal ceiling tiles with 16 mm acoustic backing pad (Class B sound absorption) in the lift lobbies.

6.2 Occupied non-residential areas

6.2.1 Entrance lobby

There are no specific acoustic requirements for acoustic finishes within entrance lobbies.

7 Ground borne noise and vibration from underground trains

A vibration assessment for the site is contained within the Sandy Brown report 15374-R03-C *Planning noise and vibration survey report.*

The vibration measurements indicate that the maximum VDV experienced in the existing building was around 0.05 $m/s^{1.75}$.

Re-radiated noise levels up to L_{ASmax} 34 dB could be expected in the completed building.

The vibration assessment did not identify a requirement for mitigation in order to achieve the project criteria for either tactile vibration or re-radiated structure borne noise.

8 Building services acoustics

8.1 General

Noise control measures will require detailed consideration once plant has been selected and noise data is available. However, key acoustic issues are:

- The control of noise & vibration from plant and equipment to acceptable levels within the building
- The control of noise egress to outside in relation to potential noise break-in to the building itself, other proposed new & existing buildings and public spaces in line with the requirements of the local planning authority, where relevant
- The acoustic sealing of penetrations through sound insulating constructions
- The control of cross-talk between rooms in supply and return air openings.

8.2 Plant strategy

Background ventilation will be provided in the residential units through the adoption of MVHR units. Boost ventilation rates will be provided by the MVHR units when either manually required or by operation of the bathroom light. The intake and exhaust will be routed to the building facade.

Overheating will be controlled through the use of opening windows.

Smoke extract fans are to be located at roof level. There is a bin store extract fan at ground floor level.

A generator, located in the basement, is to be included within the commercial building package.

All plant will need to be suitably attenuated to meet the external noise emission limits and internal noise criteria.

8.3 Internal noise

8.3.1 Criteria

Please refer to the building services noise and vibration specification included in Appendix D.

8.3.2 Apartment MVHR units

Noise from the proposed apartment MVHR units has not been assessed. A mark-up of a typical ventilation layout is included in Figure 10, with attenuators highlighted in red.

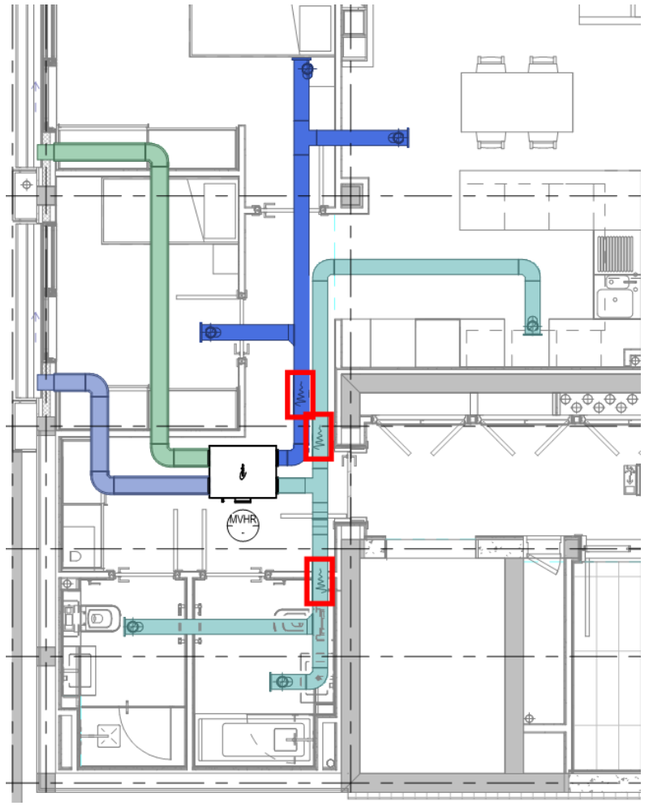

Figure 10 Typical apartment ventilation layout. Attenuators indicated in red

The proposed layouts, equipment/plant and noise control measures will need to be reviewed.

In particular, the review will need to include the following:

- Whether casing breakout noise will be adequately controlled by the suspended plasterboard ceiling
- Whether the room-side attenuation on the MVHR units is sufficient
- Whether compliance with the external noise criteria would require attenuation to the atmospheric connections of MVHR units
- Whether in-duct attenuators would be required to control audible cross talk between spaces.

8.3.3 Noise levels in plant rooms

Typically, an overall noise limit of NR70 is recommended within plant spaces. This is an indicative overall noise limit for plant rooms and will be replaced by specific octave band noise limits which are to be established as the design develops based on the sound insulation performance of enclosing elements and noise criteria in adjacent spaces.

Whilst in principle it may be possible to permit higher noise levels in plant rooms, this represents a reasonable level in relation to plant attenuation measures whilst minimising any implications for hearing protection under The Control of Noise at Work Regulations 2005.

These regulations are aimed at ensuring that workers' hearing is protected from excessive noise at their place of work, which could cause them to lose their hearing and/or to suffer from tinnitus (permanent ringing in the ears).

The level at which employers must provide hearing protection and hearing protection zones is 85 dBA (daily or weekly average exposure) and the level at which employers must assess the risk to workers' health and provide them with information and training is 80 dBA. There is also an exposure limit value of 87 dBA, taking account of any reduction in exposure provided by hearing protection, above which workers must not be exposed.

8.4 External noise

The external noise sources associated with the residential package for 150 Holborn comprise the following:

- Ground floor exhaust louvre for bin store extract fan
- Roof level smoke exhaust fans
- Apartment MVHR intake and exhaust.

8.4.1 Criteria

Please refer the building services noise and vibration specification included in Appendix D.

8.4.2 Implications on building services strategy on apartments

It is expected that MVHR units would require attenuation to all atmospheric connections. This will need to be reviewed before the selections and design are finalised.

8.4.3 Implications on building services strategy on basement services

The basement air handling equipment, including extract fans, will need to include appropriately sized attenuators to control the noise emissions. It is recommended that preliminary selections are reviewed given the distance from the inlet/exhaust louvres to the residential apartments.

The landlord life safety and tenant standby attenuators have been currently specified to achieve 65 dBA at 1 m from the unit. Additionally to this, it would be necessary for the air paths into the generator room to be acoustically treated, eg attenuators.

8.5 Vibration

8.5.1 Criteria

Internal vibration criteria are as set out in Table 1.

8.5.2 Vibration isolation measures

All Air Handling Units (AHUs), fans, pumps, chillers, cooling towers, Fan Coil Units, standby generators and other rotating and reciprocating plant will be fitted with efficient anti-vibration mountings (AVMs).

Plant mounted on AVMs will need to be isolated by flexible connections from ducts, pipes and conduits.

All pump sets will be installed on suitable concrete inertia bases on spring mounts.

Ductwork & pipework in the plant rooms and ductwork & pipework in contact with structures bounding occupiable areas will be supported on anti-vibration hangers/supports.

8.6 Cross-talk

Cross-talk issues are avoided by the use of attenuators on the MVHR unit supply and extract and with dedicated Fan Coil Units serving rooms. There are no duct penetrations located through party walls.

8.7 Acoustic sealing of services penetrations

Service penetrations (ducts, pipes and electrical services) through walls, floors and ceilings will need to be sealed in such a way that the acoustic integrity of the structure is maintained and vibration transfer is minimised.

It is noted that there are to be no building services penetrations across party walls (apartment to apartment).

8.8 Risers

Pipework and ductwork within risers is to be vibration isolated from the building structure in order to mitigate structure-borne noise transmission.

8.9 Water services

8.9.1 Horizontal sections of pipework

There is considerable risk that water services noise will be audible where there are horizontal transfers/offsets above apartments, due to the abrupt change in direction of the flow of water and waste.

Where adequate space allows an independent enclosure (formed from solid material with a minimum surface weight of 20 kg/m^2) around lagged plastic pipework will be provided. In addition to the enclosure, the following measures are recommended:

- Acoustically seal pipe penetrations at floor slabs using flexible fire-stopping to ensure no direct contact between pipe and floor
- Fix pipework only to floor slab and with the adoption of resilient fixings, eg clips and rubber inserts
- The base of stacks should comprise of 2 x 45 degree bends to smooth the transition and reduce turbulence
- Duct lagging specification as per Table 2.

Table 2 Recommended lagging specification for horizontal sections of plastic pipework

Room	Active pipework (eg soil, rain and grey)	Vent pipework
Living room and bedroom	10 kg/m^2 and 50 mm insulation	10 kg/m^2 and 50 mm insulation
Bathrooms	10 kg/m^2 and 25 mm insulation	5 kg/m^2 and 25 mm insulation
Corridors	10 kg/m^2 and 25 mm insulation	5 kg/m^2 and 25 mm insulation

It is noted that even with the above nominated provisions that there is still a risk that flow noise may be audible within an otherwise quiet apartment and the risk of audible flow noise increases when an independent enclosure is not adopted.

8.9.2 Vertical sections of pipework

Vertical sections of pipework will be located behind dedicated risers (with a minimum surface weight of 20 kg/m^2). Table 3 summarises the pipework lagging recommendations for vertical sections of plastic pipework.

Table 3 Recommended lagging specification for vertical sections of plastic pipework

	Active pipework (eg soil, rain and grey)	Vent pipework
Behind riser	5 kg/m^2 and 25 mm insulation	Unfaced 25 mm insulation

In addition to the above, all pipework will need to be independent from the plasterboard, with fixings made with resilient clips to concrete shaft walls or slab edges.

8.9.3 Pipework fixings

The pipes must only be fixed to concrete and via resilient clips and must not come into contact with the plasterboard linings in order to prevent coupling of the vibrations induced by pipework water flow and the plasterboard, which would otherwise result in an increased noise level in the apartment.

It is noted that the issue of water induced structure borne noise cannot be satisfactorily addressed with the adoption of resilient clips alone, and requires a heavy supporting structure in order to be effective across the sound frequency spectrum eg, concrete.

Intermediate supports between slabs are primarily recommended to be onto concrete via resilient clips. Where it is not possible to fix into concrete it is recommended that a separate structure (built from unistrut or similar) is created to support the pipes, rather than fixing the pipework onto plywood pattressing, plasterboard or the plasterboard frame.

8.10 Other plant items

8.10.1 Lifts

Lift noise is to be controlled to the following recommended noise levels:

- Maximum noise level in lift car L_{AFmax} 55 dB
- Maximum noise level in lift lobby L_{AFmax} 55 dB
- Maximum noise into residential areas through lift shaft walls L_{AFmax} 25 dB.

8.10.2 UKPN substation

UKPN are to provide information on their proposed noise and vibration control, so that if necessary additional measures, such as acoustic louvres etc, can be incorporated into the design.

9 Construction (Design and Management) Regulations

The Construction (Design and Management) Regulations places legal duties on virtually everyone involved in construction work. Those with legal duties are commonly known as ‘dutyholders’ and include clients, designers, contractors and workers.

Typical risks specifically associated with acoustic design are:

- Access at height to install and to maintain such elements as acoustic reflectors/absorbers;
- Manual handling of heavy building elements such as high density concrete blocks.

Acoustic treatment is proposed which will require installation at height, eg soffit of spaces. However, this would be required in any event for installation of ceiling finishes, lighting, etc and is therefore not a risk specifically related to the acoustic design.

Man-made mineral fibres (MMMF) are used extensively in the construction industry and these are sometimes specified for their acoustic properties. When contractors make use of MMMF they should act on relevant legislation and the latest guidance issued by the Health and Safety Executive.

The above risks are not unusual and would be appropriately managed by a competent contractor.

Appendix A

Acoustic Terminology

Sound levels

Sound or noise levels are commonly measured in terms of the sound pressure level in decibels (dB). The sound pressure level is often 'A-weighted' to simulate the human ear's response to sounds at different frequencies (pitch). Examples of A-weighted sound pressure levels from typical noise sources are shown in diagram given in the figure below.

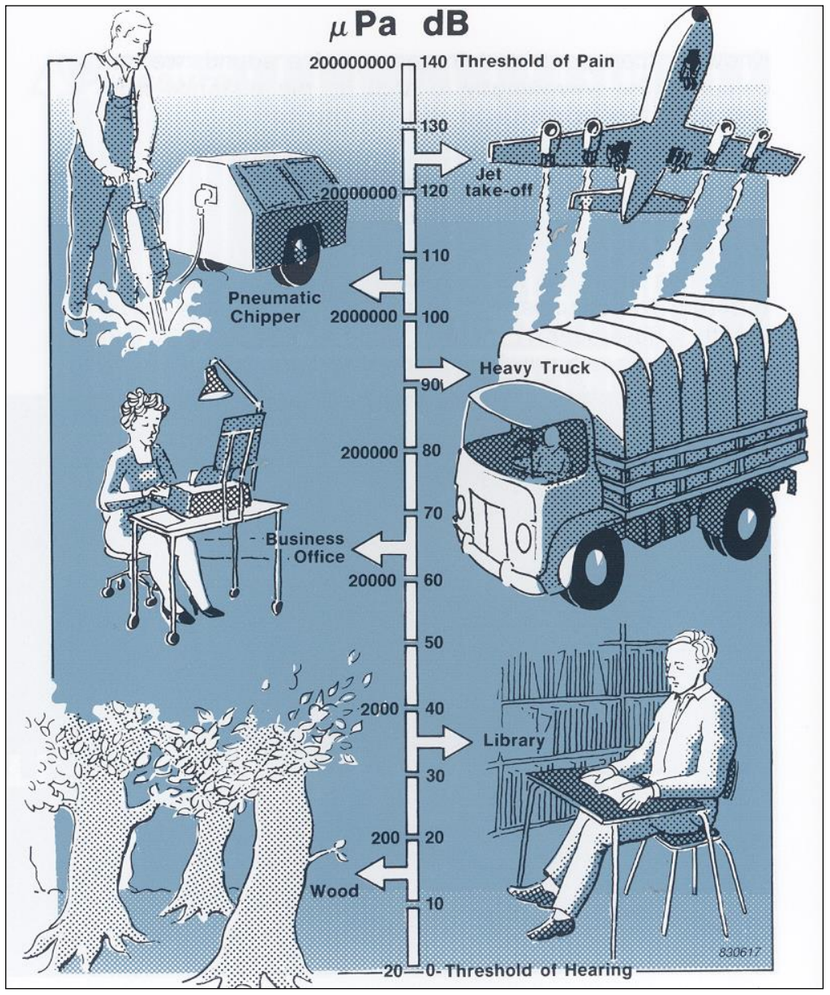

Figure A1 Weighted sound pressure levels from typical noise sources

dB — Decibel - A logarithmic scale applied to acoustic units such as sound pressure and sound power. Sound Pressure in Pa becomes dB Sound Pressure Level. Sound Power in watts becomes dB Sound Power Level.

L_{PA} — The "A" weighted sound pressure level. The ear is less sensitive to noise at low and very high frequencies than at mid-frequencies. To reflect this subjective response, the "A" weighting network was devised applying corrections to a noise, dependent on frequency, so the resultant "A" weighted sound pressure level is representative of the overall noise perceived by the human ear.

L_{A90} — This is the "A" weighted sound pressure level exceeded 90% of the period over which a noise is measured. It is used to represent the "background noise level".

L_{Aeq} — Equivalent "A" Weighted sound pressure level of a steady noise that has the same acoustic energy as a fluctuating noise over the measurement period. It can be considered the average noise level, and is an internationally accepted parameter for assessing annoyance caused by noise from most sources.

L_{A10} — The "A" weighted sound pressure level exceeded 10 % of the period over which a noise is measured. It is the accepted noise index for describing traffic noise.

L_{Amax} — The maximum rms "A" weighted sound pressure level measured in the period.

Sound absorption

Sound absorption is a term used to describe the amount of sound absorbed by a finish or object within a room. It is inversely analogous to light reflectance of a material, i.e. a finish with a low sound absorption reflects sound like an 'acoustic mirror'. Fabric upholstered seating would provide a high level of sound absorption while a masonry wall finished with ceramic tiles would provide a low amount of sound absorption

Sound absorptive finishes are required to control reverberation times (RTs) within rooms.

α_w — The Weighted Absorption Coefficient – The value used to characterise how much sound is absorbed by a material in a room. It varies from α_w = 0.0 (for minimal absorption) to α_w = 1.0 (for very effective absorption). Sound absorbent treatments are divided into Absorption Classes A (α_w < 0.90, or 90% absorptive), B (α_w < 0.80), C (α_w < 0.60), and D (α_w < 0.30).

Reverberation Time

Reverberation is a term used to describe the time it takes for sound to decay within a space. Large rooms with hard finishes, such as cathedrals, typically have long reverberation time. Living rooms with carpets and fabric-upholstered furniture typically have short reverberation times.

If the reverberation time in a room is too long it can adversely affect speech intelligibility.

The mid-frequency reverberation time T_{mf} used in this report is the arithmetic average of the reverberation time in the 500 Hz, 1 kHz, and 2 kHz frequency octave bands.

T_{mf} Mid-frequency Reverberation Time in seconds – The target decay time for sound in a room when measured at 500, 1000, and 2000 Hz arithmetically averaged. It is based on the absorption characteristics of the room finishes.
The maximum T_{mf} is used as the reference reverberation time when determining $D_{nT(T_{mf,max}),w}$ and $L'_{nT(T_{mf,max}),w}$ above.

Sound insulation

Sound insulation is a general term to describe the reduction of sound transfer between separate spaces or through a building element (eg a door). It is inversely analogous to light translucency of a material, ie low sound insulation is analogous to high translucency.

Airborne sound insulation is used to describe the reduction of sound from people speaking, road traffic, music etc. Impact sound insulation is used to describe the reduction of structure-borne sound caused by impacts on a structure, such as from footfalls on a floor.

Common measures of airborne sound insulation are:

- Weighted Sound Reduction Index, R_w (or R_w+C_{tr}) which is used to describe the sound insulation provided by a building element in a certified laboratory and published. Construction proposed to be verified (by laboratory test report or calculation report).
- Weighted Standardised Sound Level Difference, $D_{nT,w}$ which is used to describe the sound insulation provided between two rooms.
- Weighted Standardised Impact Sound Pressure Level, $L'_{nT,w}$ which is used to describe the maximum noise level allowed in a room, whilst operating a laboratory calibrated tapping machine on the floor of the room directly above.
- Weighted Element Normalised Sound Level Difference, $D_{n,e,w}$ which is used to describe the sound insulation provided by small building elements.

Sound insulation is measured in decibels (dB).

Appendix B

Sound insulation mark-ups

Title	Door and partitions (residential)
Project	150 Holborn
Project no.	15374
Version	B
Marked-up by	Sam Daintree
Reviewed by	Philip Owen
Date	24 April 2018

Mark-up key laboratory ratings

- R_w + Ctr 59 dB partition
- R_w 47 dB partition
- R_w 40 dB partition
- ≥ 140 mm solid masonry (>1400 kg/m3)
- Independent partition lining
- Partition lining on 25 mm channel
- R_w 29 dB door

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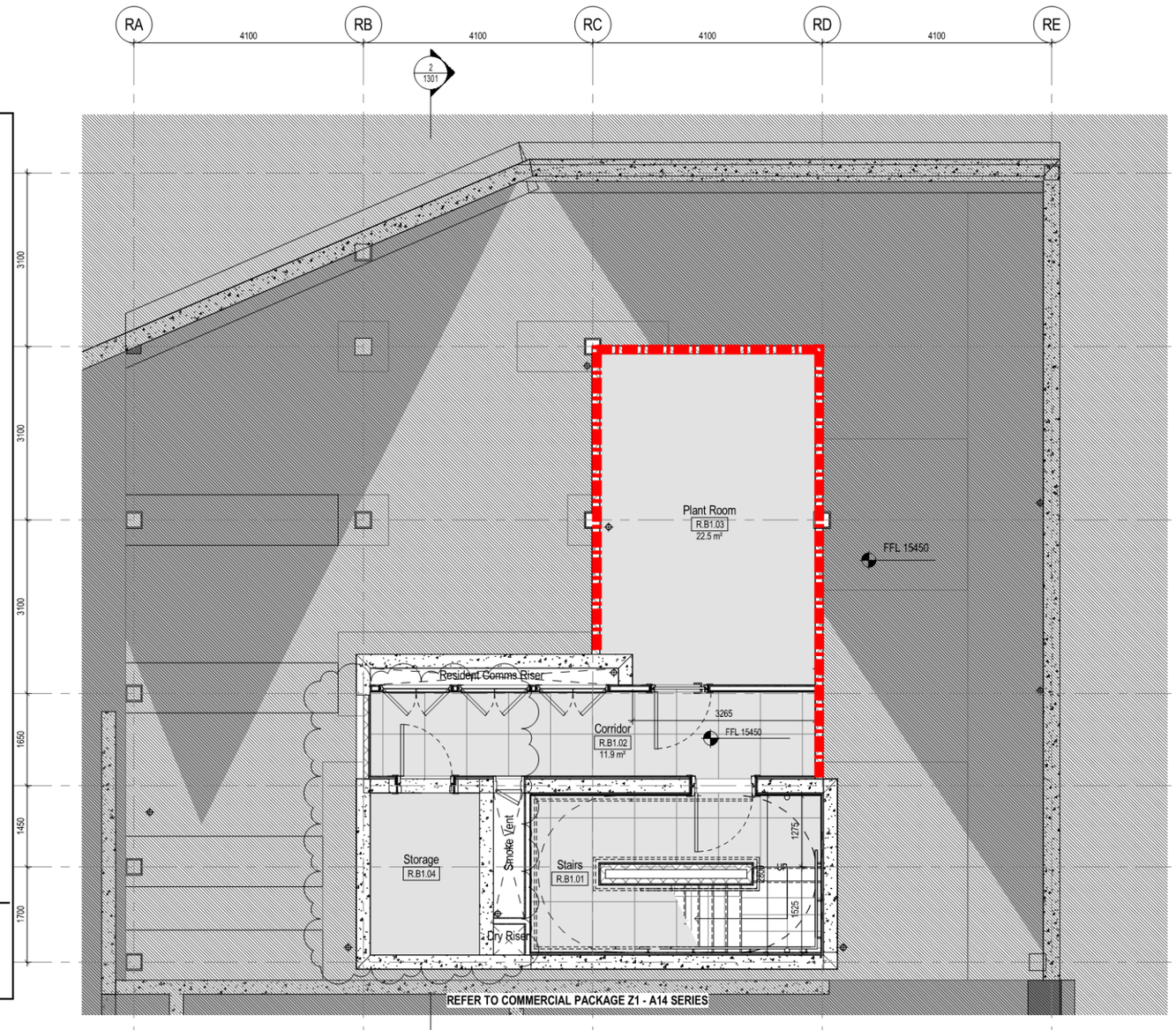

1 Residential GA Plan Basement Level
1 : 50

Title	Door and partitions (residential)
Project	150 Holborn
Project no.	15374
Version	B
Marked-up by	Sam Daintree
Reviewed by	Philip Owen
Date	24 April 2018

Mark-up key laboratory ratings

- R_w + Ctr 59 dB partition
- R_w 47 dB partition
- R_w 40 dB partition
- ≥ 140 mm solid masonry (>1400 kg/m3)
- Independent partition lining
- Partition lining on 25 mm channel
- R_w 29 dB door

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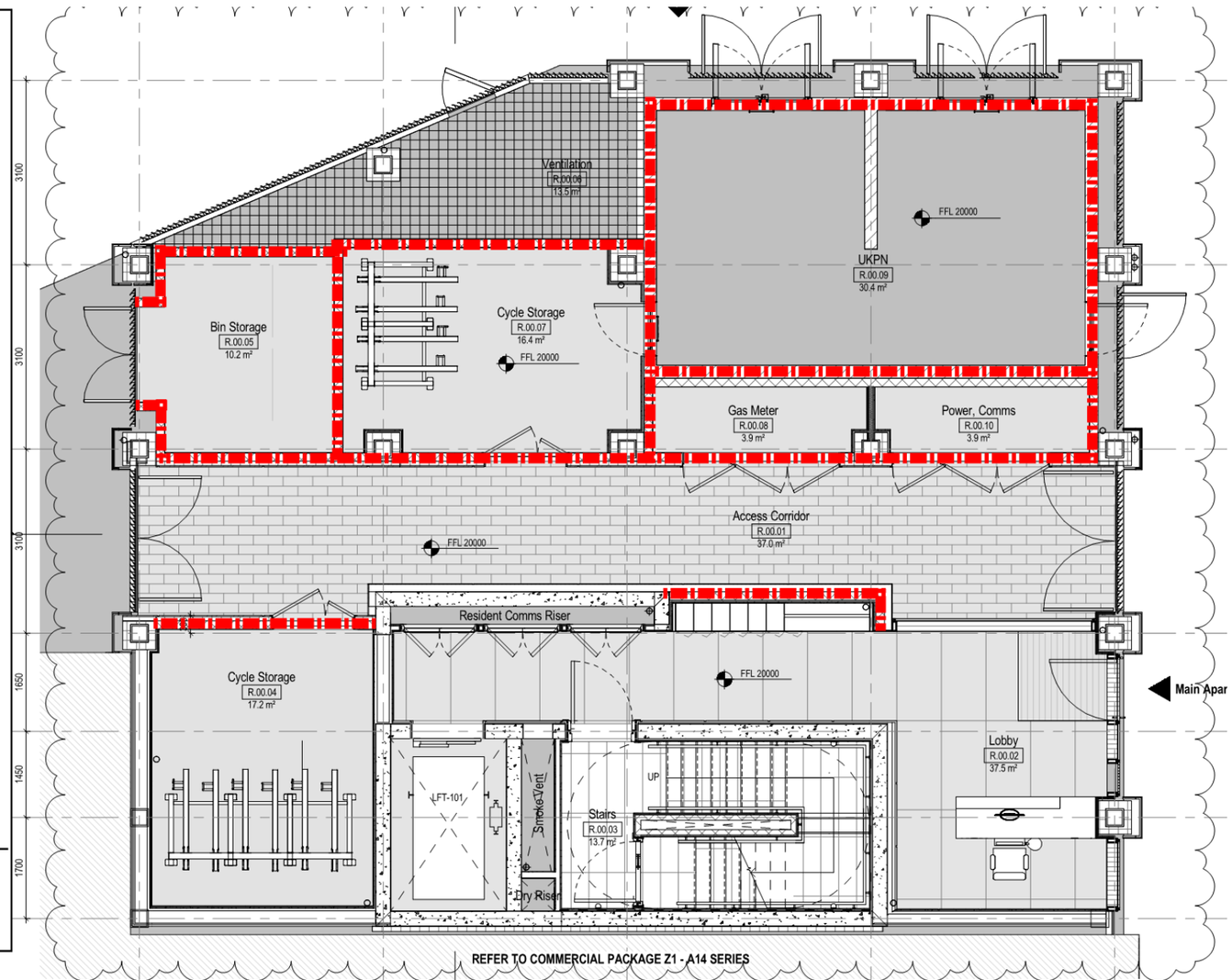

2 Residential GA Plan Ground Level
1 : 50

Title	Door and partitions (residential)
Project	150 Holborn
Project no.	15374
Version	B
Marked-up by	Sam Daintree
Reviewed by	Philip Owen
Date	24 April 2018

Mark-up key laboratory ratings

- R_w + Ctr 59 dB partition
- R_w 47 dB partition
- R_w 40 dB partition
- ≥ 140 mm solid masonry (>1400 kg/m3)
- Independent partition lining
- Partition lining on 25 mm channel
- R_w 29 dB door

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1 Residential GA Plan Level 01
1 : 50

Title	Door and partitions (residential)
Project	150 Holborn
Project no.	15374
Version	B
Marked-up by	Sam Daintree
Reviewed by	Philip Owen
Date	24 April 2018

Mark-up key laboratory ratings

- R_w + Ctr 59 dB partition
- R_w 47 dB partition
- R_w 40 dB partition
- ≥ 140 mm solid masonry (>1400 kg/m3)
- Independent partition lining
- Partition lining on 25 mm channel
- R_w 29 dB door

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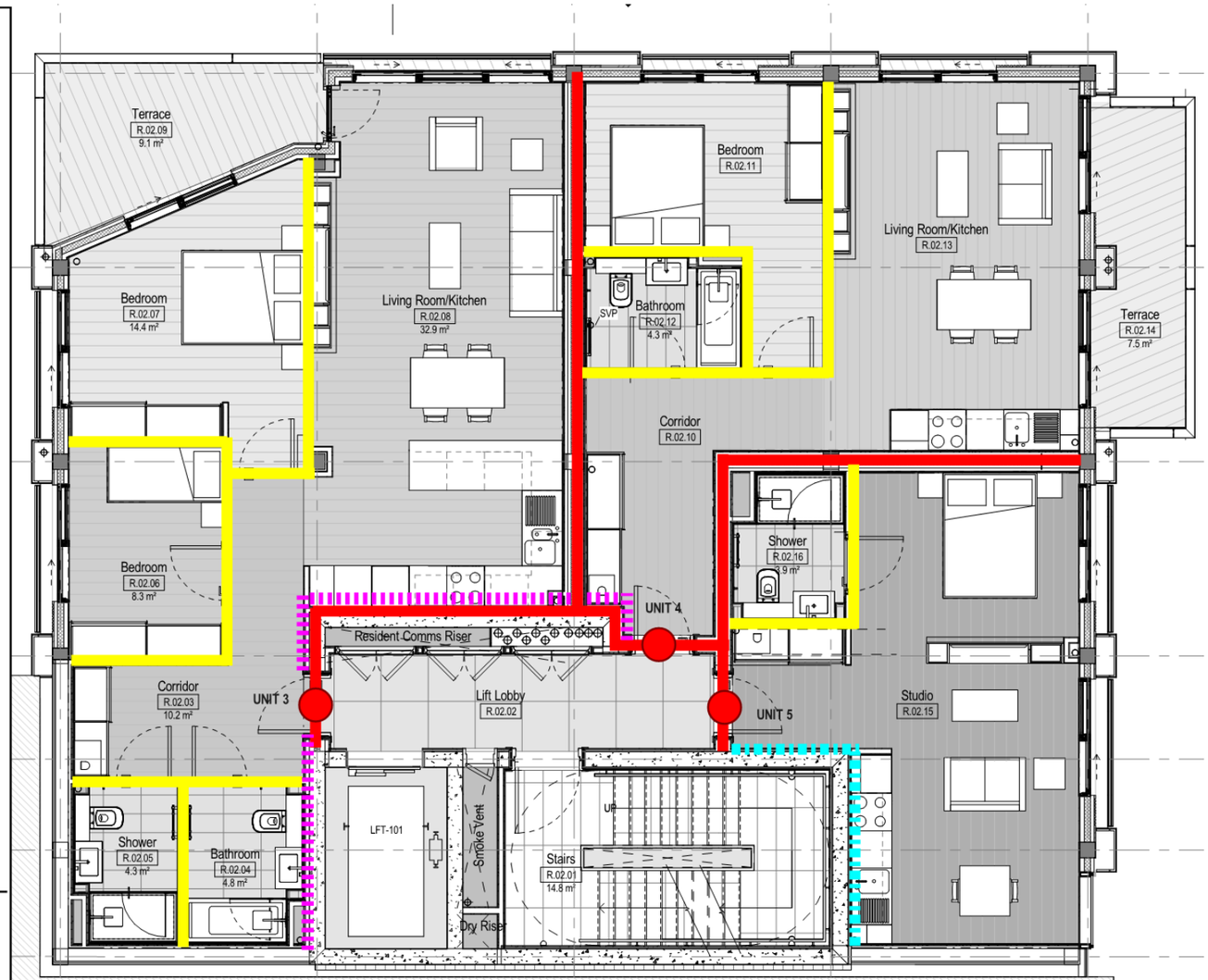

2 Residential GA Plan Level 02 to 04
1 : 50

Title	Door and partitions (residential)
Project	150 Holborn
Project no.	15374
Version	B
Marked-up by	Sam Daintree
Reviewed by	Philip Owen
Date	24 April 2018

Mark-up key laboratory ratings

- R_w + Ctr 59 dB partition
- R_w 47 dB partition
- R_w 40 dB partition
- ≥ 140 mm solid masonry (>1400 kg/m3)
- Independent partition lining
- Partition lining on 25 mm channel
- R_w 29 dB door

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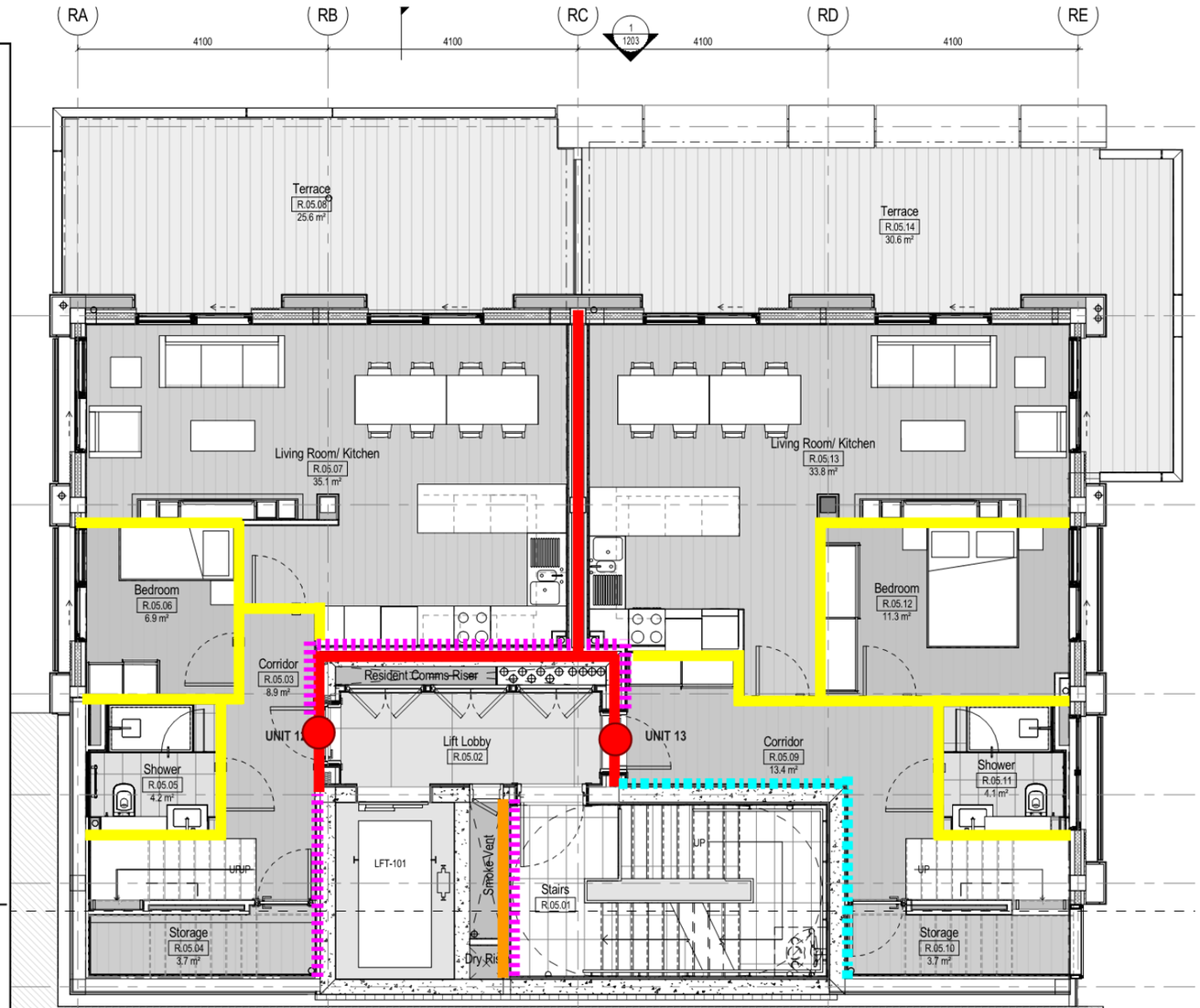

1 Residential GA Plan Level 05
1 : 50

Title	Door and partitions (residential)
Project	150 Holborn
Project no.	15374
Version	B
Marked-up by	Sam Daintree
Reviewed by	Philip Owen
Date	24 April 2018

Mark-up key laboratory ratings

- R_w + Ctr 59 dB partition
- R_w 47 dB partition
- R_w 40 dB partition
- ≥ 140 mm solid masonry (>1400 kg/m3)
- Independent partition lining
- Partition lining on 25 mm channel
- R_w 29 dB door

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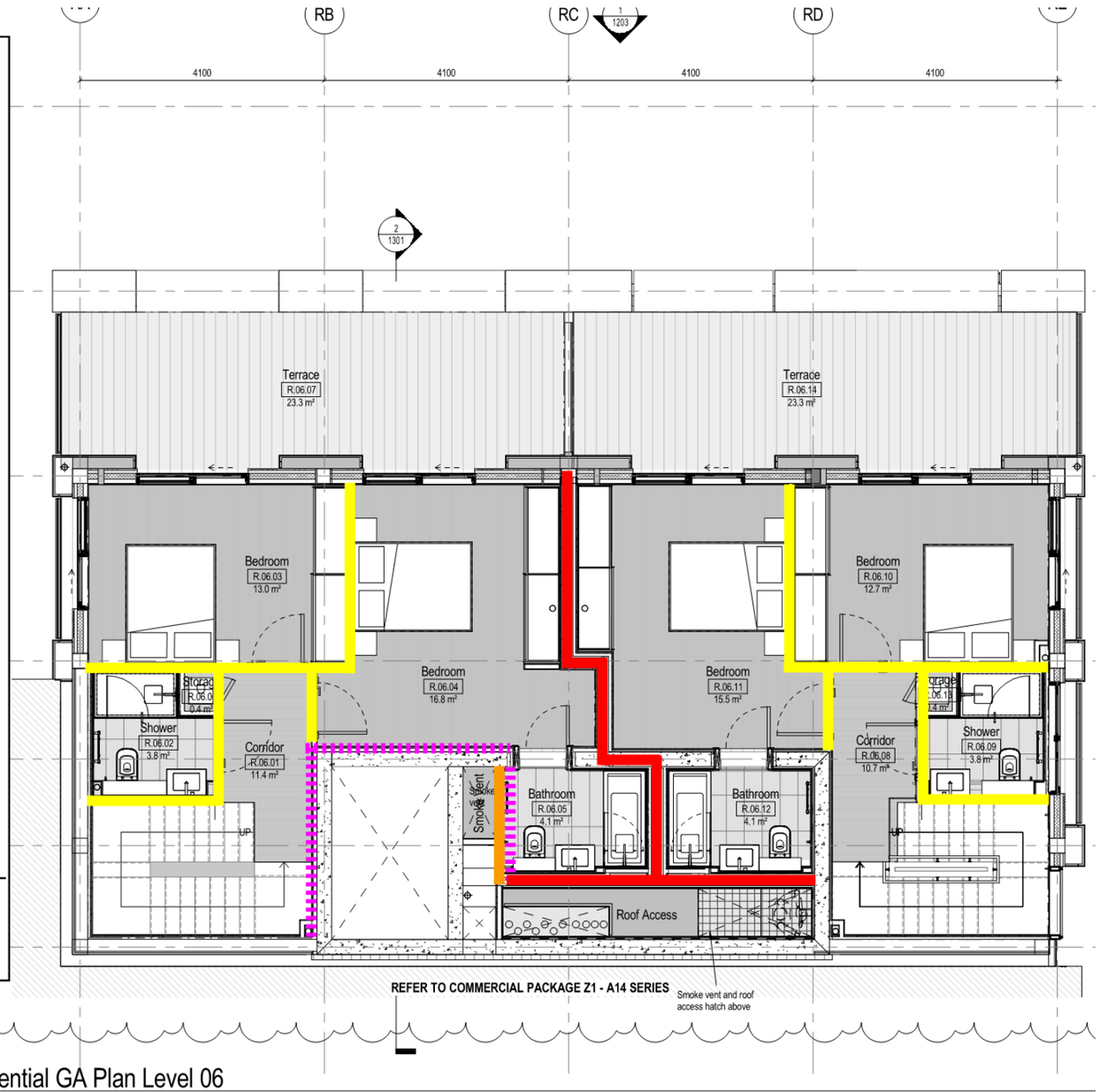
Consultants in Acoustics, Noise & Vibration



2 Residential GA Plan Level 06
1 : 50

Appendix C

Acoustic cladding specification

SANDY BROWN

Consultants in Acoustics, Noise & Vibration

15374-S01-A

2 May 2018

150 Holborn, London EC1

Residential cladding
Acoustic specification

55 Charterhouse Street, London EC1M 6HA T: +44 (0)20 7549 3500
68 Sackville Street, Manchester M1 3NJ T: +44 (0)161 771 2020
2 Walker Street, Edinburgh EH3 7LA T: +44 (0)131 235 2020 **post@sandybrown.com**
87 Caroline Street, Birmingham B3 1UP T: +44 (0)121 227 5020 **www.sandybrown.com**

Sandy Brown Associates LLP
Registered in England & Wales No. OC 307504 Registered Office: 55 Charterhouse Street, London EC1M 6HA

Version	Date	Comments	Author	Reviewer
A	2 May 18		Sam Daintree	Philip Owen

1 Scope

This specification relates to the acoustic performance of the building envelope, and its interface elements hereafter referred to as 'Cladding'.

The location of the Cladding is shown on the Architect's drawings.

This specification is addressed to the Trade Contractor who shall comply with its requirements. It shall be read in conjunction with the relevant Architect's drawings and specifications.

The Architect is Perkins + Will.

The Acoustic Consultant is Sandy Brown.

2 General requirements

All connections to adjacent elements shall be made with a flexible airtight non-hardening seal.

The Cladding shall be constructed in a way that prevents noise arising from thermal movement.

The Cladding shall be constructed in a way that prevents rattling, whistling or other attention-catching noise inside or outside the building arising from air movement over its surface.

Noise generated by rainfall on lightweight panels shall be minimised by effective damping of the outer skin.

3 Sound insulation

3.1 Acoustic rating

Acoustic rating values shall be calculated in accordance with BS EN ISO 717-1:2013 *Acoustics – Rating of sound insulation in buildings and of building elements Part 1: Airborne sound insulation*.

3.2 Laboratory performance

3.2.1 Test samples

The tested laboratory samples of the cladding shall be of the same construction as that offered, and shall incorporate glazed and blank panels, typical joints, mullions, transoms and other details similar to and representative of the installation to be carried out in this project.

3.2.2 Airborne sound insulation

The Cladding shall provide the Spectrum Adapted Weighted Sound Reduction Index (R_w and R_w+C_{tr}) performances shown in Table 1 when measured in accordance with BS EN ISO 10140-2:2010 *Acoustics - Laboratory measurement of sound insulation of building elements Part 2: Measurement of airborne sound insulation*.

Table 1 Minimum laboratory sound insulation performance ratings

Type	Laboratory performance - Spectrum Adapted Weighted Sound Reduction Index: R_w+C_{tr} (dB)	Laboratory performance - Weighted Sound Reduction Index: R_w (dB)
All residential	30	35

3.2.3 Horizontal flanking sound insulation

Where partitions abut the Cladding, it shall provide the minimum Weighted Normalized Flanking Level Difference ($D_{n,f,w}$ and $D_{n,f,w}+C_{tr}$) set out in Table 2 when measured in accordance with BS EN ISO 10848: 2006 Parts 1 and 2: *Acoustic – Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms, Part 1: Frame document* and *Part 2: Application to light elements when the junction has a small influence.*

The area of the test specimen of Cladding in both the source and receiving rooms shall preferably be at least 10 m^2 (ie 20 m^2 total). Where this is not practicable, a smaller area may be accepted by the Acoustic Consultant but the resulting level difference shall then be normalized to 10 m^2 by addition of the factor $10\lg(A_S/10) + 10\lg(A_R/10)$ where A_S is the area of the source room sample and A_R is the area of the receive room sample. Alternative correction factors may be accepted for unitised systems where sound transmission between unitised panels is minimal. These shall be discussed and agreed with the Acoustic Consultant prior to testing.

Table 2 Minimum horizontal weighted normalised flanking level difference

Type of abutting partition	Minimum horizontal Spectrum Adapted Weighted Normalized Flanking Level Difference: $D_{n,f,w} + C_{tr}$ (dB)	Minimum horizontal Weighted Normalized Flanking Level Difference: $D_{n,f,w}$ (dB)
Apartment to apartment and apartment to non-residential use	55	-
Internal wall within apartment	-	45

3.2.4 Vertical flanking sound insulation

Where floors abut the Cladding, the Cladding shall provide the minimum vertical Weighted Normalized Flanking Level Difference ($D_{n,f,w}$ and $D_{n,f,w} + C_{tr}$) set out in Table 2 when measured in accordance with BS EN ISO 10848: 2006 Parts 1 and 2: *Acoustic – Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms, Part 1: Frame document* and *Part 2: Application to light elements when the junction has a small influence.*

The height of the Cladding shall be equal to the proposed floor-to-ceiling height of the completed room. Vertical flanking sound insulation shall be determined for a slab-edge detail length of at least 4.5 m.

Table 3 Minimum vertical weighted normalised flanking level difference

Vertical adjacency	Minimum vertical Spectrum Adapted Weighted Normalized Flanking Level Difference: $D_{n,f,w} + C_{tr}$ (dB)	Minimum vertical Weighted Normalized Flanking Level Difference: $D_{n,f,w}$ (dB)
Apartment to apartment and apartment to non-residential use	55	-
Internal floor within an apartment	-	45

3.3 Site performance

3.3.1 Sound insulation

The Cladding shall be constructed on site so as to ensure that the laboratory sound insulation performance is not degraded when measured in accordance with BS EN ISO 140-5: 1998 *Acoustics – Measurement of sound insulation in buildings and of building elements*, *Part 5: Field measurements of airborne sound insulation of facade elements and facades*.

3.3.2 Site tests

Site sound insulation measurements may be undertaken by the Acoustic Consultant to check compliance with the acoustic performance requirements. If shortfalls are found, you shall carry out all necessary remedial works and pay the cost of re-testing.

4 Submissions

4.1 Sound insulation

Submit details of all interfaces between the cladding and adjacent elements.

Submit one of the following to the Acoustic Consultant allowing sufficient time for them to comment and for you to implement such comments before commencing production:

- Test certificates from an independently accredited laboratory demonstrating that laboratory performance requirements have been met.
- An assessment, carried out to the Acoustic Consultant's satisfaction, demonstrating that laboratory performance requirements have been met.

Assessments shall set out clearly the principles on which they are based, together with relevant test data on similar configurations of cladding and/or its elements. The Acoustic Consultant is not bound to accept the validity of any assessment and may require a test to be carried out.

Appendix D

Building services noise and vibration criteria specification

SANDY BROWN

Consultants in Acoustics, Noise & Vibration

15374-S02-A

2 May 2018

150 Holborn, London EC1

Residential building services noise and vibration criteria

55 Charterhouse Street, London EC1M 6HA T: +44 (0)20 7549 3500
68 Sackville Street, Manchester M1 3NJ T: +44 (0)161 771 2020
2 Walker Street, Edinburgh EH3 7LA T: +44 (0)131 235 2020 **post@sandybrown.com**
87 Caroline Street, Birmingham B3 1UP T: +44 (0)121 227 5020 **www.sandybrown.com**

Sandy Brown Associates LLP
Registered in England & Wales No. OC 307504 Registered Office: 55 Charterhouse Street, London EC1M 6HA

Version	Date	Comments	Author	Reviewer
A	2 May 18		Sam Daintree	Philip Owen

1 Scope

This specification sets out noise and vibration criteria for the mechanical, electrical, public health and air distribution services installations within the residential sections of the building, hereafter referred to as the 'Building Services'.

This specification is addressed to the Trade Contractor who shall comply with its requirements. It shall be read in conjunction with the relevant drawings and specifications issued by the Architect and Building Services Engineer.

The Architect is Perkins + Will.

The Building Services Engineer is Elementa.

The Acoustic Consultant is Sandy Brown.

2 Noise

2.1 Internal noise

2.1.1 Normally operational services

The total noise level from all normally operational Building Services shall not exceed the maximum figures given in Table 1.

Table 1 Schedule of maximum permissible internal services noise levels

Space	NR level [(1)]
Bedroom	NR 20 (MVHR normal) NR 25 (MVHR boost extract)[(2)]
Living room	NR 25 (MVHR normal) NR 30 (MVHR boost extract) [(2)]
Suite	NR 23 (MVHR normal) NR 28 (MVHR boost extract) [(2)]
Bathroom (en-suite)	NR 30 (MVHR normal) NR 35 (MVHR boost extract)
Bathroom (separate)	NR 35 (MVHR normal) NR 40 (MVHR boost extract)
Kitchen (residential)	NR40 (normal) NR45 (cooker hood low) NR55 (cooker hood high)
Corridors/circulation	NR 40
Entrance/reception	NR 45
Plant rooms	NR 75 (80 dBA)[(3)]

(1) Inclusive of all noise sources from MVHR units, when assessed at the worst-affected location

(2) Relaxation not applicable to noise from MVHRs in separate bathrooms

(3) Low frequency limit of 85 dB in the 63 Hz and 125 Hz octave bands

The noise criteria shall apply at any point greater than 1 metre from an enclosing surface (floor, wall or ceiling) unless the designed use of the space necessitates occupancy within this zone.

2.2 External noise levels

Noise levels from building services shall be limited to the cumulative noise levels set out in Table 2.

Table 2 Plant noise limits at 1 m from the nearest noise sensitive premises

Noise sensitive property locations	Day	Daytime (07:00-19:00) $L_{Aeq,T}$ (dB)	Evening (19:00-23:00) $L_{Aeq,T}$ (dB)	Night (23:00-07:00) $L_{Aeq,T}$ (dB)
Brooke Street	Weekday	50	49	42
	Weekend	46	45	41
Holborn	Weekday	57	56	49
	Weekend	53	53	47
Gray's Inn Road	Weekday	56	54	51
	Weekend	53	53	50

2.3 Characteristics

The noise from all Building Services shall not contain any distinguishable, discrete, continuous notes (whine, hiss, screech, hum etc) or distinct impulses (bangs, clicks, clatters or thumps) and shall not be irregular enough to attract attention. Where this is not possible, the total noise level shall be at least 5 dB lower than the criteria specified in Section 2.2.

2.4 Attenuation measures

All necessary sound attenuation measures shall be incorporated into the design such that the noise criteria are achieved. Such measures are to include in-duct attenuators, internal acoustic lining to ductwork and external acoustic lagging to ductwork as appropriate.

3 Vibration

3.1 Maximum vibration levels

Maximum permissible vibration amplitudes should not:

a) exceed a Vibration Dose Value (VDV) of 0.1 $m/s^{1.75}$ as given in BS 6472 Part 1: 2008 '*Guide to evaluation of human exposure to vibration in buildings : Part 1 Vibration sources other than blasting'* in any occupiable space

b) exceed 0.01 m/s^2 peak based on the W_b weighting as given in BS 6472 Part 1

c) be of a magnitude which causes the maximum noise criteria specified in Section 2 to be exceeded.