ARUP

Efficient vibration design for lab-enabled buildings

First edition

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Introduction

Laboratories are critical spaces for research and development and analytics in the science, healthcare and higher education sectors.

Over recent years there has been significant growth in demand for laboratory space, with life science and deep tech flourishing in the 'golden triangle' of London-Oxford-Cambridge, and other clusters forming outside of this area including Bristol, Manchester and Edinburgh.

As demand has increased there has been a progression towards building new lab-enabled commercial spaces, providing developers and building owners the ability to attract science tenants to their properties, whilst retaining the option for office use only, or a mix of both functions. These buildings are not designed as bespoke laboratories but have the adaptability to accommodate many laboratory related activities. There has also been a trend to convert existing commercial office space into laboratories, although occasionally this comes with a compromise in the functionality that may restrict the building's use for some areas of research.

For both dedicated laboratory and lab-enabled buildings there are a range of additional requirements that may need to be considered in the building design, as shown in Figure 1.

In this guide we show that sensitive equipment and processes occupy only a small area of lab buildings, they often aren't particularly vibration sensitive, and there are more cost and carbon efficient solutions to the traditional approach of designing whole floor plates to meet strict vibration criteria.

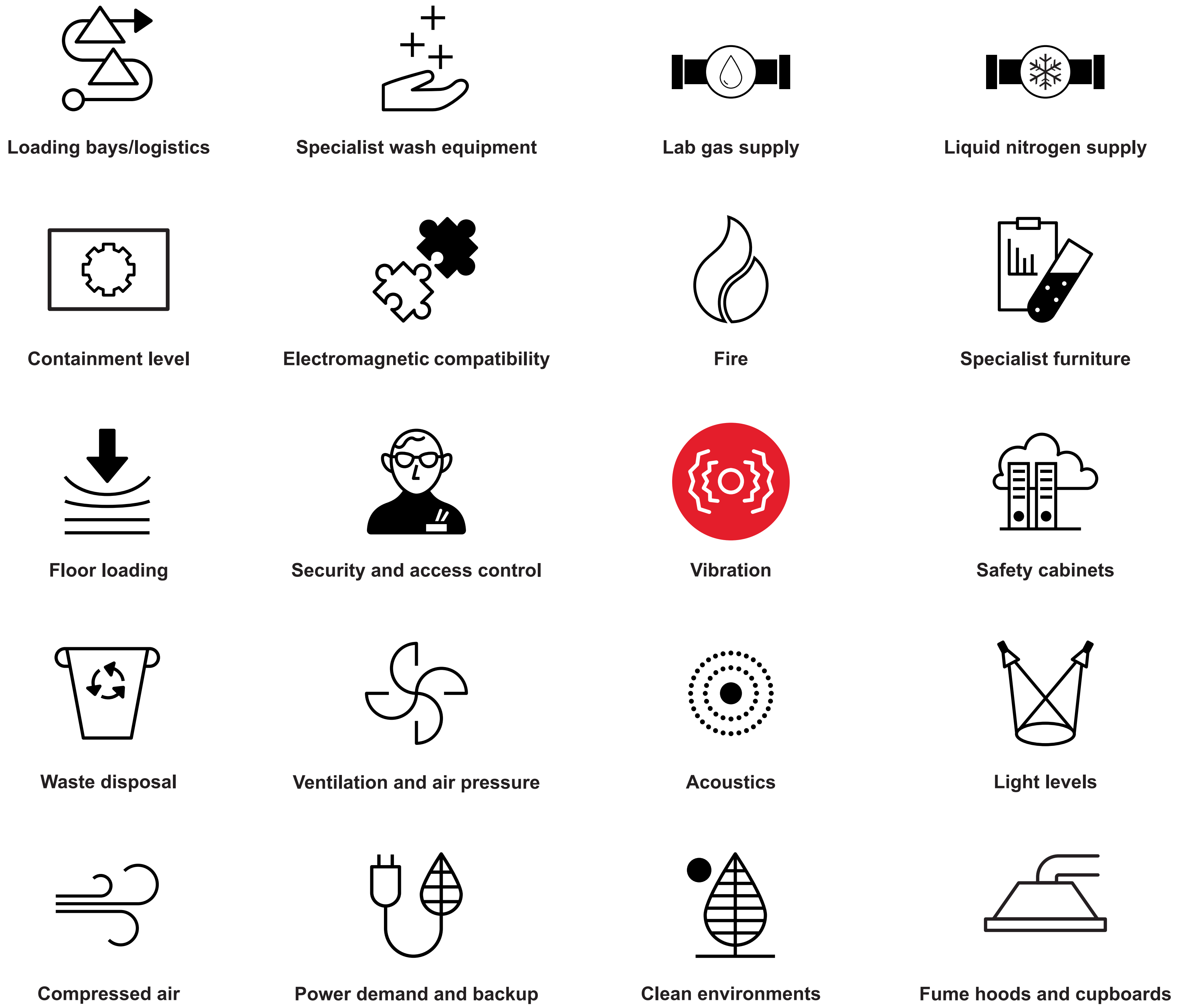


Figure 1 – Potential technical requirements for labs

Introduction

Challenges to defining vibration requirements

Identifying vibration requirements for a new lab or lab-enabled office can be difficult, because:

- Tenants might not be known at design stage,
- Science equipment might not be known at design stage,
- Tenants and equipment might change through the life of the building,
- Lab uses includes a wide range of disciplines from biology through to robotics, each with differing needs,
- Many lab users and equipment do not have particularly onerous vibration requirements,
- Some lab users and equipment have very strict vibration requirements.

Why getting vibration right is important

If vibration requirements are set too high, then additional cost and carbon will be spent for no benefit to the lab users or the building owner. Alternatively, if the vibration requirements are set too low, then vibration may limit the work that can be carried out in the building, and impact returns for the building owner. Finding the right balance is essential.

As we will explore later in this document, there are no widely adopted standard requirements for lab vibration and so labs are often designed by adopting and interpreting different standards and guides.

There are widely adopted standards for other lab specific requirements, such as Containment Level (CL). It might be tempting to link the CL requirement with a vibration requirement, but correlation between the two does not always exist. For example, consider a lab that handles a dangerous pathogen like Ebola. Ebola requires a CL4 laboratory, but pathogens themselves are not particularly sensitive to floor vibrations - it is either the people or the specialist equipment in the lab which is vibration sensitive.

In comparison, an electron microscope that is used to image minerals would have no CL requirements but is very vibration sensitive.

The purpose of this document

Without widely adopted standards for labs, an abundance of caution may lead to overspecification of new buildings. The property market has fallen into this trap before. In the London new build office market of the 1990s and 2000s the de facto specification for floor loading was 4 kN/m^2, which is far higher than actual offices of the time saw, and above the value set out in design standards. This meant that buildings were overdesigned, incurring additional cost and carbon for no real benefit.

This document is designed to guide technical and non-technical readers through vibration considerations for laboratories, enabling readers to have informed conversations about specification and design for vibration. We will do this by discussing the following topics:

- Vibration standards for labs
- Lab space vs equipment requirements
- Vibration sources affecting labs
- Space use in labs
- Vibration sensitive equipment
- Indicative equipment requirements
- Enhancing vibration performance in labs

This document draws on extensive project experience across Arup, including designing dedicated labs (e.g. Figure 2), lab-enabled offices, office to lab conversions and helping clients achieve some of the lowest vibration environments in the world.

Pathogens themselves are not particularly sensitive to floor vibrations – it is either the people or the specialist equipment in the lab which is vibration sensitive.

Figure 2 – Francis Crick Institute

Vibration standards for labs

Vibration criteria

Often generic vibration criteria are used on projects because precise equipment requirements are not known at the design stage, a degree of flexibility is required, or a combination of the two.

Generic criteria include Response Factors, which are in the range of perceptible vibrations, and "VC" Vibration Criteria, which are in the sub-perceptible range:

- Response factors (RF) are numbered – a higher number is a higher level of vibration.
- VCs are lettered – a later letter in the alphabet is a lower level of vibration.

A useful reference is that Response Factor 1 represents a level of vibration barely perceptible to the average person.

Whilst there are subtle differences in how different requirements are specified, they can be roughly compared using a characteristic limiting velocity (a 'vibration limit') for each criterion, as shown in Table 1.

Criterion	Characteristic velocity limit at 8 Hz	Example
Response Factor 8	800 µm/s	Office
Response Factor 4	400 µm/s	Premium office
Response Factor 2	200 µm/s	Residential
Response Factor 1	100 µm/s	Operating theatre
VC-A	50 µm/s	Specific vibration sensitive equipment
VC-B	25 µm/s	
VC-C	12.5 µm/s	
VC-D	6.25 µm/s	
VC-E	3.125 µm/s	

Table 1 – Vibration limits

Vibration limits and metrics

In addition to the vibration limit, to fully define a vibration requirement, or criterion, a metric is needed.

When Response Factors are defined for human comfort (e.g. for the vibration specification of an office), the metric is a 'low probability of adverse comment', but when Response Factors or VCs are used for labs, there is no standard metric. When using Response Factors or VC limits (e.g. VC-A) for labs, a metric should also be specified when setting vibration requirements.

What sort of metrics might be used with VC limits? Figure 3 shows an example of how vibration levels might vary with time. The vibration could be characterised in a number of different ways, including the maximum level of vibration experienced, or the average level of vibration experienced.

Maximum and average vibration are examples of metrics that can be combined with the VC limits to form a vibration criterion for a piece of equipment, a space or a building. Which metric you use will depend on how vibration might impact users and equipment. More refined metrics, such as the vibration level which is exceeded only 1% of the time, are often useful in addition to maximum and average metrics.

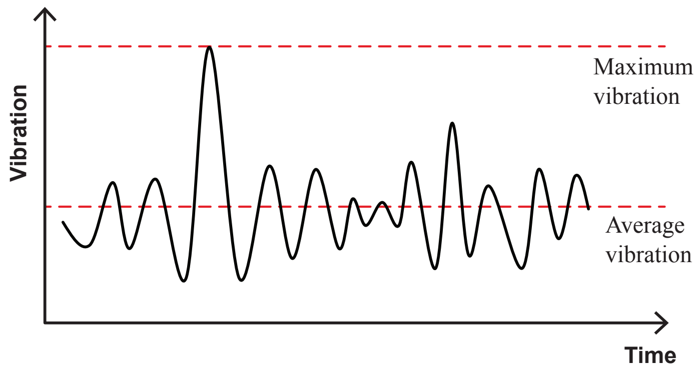


Figure 3 – Example of different vibration metrics

More information on limits and metrics can be found in the Arup authored paper: N. Simpson, J. Hargreaves and R. Harrison (2019) Delivering low-vibration environments in laboratory structural design, The Structural Engineer.

Vibration standards

There are no widely adopted vibration standards for laboratory buildings and guidance published by different organisations varies greatly.

Three prominent publications that propose lab vibration requirements are:

- NHS guidance document Health Technical Memorandum 08-01: Acoustics
- British Council for Offices (2021). Who is the Science Occupier?
- NIH Design Requirements Manual

The NHS guidance defines vibration requirements for "General" and "Precision" labs, equivalent to Response Factor 4 and 1 respectively.

The BCO document suggests a range between VC-A and Response Factor 2, whilst noting commercial laboratory spaces typically range between VC-A and Response Factor 1.

The NIH guidance recommends VC-A for a general laboratory, although unlike the other two documents, it includes prescribed walking speeds for analysis, which are less onerous than in equivalent UK guidance. The different recommendations are compared in Table 2:

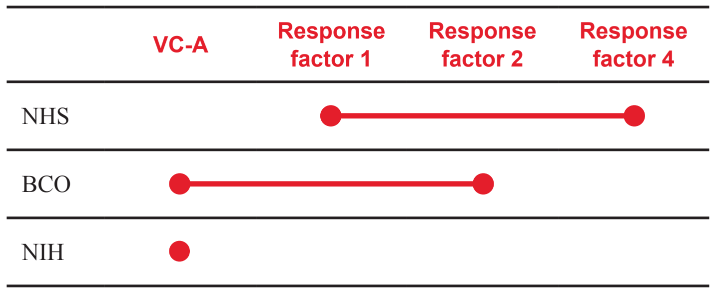


Table 2 – Vibration recommendations for labs in published guidance

Taking all three documents together, there is a big range in the proposed vibration requirements for labs, from VC-A to Response Factor 4. To understand why this range exists, it is important to differentiate between space requirements and equipment requirements, which we will explore in the next section.

There are no widely adopted vibration standards for laboratory buildings.

Lab space vs equipment requirements

To understand why there is such a wide range of vibration requirements used for designing labs, it is useful to split vibration requirements into two categories:

1. Space requirements (e.g. a general laboratory to NHS guidance) requires a Response Factor 4. This isn't based on a specific person or process, it represents a general performance level needed.
2. Equipment requirements e.g. VC-C for a MRI Scanner. The requirement is specific to the item of equipment and the floor location it is at. The vibration requirement doesn't need to be met across the rest of the room the MRI scanner is in, let alone the rest of the floorplate or building.

Commonly, vibration requirements of Response Factor 1 or higher represent space requirements. To NHS guidance, Response Factor 1 is the space requirement for Precision Labs and Response Factor 4 is the space requirement for General Labs. These are more onerous vibration requirements than, for instance, typical offices – which are usually designed to Response Factor 8.

Vibration requirements of VC-A or lower commonly represent equipment requirements – the vibration level that needs to be achieved to avoid impairing the function of specific piece of equipment.

What does this mean for specifying a lab?

A practical way to think about specifying lab vibration requirements is having the overall floor meeting a space requirement between Response Factor 1 and 4, with a proportion of the lab area achieving higher performance for specific items of equipment (e.g. by designing a certain percentage of the floor area to achieve VC-A). Write-up and office areas would typically be designed for a relaxed requirement (e.g. Response Factor 8).

This approach is analogous to compactus shelving/storage loading allowances in offices: The overall office floor is designed for the typical loading requirement, with a smaller area designated to carry the higher storage loads. This avoids overdesigning the whole floor for individual specialist items, while keeping sufficient flexibility for such low occurrence, more demanding, items to be located on the floor.

To NHS guidance Response Factor 1 is the space requirement for Precision Labs and Response Factor 4 is the space requirement for General Labs.

Figure 4 – Sainsbury Laboratory, University of Cambridge

Vibration sources affecting labs

There are a range of different vibration sources that can impact people and equipment in lab environments.

Vibration due to equipment which lab users have control over (e.g. centrifuges) is not usually considered in the structural design of labs for several reasons:

- The placement of this equipment relative to sensitive items is in the control of the lab user.
- The items run intermittently and are controlled by the lab user.
- The processes they may impact are also likely to run intermittently and are also controlled by the lab user.
- Spatial separation and work coordination by the users mitigates vibration problems.
- Information on such equipment may not be readily available at the design stage.

Vibration sources that are considered in the structural design of a building will depend on the target level of vibration. An indicative guide for suspended floor slabs is shown in Table 3.

The table shows that footfall vibration – people walking around the building – is usually the most significant vibration source affecting suspended floors in labs.

Generally, vibration due to building plant (Figure 5) and lifts can be mitigated through specification of anti-vibration mounts and hangers.

Highway and rail vibration sources are often beyond the control of the building occupant, but typically cause vibration at levels that only affect the most sensitive of equipment. In some cases, vibration due to traffic and trains can be improved, for example by improving the smoothness of road surfaces, and removing speed humps close to the building.

The vibration sources listed in Table 3 are often present through the life of the building. Construction vibration, e.g. due to heavy vehicle movement, pile driving and demolition, is a vibration source that can have significant impact on the vibration performance of a building, but is often only present for relatively short periods in the life of building e.g. during the construction or demolition of a nearby building. Construction vibration is beyond the scope of this guide.

There can be other, less common sources of vibration that affect specific buildings, one example is vibration from low flying aircraft, e.g. air ambulances operating near hospital laboratories. Such site and building specific vibration sources are best considered on a project by project basis.

Footfall vibration – people walking around the building – is usually the most significant vibration source affecting suspended floors in labs.

Footfall vibration rarely governs the vibration performance of ground bearing slabs.

"Free" vibration performance

Footfall vibration is often the critical vibration source for suspended slabs in lab buildings.

Designing to reduce the impact of footfall vibration is a significant part of designing a lab for vibration.

Even when a floor is designed for Response Factor 8 at the worst point, large areas of the floor will achieve better vibration performance, and parts of the floor close to columns and walls can achieve VC-A or better, providing "free" vibration performance (i.e. performance which does not require additional structural effort or cost).

Footfall vibration rarely governs the vibration performance of ground bearing slabs (i.e. the lowest floor in a building). Ground-borne vibration is often the dominant vibration source for ground bearing slabs, e.g. from external traffic, trains etc. Often ground bearing slabs achieve vibration levels below VC-A without any special vibration considerations, essentially "free" vibration performance. This means ground bearing slabs are a good place to locate lab functions that have a large number of items requiring stricter vibration control, e.g. imaging and microscopy suites.

Vibration level	Footfall vibration	Highways and rail	Building plant and lifts
Response Factor 8	High	Low	Low
Response Factor 4	High	Low / Medium	Low
Response Factor 2	High	Medium	Medium
Response Factor 1	High	Medium	Medium
VC-A	High	Medium	Medium
VC-B	High	High	Medium
VC-C	High	High	Medium
VC-D	High	High	Medium

Risk of causing vibration at this level
- Low
- Medium
- High

Table 3 – Vibration sources affecting labs on suspended floors

Figure 5 – Building plant is typically only a concern where higher vibration requirements need to be achieved.

Space use in labs

In a lab building, the actual floor area dedicated to lab function is only a portion of the total floor area. As a minimum, circulation space, storage, amenities and risers will also be present on a floor in addition to office and write-up space.

Figure 6 shows a typical lab scene. A large amount of the floor area within the lab rooms is space between benches and a significant portion of the benchtops is left open, perhaps less than half of the total bench space houses equipment. Of that equipment, only some will be vibration sensitive. In some cases, the equipment will be vibration sources, e.g. centrifuges.

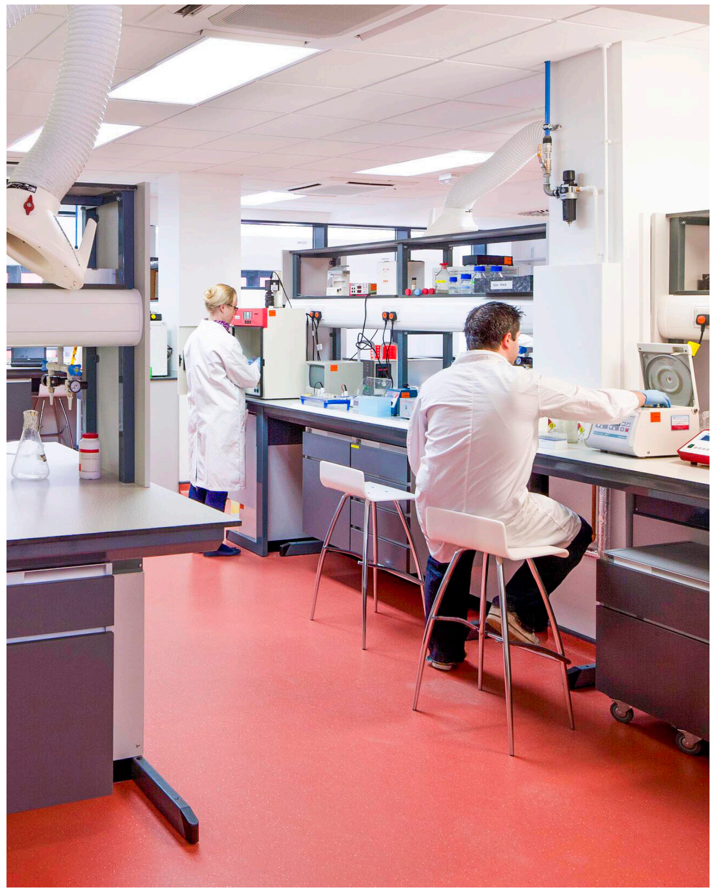


Figure 6 – ChELSI Project – University of Sheffield

To quantify how floor area is used in lab buildings, we have carried out a floor area analysis of 21 different floor layouts across 8 lab buildings. The buildings include specialist research buildings, life science labs and lab enabled offices. We have excluded cases which are less representative of typical lab floors (e.g. teaching labs and ground floor imaging suites) – see the “Exceptions to the norm” sidebar. The average space use calculated is presented in Figure 7.

In the study the percentage of floor assigned to labs varied between 17% and 51% and on average was around one third of the floor area.

Within lab rooms most of the area was clear space between benching. In our study we found on average only one third of the laboratory areas was assigned to benching

Information on the use of bench space was not available for the study, therefore we have assumed 50% of bench space is used to house equipment.

Combining the proportions of floor area used for laboratory spaces, the proportion of those spaces that are benching, and the proportion of the benches that have equipment on them shows, on average, only 5% of floor area has laboratory equipment on it (Table 4) and not all equipment is vibration sensitive.

Summary of average space use from study	
% of floor area that is labs	33%
% of lab area that is benching	33%
% of benching that houses lab equipment	50%
% of floor area with lab equipment	5%

Table 4 – Summary of average space use from study

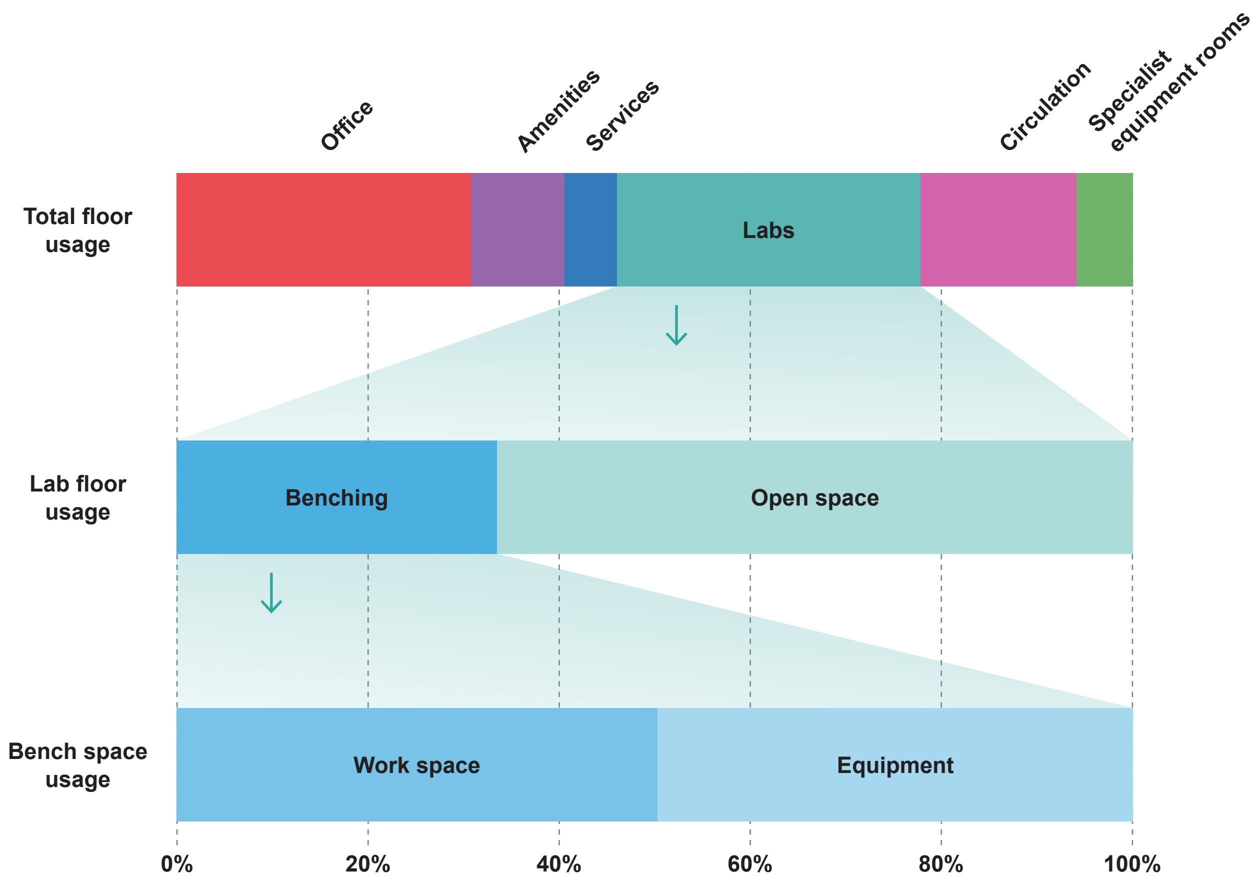


Figure 7 – Floor usage in labs

On average, only 5% of floor area has laboratory equipment on it and not all of that equipment is vibration sensitive.

Exceptions to the norm

Some labs will have a different split of floor use – teaching labs can have a much higher percentage of floor area dedicated to lab function, and correspondingly a lower percentage of floor area for offices and write up.

Areas of lab buildings that house imaging or microscopy suites generally have a higher percentage of floor area dedicated to lab function. Where these imaging suites house particularly vibration sensitive microscopes, such as Transmission Electron Microscope (TEMs), they are often housed on the lowest floor of the building where it is easier to achieve higher vibration performance than on suspended floor slabs.

Vibration sensitive equipment

As part of the study on lab usage, we carried out an analysis of equipment lists for five lab projects across a range of uses and grouped the equipment under typical vibration requirements for the equipment types.

The distribution of equipment is shown in Figure 8.

To gain a deeper insight into what drives this distribution of equipment, it is useful to consider the equipment in the following vibration requirement bands:

- The equipment requiring Response Factor 8 is made up of items such as incubators, centrifuges, washers, all of which are common in life sciences labs. The Response Factor 8 requirement is based on the typical requirement for an office (i.e. human perception), rather than specific equipment need.
- The equipment requiring Response Factor 4 include analysers and PCR machines. This group also includes a large proportion of equipment included in the equipment lists with unspecified vibration requirements (see the "Unspecified vibration requirements" sidebar), and so have been assigned a Response Factor 4 requirement of a General Lab.
- The most common item of equipment requiring Response Factor 1 was microscopes.
- Very few items require better performance than Response Factor 1.

This data suggests designing the whole of a lab for a vibration performance better than Response Factor 1 would only benefit very few pieces of equipment.

Considering a lab designed for Response Factor 4 will achieve Response Factor 1 over a portion of the floor area; a practical approach may be to adopt a space requirement of response factor 2 or 4, depending on the proposed lab use.

The enhanced vibration performance required for equipment with higher vibration requirements could be met by targeted measures, such as those discussed in the controlling vibration section later in this document.

Designing the whole of a lab for a vibration performance better than Response Factor 1 would only benefit very few pieces of equipment.

Indicative vibration requirements

On the next page we explore a range of typical lab equipment items, their occurrence (e.g. do they have a high occurrence, and are found in higher numbers in labs, like a centrifuge, or a low occurrence, and are comparatively rarer, like a transmission electron microscope), and their indicative vibration requirements. It is important to note that the requirements of specific items of equipment from different suppliers can vary, therefore the information provided should be used as an approximate guide.

Unspecified vibration requirements

Many pieces of equipment, including those commonly used in biomedical settings such as PCR machines/ Thermocyclers, DNA Sequencers/Analysers and HPLC systems have loosely defined vibration requirements such as "excessive vibration will affect instrument performance" and the instrument must be on a surface "free of significant vibrations".

Given these instruments are often in laboratories with significant vibration sources such as centrifuges, then significant and excessive vibration will likely be from these devices, and the acceptable vibration level due to other sources, e.g. footfall, has been assumed to align with the NHS General Laboratory requirement of Response Factor 4.

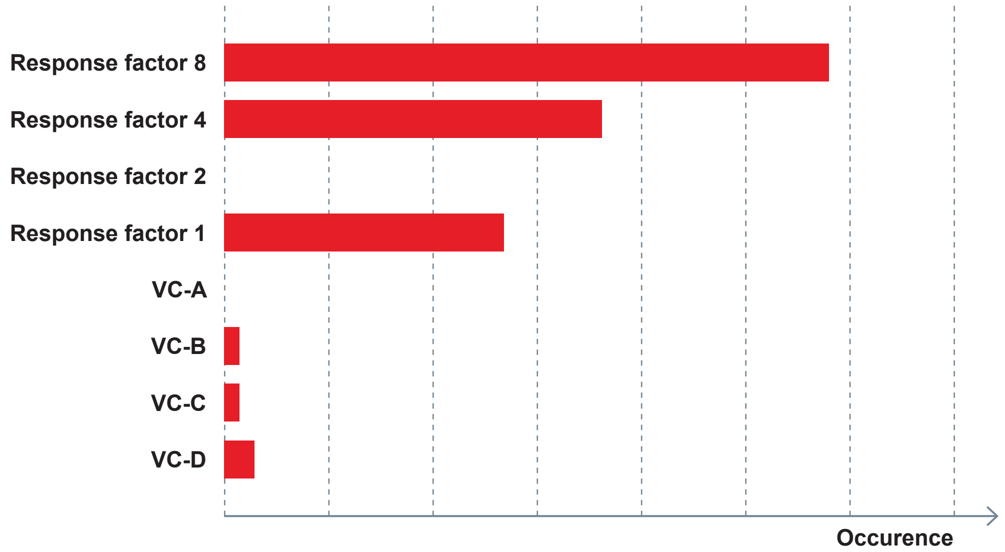


Figure 8 – Occurrence of equipment grouped by vibration requirements

Figure 9 – The Ogilvie Building, Wellcome Genome Campus

Indicative equipment requirements

Equipment		Occurrence	RF 8 Office	RF 4 General lab	RF2	RF 1 Precision lab	VC-A	VC-B	VC-C	VC-D	VC-E
General equipment	Incubator	High									
	Hot plate/Stirrer	High									
	Centrifuge	High									
	Autoclave	High									
	Mills	High									
Balances	Precision balance	Medium									
	Analytical balance	Medium				Unisolated					
	Micro balance	Low					Unisolated				
Bioscience	PCR/Thermocycle	High									
	Flow cytometry	High									
	DNA sequencer/Analyser	High									
	Gas chromatography	Medium									
	High performance liquid chromatography	Medium									
Mass spectrometry	Sector	Medium									
	Ion trap	Medium									
	Quadrupole	Medium									
	Time of flight	Medium									
	Thermal ionisation	Low									
Microscopy	Optical up to 40x	Medium	Isolated		Unisolated						
	Optical up to 400x	Medium		Isolated			Unisolated				
	Optical up to 1000x	Low					Isolated		Unisolated		
	Digital and/or fluorescence	Medium				Isolated			Unisolated		
	Confocal laser scanning	Low					Isolated			Unisolated	
Medical imaging/ equipment	Gamma camera	Low									
	PET/CT Scanner	Low									
	MRI Scanner	Very low									
	LINAC	Very low									
Electron microscopy	Scanning electron microscope (SEM)	Very low									
	Transmission electron microscope (TEM)	Very low									

Figure 10 – Indicative equipment requirements

Note: The vibration requirements assigned to items is indicative of typical equipment of that type. Specific products, and specific applications, may be more or less sensitive to vibration.

Enhancing vibration performance in labs

Vibration performance of buildings can be improved using a range of different approaches, from heavy solutions such as increasing the thickness of slabs, through smart solutions such as providing vibration isolation benches to simple solutions like space planning (e.g. putting vibration sensitive equipment closer to columns).

It is useful to consider the cost, in terms of financial, carbon and flexibility, of vibration control methods against a baseline version of the building. A good starting point is what the building would look like if there were no special vibration requirements, i.e. what if the building were designed to have typical vibration requirements of an office. This is a good starting point because a good proportion of floor area in laboratory buildings is used for "offices" – write up space, administrative functions etc.

Whole slab thickening, where the structural depth is increased to achieve the desired laboratory vibration performance everywhere, can be a blunt solution to a problem where just over half the floor area is lab space, and less than 5% might house vibration sensitive equipment. Therefore, we have presented a wide range of more subtle and selective methods of controlling vibration.

Comparing options

Methods of improving vibration performance can be rated based on the area of the floor they positively impact, and whether they require an upfront investment in cost and carbon (e.g. when the building is first constructed), or whether they can be deployed later, as required by the building use and specific tenants.

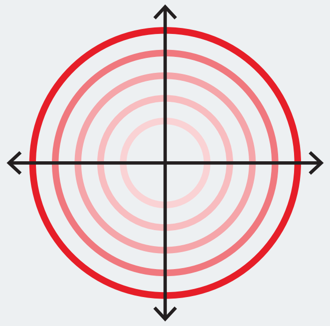
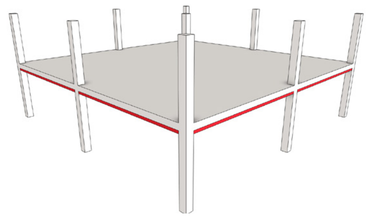


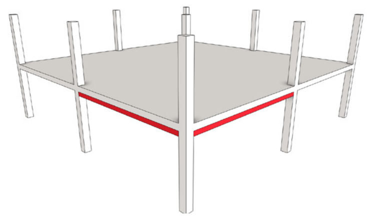
Figure 11 – Comparing options

Whole slab structural thickening



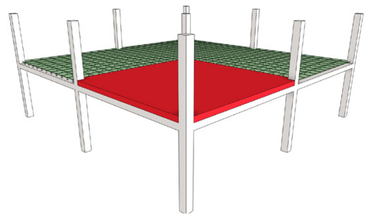
- **+** Maximal future flexibility
- **–** Upfront cost and carbon

Local structural thickening



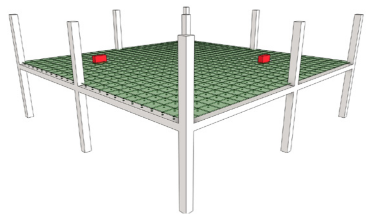
- **+** Targeted future flexibility; Limited upfront cost and carbon
- **–** Upfront decision; Lower vibration area fixed at design stage

Non-structural thickening (e.g. screed)



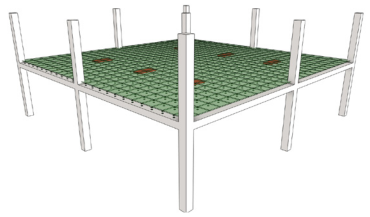
- **+** Flexibility through retrofit; Minimal upfront cost
- **–** Upfront cost for extra load

Active mass dampers



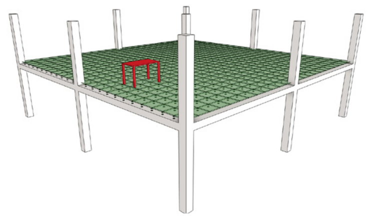
- **+** Materially efficient; Minimal additional mass, can be moved about; Minimal upfront cost
- **–** Fit out coordination; High cost per unit; "Active" system, higher and ongoing service cost

Tuned mass dampers



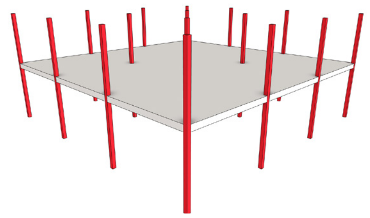
- **+** Minimal additional mass; Materially efficient; Minimal upfront cost; "Passive" system; Lower cost per unit than "Active"
- **–** More units than "Active"

Isolation bench or base



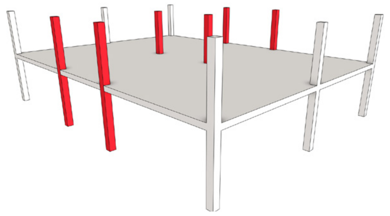
- **+** Provided at point of need; Minimal upfront costs
- **–** Assumes most equipment doesn't need specific isolation and doesn't have its own isolation already

Reduced column grid – Reduce the column spacing to improve vibration performance with same slab thickness



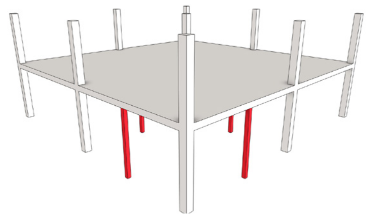
- **+** Efficient
- **–** More columns; Upfront costs and carbon; Reduced column grids

Irregular column grid – Locally flex the column grid to create bays with smaller spans and better vibration performance



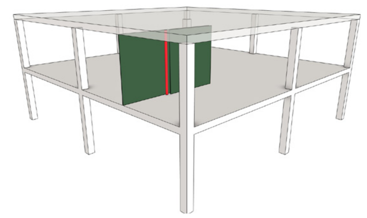
- **+** Efficient; Fewer additional columns than an overall reduced column grid
- **–** Upfront costs and carbon; Limits areas of better performance; Reduced column grids; Lower vibration area fixed at design stage

Local columns – Provide additional columns in some bays at lower floors



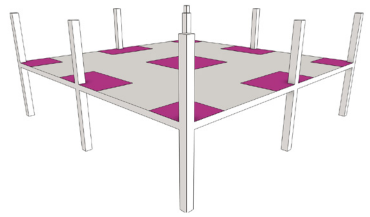
- **+** Materially efficient
- **–** Best suited to lower floors; Reduced column grids in places; Lower vibration area fixed at design stage

Vibration ties – Link floors together to enhance vibration performance



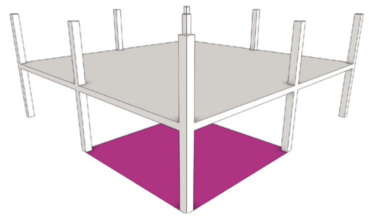
- **+** Efficient and targeted; Concealed in partitions; Provide if/when needed
- **–** Need coordination; Vibration transmitted between floors; Tie/partition position may not be ideal for space use

On-floor space planning – Place sensitive equipment where the structure has better vibration control near columns and walls



- **+** No additional cost or carbon
- **–** Required tenant cooperation

Across floor space planning – Locate sensitive process on the lowest floor



- **+** No additional cost or carbon
- **–** Equipment not close to write up; Restricted light for users if in basement; May take away other space uses at ground level (e.g. street-facing commercial premises)

Figure 12 – Enhancing vibration performance in labs

Other considerations

Further ways to enhance vibration performance

The examples for enhancing vibration performance on the previous page are common solutions, but it is not an exhaustive list. There are other subtle ways to improve vibration performance specific to different forms of construction.

- In concrete structures, projecting slabs edges beyond perimeter columns can improve the vibration performance of slabs, and increasing column dimensions can offer the same improvement in performance as thickening the floor slab, but with less volume of concrete and associated cost and carbon.
- In steel structures constrained layer damping can be introduced between steel beams and the floor slab to reduce vibration levels.
- Hybrid structures e.g. concrete beam structures with timber infills, can have their vibration performance improved at construction or later in the building life by adding screeds or replacing the timber infill with concrete.

Limits to enhancement by different options

Some of the methods to enhance vibration performance, such as adjusting column spacing or slab thickness, can improve vibration performance more than others, such as adding damping through active mass dampers, tuned mass dampers or constrained layer damping.

The improvement that can be achieved through adding damping is limited by the initial base structural vibration performance, so in some cases where more onerous vibration requirements are needed, a combination of approaches may be required.

An additional consideration is procurement and installation - measures that involve altering the primary structure can be accomplished as part of the long established construction process. Those that involve specialist items such as tuned mass dampers or active mass dampers will require additional suppliers, specifications and installation and commissioning activities.

Raised access floors

Typically, offices spaces are designed with raised access floors to allow distribution of power and networking cables to desks. Specialist lab buildings tend not to have raised access floors. A tension arises in lab-enabled office buildings where flexibility is required. Here, either careful selection of a raised access floor system can be undertaken to ensure it does not have a significant negative impact on vibration performance, or a solution that infills the depth of the raised access floor in lab areas could be adopted.

Other vibration sensitive equipment

The list of vibration sensitive equipment could be extended to include items such as Atomic Force Microscopes (AFMs), Scanning Tunnelling Microscopes (STMs), Scanning Transmission Electron Microscopes (STEMs) and more. These devices can have onerous vibration requirements, even lower than VC-E, but typically occur less often in life science laboratories. When they are present in labs, they are often placed on a ground bearing slab as the low vibration levels required are challenging to achieve on suspended floor slabs.

Base isolation of buildings

Base isolation of whole buildings (i.e. mounting a building on springs) is relatively rare in the UK for laboratories. The most frequent application of base isolation is to control structure-borne noise and perceptible vibration for residential buildings built close to, or above, railway lines.

Base isolation, by design, will amplify vibration at low frequencies. This can be less desirable for science buildings as it can negatively impact sensitive equipment which already has low frequency vibration isolation.

Figure 13 – Sir William Henry Bragg Building

Summary

This guide has shown that:

- Only a small percentage of lab floor area actually houses equipment.
- Most of that equipment is not particularly vibration sensitive.
- Space requirements between Response Factor 1 and 4 are suitable for most lab areas.
- Vibration requirements for equipment of higher sensitivity are achieved for ‘free’ with no additional structural effort close to columns and on ground bearing slabs.
- There are a range of mitigations available that can improve vibration performance across the whole structure, specific areas, structural bays or for specific pieces of equipment.
- A “traditional” specification of blanket VC-A or Response Factor 1 requirement for commercial labs are likely resulting in additional upfront cost and carbon being put into buildings for little additional benefit.

Having read this guide we hope you feel empowered to discuss vibration requirements in labs, and are informed to make decisions that balance risk against cost and carbon in the design and specification of labs for vibration.

Arup’s services and expertise

Arup has extensive, global experience in designing specialist laboratories, lab-enabled offices and retrofit existing buildings with laboratory functions. Our services include:

- Technical engineering and design
- Laboratory planning
- Logistics and transport planning
- Project and programme management
- Smart laboratories and buildings with AI integration
- Decarbonisation
- Low carbon and net-zero carbon laboratories
- Masterplanning
- Retrofit and refurbishment
- Office to laboratory conversion
- Science parks and campuses

These services are supported by our experts in architecture, structural engineering, mechanical electrical and public health engineering, civil engineering, geotechnical engineering, lighting, acoustics, fire, ecology, air quality and façades.

Our specialist structural vibration engineers are highly experienced in understanding vibration requirements of lab users, developing vibration requirements for clients, advanced simulation of vibration from internal and external sources, along with on-site measurement of vibration before, during and after construction.

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