



Gym Acoustics Guidance - the standardised UK approach

Peter Rogers¹

Sustainable Acoustics

Unit 1, The Rural Business Hub Gander Down Barns, Rodfield Lane, Ovington SO24 0HS

Sebastian Woodhams²

Sustainable Acoustics

Unit 1, The Rural Business Hub Gander Down Barns, Rodfield Lane, Ovington SO24 0HS

ABSTRACT

A drive for low to net zero carbon structures has required a change of direction for Modern Construction Methods to lighter weight buildings, which need to be suitable for many uses over its lifecycle. Gyms present one of the more challenging uses within a building, especially when in close proximity to residents, which is a desirable aim for sustainable living close to facilities that are positive for health and wellbeing. A standardised approach has therefore been developed for assessing the suitability of buildings for Gym uses, bringing together the experience of those acoustic professionals working in this area in the UK. The results of this collaboration by a Working Group of the Association of Noise Consultants, with other professional bodies are discussed, with a working draft document now available ahead of its publication. A look at the approaches it contains include a standardised measurement approaches for heavy drops, a practical prediction method, advice for developers and Local Authorities, with insights of the thinking behind it. This paper shares the UK's approach to this challenge, which is an important future noise control solution for the sustainable future of multi-use buildings.

1. INTRODUCTION

The trend to use lightweight structures and placing Gyms close to where people live or work, often means that noise sensitive receptors are in close proximity, making acoustic separation an important consideration. Building Regulations requires specialist advice to be sought between commercial and residential spaces, but no technical guidance is available to assist practitioners.

The authors raised a suggestion to standardise testing methodology in a paper to the Euronoise conference in Crete in 2018 and shortly afterwards a Working Group of interested parties was formed. The Working Group includes a wide range on contributors, including independent private practices, public body practitioners and manufacturers with years of experience working with Gym clients and dealing with planning applications and complaints relating to Gyms. The ANC (Acoustics and Noise Consultants), IOA (Institute of Acoustics) and CIEH (Chartered Institute of Environmental Health) then collaborated across the industry to produce guidance that presents a standardised approach to assessing how the acoustics of Gymnasiums, Fitness and Exercise Spaces (referred to as 'Gyms' for brevity) affects noise-sensitive adjacencies. The guidance is based on the experience and current state of knowledge of the Working Group.

¹ progers@sustainableacoustics.co.uk

² swoodhams@sustainableacoustics.co.uk

It is recognised by the Working Group that current Government regulations, policy and guidance sets clear objectives, but does not attempt to prescribe specific numerical acoustic standards that assist practitioners to achieve those objectives. A key aim of the guidance is to result in a more consistent approach in support of the delivery of sustainable development and to assist the successful location of Gyms near to noise sensitive adjacencies, where it is appropriate and to identify where it is not. Guidance is also included for Developers and Local Authorities to help identify where such development should be avoided unless there are extensive design considerations. Also, to help understand the potential mitigation and define a standard methodology to follow when dealing with planning assessments and complaints.

Good acoustic design is necessary to achieve an elevated level of airborne, structure borne sound and vibration isolation, which is often achievable only with complex design methods that structurally isolate the noise generating activities from the noise sensitive ones. In light weight structures or spaces not intended for Gyms this can be extremely challenging. Where successful acoustic separation can be achieved this enables the health and wellbeing benefits of a fitness and exercise space to viably exist near noise sensitive adjacencies, whilst not adversely interfering with activities or quality of life.

The guidance provides broad advice applicable with the planning framework, but also in investigating complaints in existing buildings, as part of achieving sustainable development into the future.

This paper presents a summary of the key sections of the guidance and insights to some of the discussions surrounding it. Further justifications and clarifications to the guidance presented in this paper is available in the full guidance document, or through contacts via the authors.

2. CRITERIA & GOOD PRACTICE

There are three common approaches on which noise and vibration assessments are generally based:

- Absolute Guideline Values
- Change in Noise Level
- Relative Effect

The approach to assessment adopted within the guidance was the absolute approach, with qualifying comments regards low background noise conditions (approximately 20dB(A) or below). The guidance is intended primarily to be of use by Suitably Qualified Acoustician's (SQA) and Environmental Health Practitioner's (EHP) where they have sufficient expertise. It was considered necessary that liaison and correspondence takes place so that any decision to adopt a particular approach on criteria is professionally supported, with a clear rationale.

2.1. Noise

Guidelines and standards which have some relevance to the assessment and control of noise from fitness and exercise spaces, but none of them are specifically intended to be applied to assess sound from music or noise from recreational or Gym activities, which include:

- **BS4142:2014+A1:2019** - Methods for Rating and Assessing Industrial and Commercial
- **BS8233:2014** - Sound Insulation and Noise Reduction for Building
- **NANR45** - Low Frequency (LF) Noise Assessment Protocol 2011
- **Noise Rating (NR) Curves**, proposed by Kosten & van Os (1962)
- **Low Frequency Noise Rating Criterion (LFNR)**, Broner and Leventhall (1983)
- **The threshold of hearing (ISO226:2003 (en)).**
- **WHO guidance** (relates to anonymous environmental noise).

Table 1 presents a summary of assessment metrics and guidance on target thresholds that exist in current standards, summarised as background. The Working Group did not recommend any of those targets as being appropriate for assessment of music or heavy impact criteria in Gyms, but it was

considered sensible to include reference to them for background information only as examples can be seen in local planning authorities conditions in the absence of guidance:

Table 1: Reference Assessment Threshold Ranges for Airborne Noise from current guidance or standards

BS8233	Living Room/Bedroom (Day, 16 hours)	35-40 dB $L_{Aeq, T}$
	Bedroom (Night, 8 hours)	30-35 dB $L_{Aeq, T}$
	Lift noise in Bedroom (Night, 8 hours)	25 dB $L_{Amax, F}$
Noise Rating NR (L_{eq}, L_{max})	Living Room/Bedroom (Day, 16 hours)	20-30
	Bedroom (Night, 8 hours)	15-20
LFNR	Living Room/Bedroom (Day, 16 hours)	25-30
	Bedroom (Night, 8 hours)	20-25
NANR45	Living Room/Bedroom (Day, 16 hours)	Above 1/3 Octave above LF criterion curve thresholds by more than 5dB in any 1/3 Octave band
	Bedroom (Night, 8 hours)	Above 1/3 Octave above LF criterion curve threshold in any 1/3 octave band
BS4142 Relative Type Approach	Living Room/Bedroom (Day, 16 hours)	Internal $L_{ArTr} - L_{A90, T} = 0$ to +5
	Bedroom (Night, 8 hours)	Internal $L_{ArTr} - L_{A90, T} = -5$ to 0
WHO Guidelines for Community Noise (1999)	Bedrooms (Night, 8 hrs)	Internally: $L_{Amax, F}$ 45 dB
European WHO Environmental Night Noise (2009)	Bedrooms (Night, 8 hrs, yearly)	Externally: L_{night} 45 dB to 50 dB (interim)
	Bedrooms	Internally: $L_{Amax, F}$ 35 dB

Note 1: In line with other assessment methods, such as BS4142 a level of +5dB above the $L_{A90, T}$ is indicative of an adverse impact and a level of +10dB or above indicative of a significant adverse impact, depending on the context.

Note 2: Structure borne noise contribution may generally form part of the overall noise contribution, and the above do not necessarily relate to structure borne criteria, apart from the lift noise within BS8233, which may be more stringent.

The Working Group agreed that NR curves had proved to be a useful starting point when considering guidance using absolute criteria, combining targets at different frequencies into a single figure. This approach is already used by many Local Authorities. The Working Group therefore proposed the use of newly defined G-Curves, which are based on derived versions of the octave values of the NR curves as third octave bands, which are set out in the full guidance. This means that a G-value for the same receptor sound level may be lower than the NR equivalent value, because the third octave band values impose a tighter constraint when applying the same approach as for NR curves. These reference curves are intended to provide a simple common framework for discussion of suitable target criteria, with a greater regard for frequency resolution.

A good starting point for the selection of suitable criteria for vibration and airborne and structure borne noise suitable to protect residential amenity and other activities adequately are set out in Table 2 and 3 of the guidance, which is based on the Working Group's experience. However, each case should be considered on its own merits, mindful of local context and other considerations. For complaint investigations the upper figures were felt to be appropriate as indicative of the threshold above which a significant observable effect may occur (SOAEL) as a guide, dependant of the context.

Good acoustic design is an approach described within ProPG 1: Planning & Noise, Section 2 and expanded upon in Supplementary Document 2, which when applied to Gyms will require the type of structure, and context of the location to be carefully considered to determine what may be practicable to achieve and when determining what suitable criteria are.

It is recognised that the values presented in Table 2 and graphically in Figure 1 will not be suitable in all settings, particularly where the background noise is particularly low, or where operational times continue into sensitive periods. Equally where background levels are higher, more relaxed criteria may be appropriate.

Table 2: Guidance Internal Sound Target Criteria for Gym Activity – Residential & Other Areas

Receptor type	Guide Criteria (for third octave band values plots against the stated G curve - see Figure 1)	
	Airborne Sound (e.g. music) <i>L_{eq, T}</i> (31.5Hz to 8kHz)	Heavy Impact Sound <i>L_{max,F}</i> (31.5Hz to 8kHz)
Commercial Offices	G25-G35	G35-G45
Retail Areas	G30-G45	G35-G50
Residential Areas	G15-G25 (day)	G20-G25 (day)
	G10-G20 (night)	G15-G20 (night)

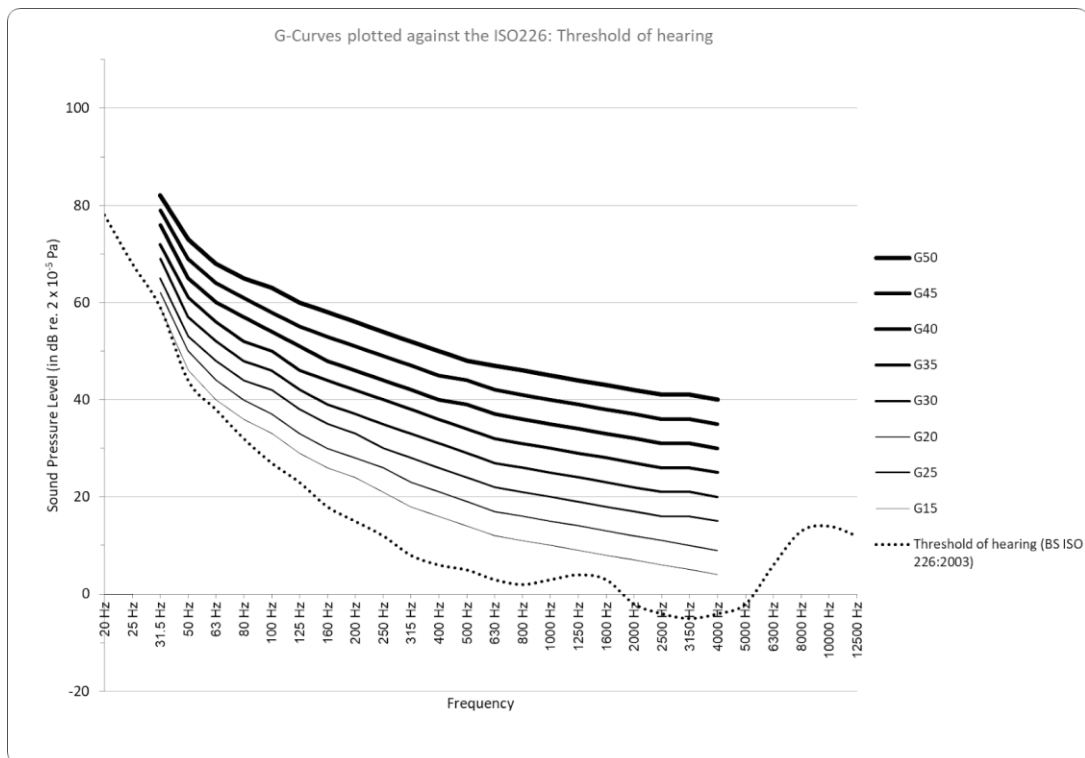


Figure 1: G-Curves plotted against the ISO 226:2003 Threshold of Hearing (Minimum Audible Field) for pure continuous tone perception of ontologically normal persons in the age range 18 to 20 years inclusively.

There are three areas clarified, which include what to do at frequencies outside the NR curve values, which is where there can be a lot of energy at the low end. It is recommended that resulting impact noise levels at frequencies 80Hz and below are considered, do not exceed a level of 20dB above the existing background noise dB $L_{A90,5\text{minutes}}$ within commercial and retail adjacencies (without source/Gym related activities). This means that extended range measurements will need to be taken.

The second point is around the frequency resolution and for heavy impact noise at least 1/3 octave bands analysis is desirable over the audible range from 31.5Hz, although measuring down to 20Hz is desirable to cover the audible range and may assist in identifying outlying peaks of energy.

For music noise, particular care should be given to controlling noise in the low frequency region, in the range 31.5Hz to 200Hz and $L_{\text{max},F}$, L_1 , L_{10} may also be used as parameters as a substitution for $L_{\text{eq},T}$.

The threshold of hearing is also defined in ISO 226:2003(en) 'Acoustics - Normal equal-loudness-level contours' and is specifically not offered as a target for criteria, but as an indication of a threshold below which can be taken as a positive indication of no adverse effect (NOEL). The point is made that because this contour is only applicable for pure tone sound whether a sound is audible or not depends on it being of sufficiently low level but also the listening conditions need to be considered. At this level the character of the sound would be likely to mean that some sound would still be audible to the normal person.

2.2. Vibration

It is commonly the case when designing mitigation works to achieve appropriate levels of re-radiated structure-borne noise, that resultant levels of vibration within the receptor space will be imperceptible. As such, tactile vibration is usually a secondary concern after sound (or noise) when considering the effects of Gym activity on occupants of neighbouring spaces.

Although instances are rare, it is nevertheless possible for tactile vibration to be the main, or a major, factor in the appraisal of a Gym site or a developed acoustic control strategy. For this reason, guidance on suitable criteria relating to vibration is also contained in Table 3.

Example situations that may occur include:

- Within neighbouring premises which operate with a relatively high level of ambient masking noise, such as a themed restaurant or bar.
- An unoccupied adjacency might house vibration-sensitive equipment.
- A receptor's floor structure which has a very low natural frequency and/or is poorly damped. In this case the values in Table 3 may be applied as criteria.

Table 3: Guidance Internal Vibration Target Criteria for Gym Activity – Residential & Other Areas

Receptor type	Guide Criteria		
	Tactile Vibration (point of entry to the body) RMS Acceleration (mm/s ²)		
Commercial Offices	rms 20mm/s ² W _g	Peak 40mm/s ² W _g	base curve multiplier of 4 (ref. BS 6472:1992)
Retail Areas	rms 20mm/s ² W _b	Peak 60mm/s ² W _b	base curve multiplier of 4 (ref. BS 6472:2008)
Residential Areas	rms 7mm/s ² W _b	Peak 21mm/s ² W _b	base curve multiplier of 1.4 (ref. BS 6472:2008)

Note 1: When measuring vibration, a similar approach down to at least 6Hz is recommended

Note 2: For facilities that are particularly sensitive (like scientific facilities) a specific methodology might be appropriate

The acoustic practitioner will rely on their own knowledge and experience in providing advice but should also consider the various guidance and standards that are available.

The guidance does not attempt to address this, but the included discussion on available guidance may be of assistance to highlight their application and possible limitations regarding Gym activity.

Further information on vibration criteria is available in the full guidance document.

3. TESTING METHODOLOGY

There are two proposed stages to an assessment of Gyms, Stage 1: Initial Site Risk Assessment and Stage 2: Full Assessment. In addition, there are two testing methodologies presented in the guidance document: Method 1 and Method 2. The part of the methodology that is best suited to each stage in the approach will be determined by the specific use scenario proposed, however it is expected that a heavy drop methodology (Method 1) will be most suited to the Stage 1 assessment, and where there is an existing Gym operation that Method 2 can be used, over a suitably representative period of operation. The complete assessment process is presented in the full guidance document.

The primary aim of the assessments are to determine whether the building being assessed is likely to be suitable for the intended use, or to assist in the investigation of complaints related to existing Gym operations. In determining the former the risk of causing adverse impacts on sensitive receptors, as a result of sound and vibration, requires a feasibility assessment to be completed as part of Stage 1.

In many lightweight structures there may be a high risk of causing adverse impacts identified, which may be difficult to overcome. The Stage 1 assessment is therefore an important viability check, to determine if the proposal is not commercially viable and should be avoided as a result. Where the risk is identified as medium or below it is likely that with mitigation an acceptable outcome could be achieved. This process will likely assist with the costing exercise by others for the project. This is then followed by a Full Assessment and a production of an Acoustic Design Statement to set out how this would be done. The methodology is applicable for both baseline and commissioning testing of all Gym areas.

Acoustic issues from Gym activity can be separated broadly into three subgroups:

- High Impact Response (HIR) (e.g.: Impacts with hard/ soft masses)
- Synchronised Repetitive Excitation (SRE) (e.g.: Running on a treadmill)

- Airborne Noise (AN) (e.g.: Amplified Music)

It is understood that an Airborne Noise assessment can be completed following other standard methodologies such as guidance given in BS EN ISO 16283-1. However, for HIR and SRE analysis the following assessment methodologies are recommended to provide a standardised framework for assessments.

For HIR assessments, a single high-impact impulse can be generated by dropping or slamming of a heavy weight (e.g.: dumbbell/barbell/kettlebell/slam-ball/tractor tyre/ battle ropes), which is referred to as a “weight drop” event.

In an ideal scenario, final commissioning of Gym equipment could reasonably be undertaken by measuring the specific items of Gym equipment being used by professionally trained Gym users as part of Method 2. However, in practical terms, this is usually not always possible. What is usually the situation is an opportunity to undertake baseline acoustic tests prior to Gym floor installation. This means a consistent assessment methodology using Method 1 is helpful. The results of such an analysis should form the objective part of the assessment process, which should also consider other subjective considerations (e.g.: how ‘noticeable’ the noise is subjectively).

The aim of the testing methodology is to simulate the source activity (HIR or SRE) in the proposed Gym area(s) and measure resulting noise levels in the nearest sensitive receptors, which can then be assessed against defined criteria.

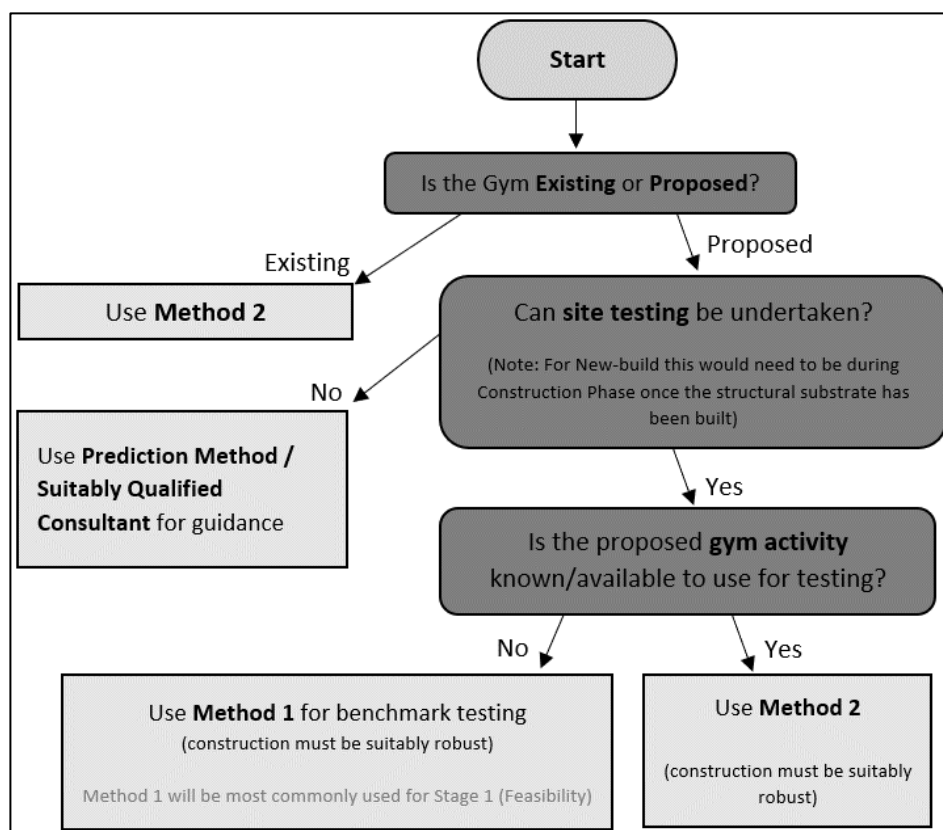


Figure 2: Flowchart to determine appropriate Gym testing methodology

A simple heavy drop method is likely to be useful as part of a Stage 1 assessment, but it may also assist as part of a Stage 2 assessment. To generate a source impulse through weight drops, the source ‘weight’ should:

For Method 1 Testing:

- Be selected with a mass that is suitable for exciting the structure to a point where a response will be achieved (or highest weight to be used by the Gym if less than 35 kg). This is typically between 20 to 35 kg dropped from a height of 0.5m. Maintaining an equivalent mass will allow comparison of data across different projects. The uncertainty becomes greater for lightweight structures, and Method 2 would be preferred.

- Be of a shape which will consistently impact the floor with an equal surface area. The normal way of achieving this would be to utilise a kettlebell with a rounded (or partially rounded) base, allowing for the generation of a consistent and repeatable impulsive force. If this is not practicable, then additional numbers of weight drops are advised to ensure that a typical worst-case can be determined from the measured drops.

- Have a rubberised finish.

Method 1 excludes drops from 0.5m above 35 kg - Anything above this weight would be classed as Method 2 testing. Practitioners should also carry out a response factor test of the structure.

Note: If possible, mass selection used in Method 1 should be representative of typical proposed activity, which should be justified and may result in a limit on the use through planning condition restrictions and or a noise management plan.

For Method 2 Testing:

The purpose of Method 2 testing is to measure realistic anticipated /existing resulting noise levels from activity that is representative of the proposed Gym activity in the space. This may be helpful in complaint investigations or where known activities are being planned, and as such would tend to be part of a Stage 2 assessment. Any proposed Gym equipment can be used but this is likely to involve dropping heavier weights/barbells from greater heights etc. Guidance on Health & Safety is presented in the full document. Where possible, measures should be taken to prevent the testing method from damaging the building structure (e.g., bare or untreated floor surfaces).

Due to the variation in the way energy will be transferred into the structure for different activity types, Method 2 testing should ideally include assessment of one of each of the following activities (where these items are proposed or are expected to occur in a Gym):

- Slamball/Medicine ball/Weight bags: slams using the heaviest proposed unit, ‘slammed’ from head height (approx 1.5 m). If slamballs are proposed to be slammed on walls, this should be measured. Generally, the worst-case weight would be around 10 kg in that case.
- Dumbbell: drops using the heaviest proposed unit, in line with drop methodology given in Method 1. Generally, the worst-case weight would be around 35 kg.
- Barbell: drops using the heaviest proposed unit, in line with drop methodology given in Method 1. Typically, the worst-case weight would be around 150 kg.
- Treadmill: running on the treadmill at a setting representative of a fast run (around 10 km/h) with shoes and with a flat-footed running style. This should ideally be measured continuously for a minimum of 30 seconds.
- Fixed Pin Weight Machines: given that the weight is fixed in the machine, it is recommended that the weight bars are released to drop from a height of around 0.2m typically, the worst-case weight would be 50 kg (depending on the type of machine). Depending on the placement of such machines, a judgement would have to be made on site, to ensure the worst-case situation has been assessed, taking into consideration the maximum weight of different machines and their proximity to the noise-sensitive receptors.
- Other: significant bespoke activities should be assessed such as battle ropes, weight bags, tractor tyre flips etc.

Note: The ‘heaviest proposed unit’ may not necessarily be the heaviest weight available, particularly for units with interchangeable weights, however, should be representative of the typical upper limit used by the strongest/most experienced Gym users. A view should be taken in consideration of guidance from the Gym users and operators.

4. PREDICTION

The prediction section provides a simplified prediction methodology based on building physics theory for sound (and vibrational energy) generated from the action of falling masses upon floor

slabs above. The intention is that this approach could be used as an initial scoping tool where a building does not yet exist or prior to doing site testing on a known construction, designed for use early in a project where it may not be possible to complete initial on-site testing or occasions where client decisions regarding mitigation provisions may be of concern.

The justification of this section has come from the Working Group's experience of more complex computer modelling and numerous occasions where early insight ahead of a testing campaign would be of merit. The method is therefore provided to bridge the gap between initial discussions relating to feasibility via approximation of noise/vibration transfer which could be used ahead of confirmatory site measurements. It is reiterated that testing in-situ shall always be considered the preferred option due to the degree of uncertainties involved.

It is acknowledged that the methods presented in the full guidance document may not be practical, particularly where cost-efficient and time sensitive appraisals of Gyms are required and, as such, this method is provided to give an approach that permits an order of magnitude indication of potential effects, the aim being to inform the level of mitigation that maybe required or illuminate any issues a candidate space may have in terms of feasibility.

The focus of prediction is for that of noise (and vibration) from Gym activities on a suspended slab floor above a receiving room. Further guidance on vibration levels within the Gym slab, the potential for transmission vertically and throughout a structure in addition to isolator considerations are not covered by the prediction method but are discussed in the guidance document.

5. SPECIFICATION OF MITIGATION

The primary purpose of specification is to ensure that the client is provided with the correct and optimal treatment, an understanding of why they are recommended and the practical ramifications of them. Not all treatments can be accommodated structurally, there will be a loss of height, which can affect thresholds and ability to lift weights above head height plus a financial implication which may affect the Gym operation and business model. It is recommended that the scope of works for the acoustician extends to a review of the system proposed by the supplier(s).

Site testing of mock-ups is the preferred approach for determining the optimum floor configuration, although there are limitations that need to be taken into account. This approach should be made clear to the contractor/client to ensure that they understand that every floor is different. In some cases, floor treatment can be over specified and needless additional costs to the client could result. There is very significant variance in materials, design and floor construction methods so all should be detailed. For covering layers, the following apply. Some aspects may require support and assurance from the supplier:

- Material of each layer required.
- Thickness of each layer required.
- A construction method that will not cause issues in the future, for example layers 'rucking' up or separating due to incorrect adhesion.
- A heavy wear layer suitable for adult Gym use to prevent the material breaking down over time.
- Consideration on stability under foot, overly soft constructions pose a health and safety risk and may require subjective assessment by the client.
- Consideration of stability of the structure is also important to be accurately understood, with the assistance of structural engineers so that isolation can be appropriately specified, and to avoid unacceptable deflections for clients, which is beyond the SQA area of expertise.
- Layers and construction should be appropriate for equipment loadings. (Heavy Gym equipment can cause damage or cause layers to separate). If a floating floor is required under covering layers, the following would be helpful. Some aspects may require support and assurance from the supplier:

- Where a specific floor system is not provided the required natural frequency of the isolating elements or force reduction performance, to be achieved under dead load of the floor and equipment, may be helpful.
- All isolating elements to be individually adjustable or shimmed to ensure uniform load and performance of floating floor across the floor plate for floor level and assured response. Alternatively proof of uniform load across the floor plate would be equally acceptable.
- The maximum creep should be limited to 25% deflection or another suitable standard.
- If elastomeric, the dynamic stiffness can be specified by either the acoustician or the supplier. Typically, this would be a maximum of 1.4 and should not change over the design life of the project.
- If spring, they should sit in an elastomeric cup capable of eliminating spring ring frequencies.
- Specify the minimum air gap required and if necessary, venting measures.
- Specify the minimum floating floor thickness and mass.
- The floor design should provide consistent response irrespective of floor loading due to equipment or other features.

If it is found that there is no specialist floor requirement, a simple impact layer is recommended beneath the Gym floor finish, this provides slab or subfloor protection so that when flooring might be replaced, it can be undertaken on an undamaged subfloor.

The aim is to isolate the Gym activity from the building structure by means of a floating floor and/or covering layer(s). The result shall be a flooring system which isolates Gym activities to a degree as determined by physical testing/prediction carried out by the project acoustician.

The flooring system supplier should provide independent evidence of final system performance in line with testing carried out, construction guidance, products of demonstrable quality and support to ensure correct installation.

The supplier should have a responsibility to work with the project acoustician and the client team to demonstrate (by calculation or empirical evidence as applicable) that the proposed floor system:

- Will provide isolation in line with physical testing carried out on site. It is advised that the supplier supports the testing process.
- Will be capable of supporting all intended Gym equipment without detriment.
- Will not exceed the structural capacity of the existing structure. The supplier shall further provide any loading information required by the client team. The supplier should work with the team and make recommendations on how limitations can be overcome.
- Will allow for safe access by users, including those with disabilities.
- Will allow for system penetrations for piping, drainage ducts etc. considering system moment while ensuring isolation is not compromised.
- Will be appropriately restrained if within a seismic or blast zone.
- Will be appropriately interfaced with any surrounding walls.

6. CONCLUSIONS

This paper has presented as an insight to the Gym Acoustics Guidance document written by the Gym noise Working Group, supported by the ANC, IOA and CIEH in the UK. The full guidance document includes more detailed advice in the sections referenced to in this paper, and the appendices includes other information which may be helpful including advice for developers and

operators, wording of conditions for EHPs, a review of legislative framework, health & safety advice, and case studies.

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- Anthony Robinson, Westminster City Council
- James Stokes, RBA Acoustics Ltd.
- Matthew Sugden, Clarke Saunders Associates
- Sebastian Woodhams, Sustainable Acoustics Ltd, Secretary of Working Group

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