2025 Annual Seminar & Trade Show

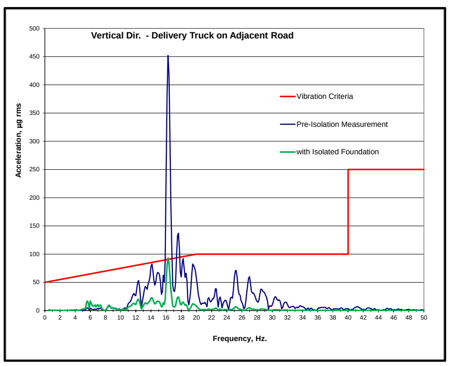
Vibration and Control of Building Structures

Over the years, vibration serviceability has been a high-profile issue on projects like the Millennium Bridge in England and several stadium grandstands in Europe. There are many less known vibration problems on office floors, monumental staircases and in manufacturing facilities throughout the U.S. Locally in Minnesota, many MNSEA members have noticed footfall vibration on floors at the Mall of America, and there was a wind-induced vibration failure of the Martin Olav Sabo Suspension Bridge (Midtown Greenway). This observed performance failures and MNSEA's strategic goal to advance technical knowledge are the motivation for this year's seminar topic.

SESSION 1: Vibration Engineering and Active Vibration Control of Floors
Paul Reynolds, PhD: CEO of CALMFLOOR, Honorary Professor at University of Exeter, UK

Innovative technologies for controlling building floor vibrations provide significant advantages over traditional methods throughout a building's lifecycle. Modern floor designs often prioritize vibration serviceability, and advanced vibration control solutions can reduce both construction costs and the carbon footprint of new buildings. For existing buildings, these technologies offer a cost-effective and non-disruptive way to resolve vibration issues without requiring extensive structural modifications. They also enable upgrades to accommodate more sensitive uses, such as converting office or commercial spaces into laboratories, healthcare facilities, or residential properties. This presentation offers a concise introduction to vibration engineering in buildings, focusing on the concept of active mass damping and its practical application to building floors. Several global case studies illustrate the successful deployment of this technology.

SESSION 2 – Vibration Serviceability and Measurements: Discussion, Demonstration, Case Studies.
Anthony J. Baxter, P.E., Principal at ESI Engineering
Peter G. Olney, P.E., Consulting Engineer at ESI Engineering



Vibration serviceability refers to the ability of a structure to function as intended without causing annoyance to its occupants or compromising the performance of sensitive equipment. It is an important design issue for buildings where human comfort is a priority, such as office buildings, hospitals, and residential structures. It is critical for buildings with sensitive laboratories, operating rooms, and equipment, such as high magnification microscopes, MRIs, and microelectronic fabrication tools. Understanding the vibration requirements is part of the challenge. Analysis during design and measurements of vibration levels can also be challenging. In this presentation, we will discuss the breadth of vibration serviceability, considerations for the structural engineer, measurements, and several project examples.

SESSION 3 – Introduction to passive TMDs, base isolation of structures & industrial equipment.
Florian Sassmannshausen – Vice President, Building Acoustics at GERB Vibration Control Systems

Tuned Mass Dampers (TMDs) and vibration isolators, though often hidden from view, play a crucial role in the performance of buildings and structures, impacting human comfort, acoustic comfort, or protecting vibration-sensitive equipment. Tuned mass dampers are essential for minimizing motion in tall and slender buildings, towers, long-span bridges, monumental staircases, and floors. Vibration isolators, on the other hand, protect vibration- or noise-sensitive spaces by reducing vibration transmission within mixed-use buildings, shield buildings from rail-induced vibration, or protect foundations and adjacencies from extreme vibrations from industrial equipment.
Established in 1908, GERB stands at the forefront of vibration control technology, offering tailored solutions for architectural, structural, and heavy industrial applications. This session will explore common challenges posed by vibrations in structures and delve into advanced engineering solutions that empower structural engineers in performance-based design, ensuring human comfort in buildings and structures.

MNSEA

Minnesota Structural Engineers Association

SEMINAR AND TRADE SHOW – MAY 13, 2025

Paul Reynolds, PhD: CEO of CALMFLOOR, Honorary Professor at University of Exeter, UK

Paul Reynolds is the CEO of CALMFLOOR, a company dedicated to commercializing innovative Active Mass Damping (AMD) technology for controlling vibrations in building floors. Prior to this, he spent over 15 years as an academic at the Universities of Sheffield and Exeter, where he led pioneering research in vibration control and serviceability and published over 150 papers in this field. Paul has also been a trusted consultant to the industry, contributing to dynamic testing and monitoring projects, including several UK sports stadiums, and providing solutions for high-profile challenges such as the London Millennium Bridge vibration issue. He currently holds an Honorary Professorship at the University of Exeter.

Anthony J. Baxter, P.E. – Principal at ESI Engineering

Tony Baxter has been principal at ESI Engineering since 2012. He has 36 years of experience, with 25 of those years at ESI, specializing in building and equipment vibration and noise control. Sensitive hospitals, labratories and microelectronics facilities are his speciality, including requirements for structural design. He has used modal analysis and other techniques to solve critical vibration related issues. His experience in vibration and noise analysis includes mechanical equipment vibration isolation, HVAC noise control, isolation system design, development of unique solutions, and troubleshooting. Tony has a passion for finding simple solutions to complex problems. He has published papers on Tuned Mass Dampers to control vibration in buildings and on predicting ground vibration from equipment foundations. Tony has a B.S. degree in Mechanical Engineering from Iowa State.

Peter G. Olney, P.E. – Consulting Engineer at ESI Engineering

Peter Olney joined ESI in the Summer of 2021 and serves as a Consulting Engineer in Structural Dynamics and Design. Peter holds a B.S. degree in Civil Engineering from the Illinois Institute of Technology in Chicago, IL. He has a M.S. degree in Natural Hazards and Risks in Structural Engineering from the Bauhaus-Universität Weimar in Germany where he also was a research associate for GRK 1462: Evaluation of Coupled Numerical and Experimental Partial Models in Structural Engineering. As part of the research group, Peter presented conference papers around the world related to the design of monitoring systems for structures. Peter has experience with vibration measurement systems, as well as design of building and industrial structures. He is a licensed civil engineer in Minnesota and Oregon.

Florian Sassmannshausen – Vice President, Building Acoustics at GERB Vibration Control Systems, Inc.

Florian is the Vice President at GERB Vibration Control Systems and specializes in building vibration and acoustics. With 15 years of experience, he has successfully overseen the design and implementation of vibration mitigation solutions across a broad spectrum of global projects. Florian's expertise allows him to approach complex, technically demanding challenges with innovative, out-of-the-box thinking. Typical projects encompass building base vibration isolation, floating floors to protect vibration-sensitive areas, noise mitigation in mixed-use developments, discrete isolation of beams and columns, and the retrofitting of existing structures, rooftop helipads, and buildings.

"It's all springs and dampers," – but with the unique challenge to balance structural integrity with minimal displacement, while delivering exceptional isolation performance through elasticity – two seemingly opposing objectives. Collaborating with a talented team of structural, civil, and mechanical engineers at GERB, Florian helps drive forward the company's legacy. Founded in 1908 in Berlin, GERB is a world-renowned leader in vibration isolation and vibration control engineering and manufacturing.

Vibration Engineering and Active Vibration Control of Floors

Dr Paul Reynolds, CEO CALMFLOOR

MNSEA Seminar, 13 May 2025

Active Vibration Control for World Leading Performance and Sustainability

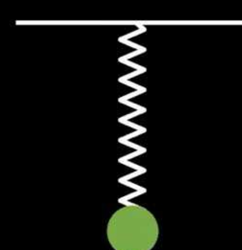
Outline

- Some basic vibration concepts
- Floor vibration control challenges
- CALMFLOOR active mass dampers
- Why use active mass damping?
- Analysis and specification of AMDs
- Implementation case studies
- Summary

Some basic building vibration concepts

BASIC CONCEPTS :

What is vibration? When is it important?



Structural vibration is an oscillation about an equilibrium position.

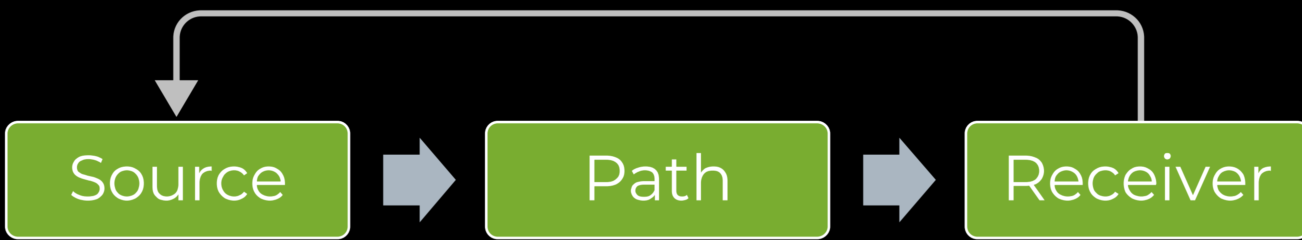
It is generated by dynamic loading, which varies sufficiently fast to generate significant inertial forces in a structure.

If the nature of the structure and dynamic loading is such that significant vibration responses may be generated, then it is important to understand and design for this.

As structures become more lightweight, more efficient, more lightly damped, the importance of vibration design is increasing.

BASIC CONCEPTS :

Components of any vibration problem



BASIC CONCEPTS :

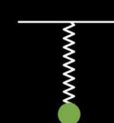
Equations of motion

Single-degree-of-freedom system:

$$m\ddot{x}(t) + c\dot{x}(t) + kx(t) = f(t)$$

inertia force damping force spring force external loading

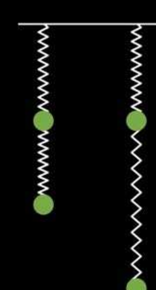
one mode, with
- natural frequency
- damping ratio
- mass



Multi-degree-of-freedom system:

$$[M]\{\ddot{x}(t)\} + [C]\{\dot{x}(t)\} + [K]\{x(t)\} = \{f(t)\}$$

many modes, each with:
- natural frequency
- damping ratio
- modal mass



For a proportionally damped system, for each mode, r:

$$m_r\{\ddot{q}_r(t)\} + c_r\{\dot{q}_r(t)\} + k_r\{q_r(t)\} = \{P_r(t)\}$$, where

$$\{x(t)\} = [\Phi]\{q_r(t)\}$$ and $$\{P_r(t)\} = [\Phi]\{f_r(t)\}$$

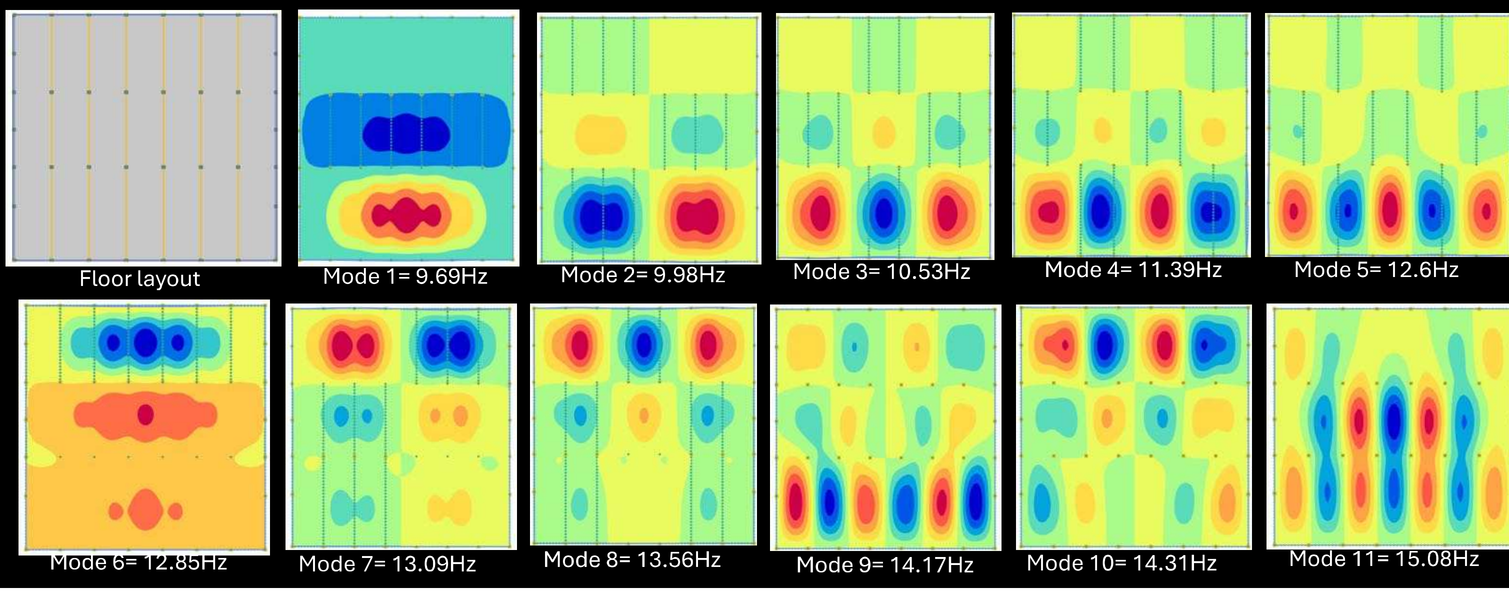
i.e. total response of a system can be calculated from sum of individual modes

BASIC CONCEPTS :

FE analysis

Modal analysis and response simulations readily carried out using commercial FE software.

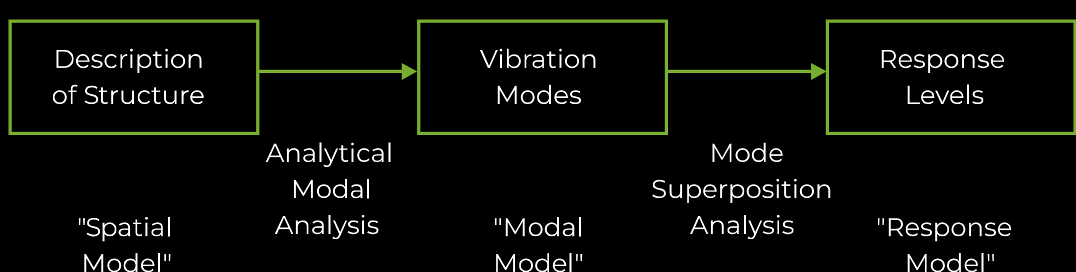
Below is a typical example from a floor modal analysis:



BASIC CONCEPTS :

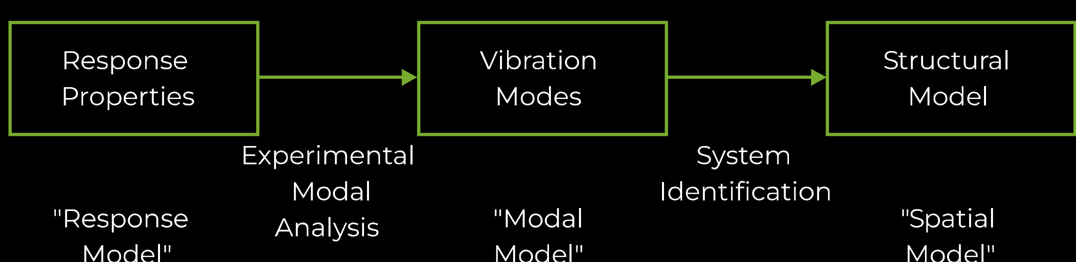
Routes to vibration analysis

(a) Theoretical Route to Vibration Analysis



FE modelling

(b) Experimental Route to Vibration Analysis



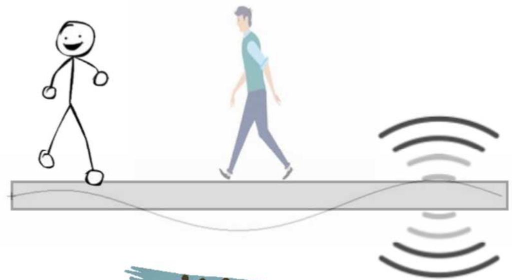
Vibration testing (and data analysis)

BASIC CONCEPTS :

What causes vibrations? Why problematic?

Floor vibrations can be caused by:

- Human activities (people walking around)
- External road/rail traffic
- Machinery and equipment operating within a building



Excessive vibrations can cause:

- Annoyance, concern and distress to occupants
- Fatigue and lack of productivity in office environments
- Sensitive equipment (e.g. in labs) to perform badly
- Non-compliance with health and safety standards

BASIC CONCEPTS :

Periodic vs transient responses

Periodic

- Typically caused by repetitive loading (e.g. footfalls or machinery)
- May cause resonance if excitation and structure frequencies coincide

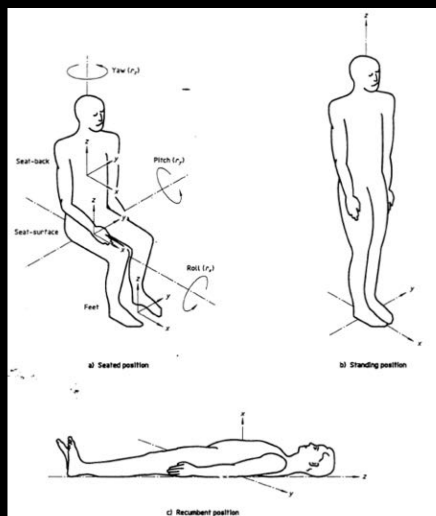
Transient

- Typically caused by loads which are of short duration
- Response decays to (near) zero before further loading is applied
- Repetitive loading can produce transient responses if response decays quickly – e.g. footfall loading on 'high frequency floors'

Assessment of vibration response

Human response to vibration - frequency weightings to account for:

- different frequencies
- different directions
- different activities



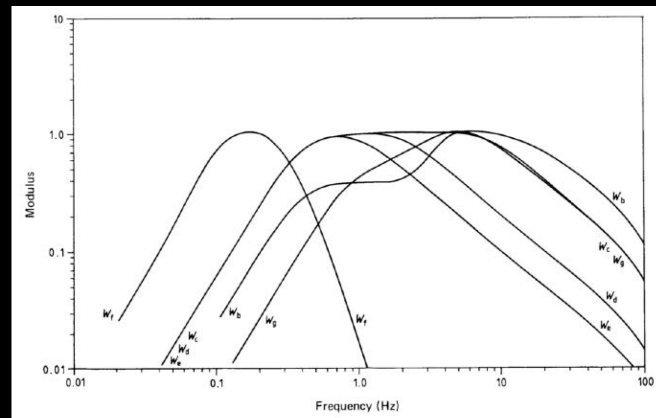


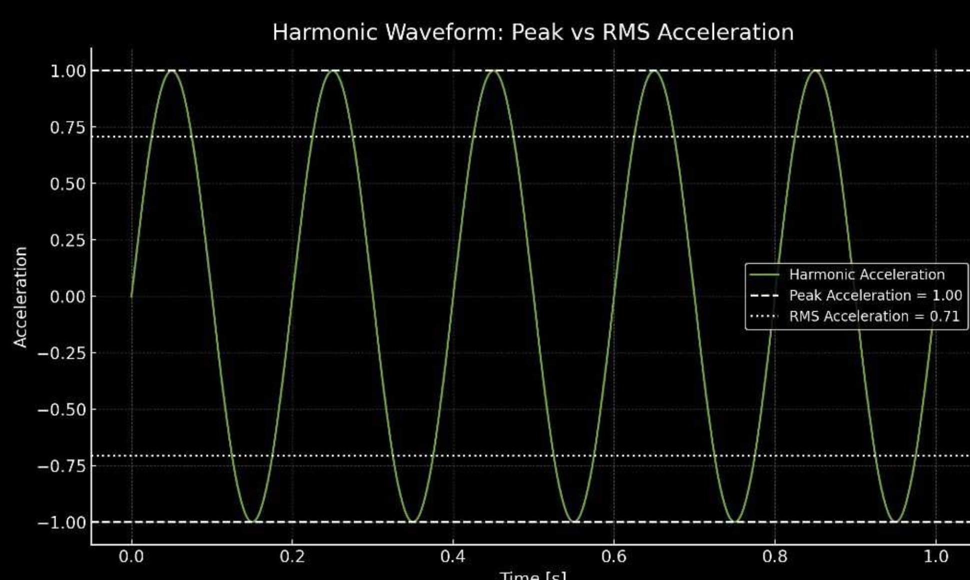
Table 1 — Outline guide to the application of frequency weightings

Clause reference	4	5		6		7
Frequency weighting	Health	Hand control	Vision	Discomfort	Perception	Motion sickness
W_b	z-seat	—	—	z-seat x-, y-, z-feet z-standing vertical lying	z-seat — z-standing vertical lying	—
W_c	x-back	—	—	x-back	—	—
W_d	x-seat y-seat	x-seat y-seat	— —	x-seat y-seat x-, y-standing horizontal lying y-, z-back	x-seat y-seat x-, y-standing horizontal lying	—
W_e	—	—	—	r_x, r_y, r_z seat	—	—
W_f	—	—	—	—	—	z-vertical
W_g	—	z-seat	z-seat	—	—	—

Assessment of vibration response

Human response to vibration - vibration metrics:

- peak accelerations (g or m/s^2)
- RMS accelerations (g or m/s^2)
- vibration dose values ($m/s^{1.75}$)
- R factors
- 1/3 octave band spectra

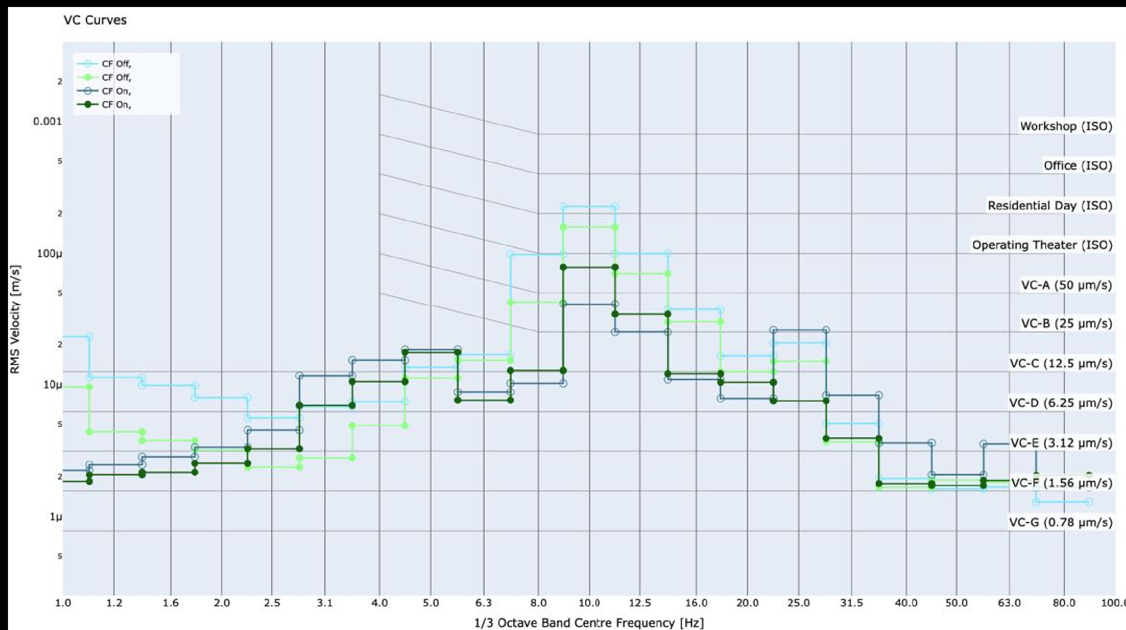


BASIC CONCEPTS :

Assessment of vibration response

Vibration sensitive equipment:

- usually assessed using velocity criteria
- usually 1/3 octave bands



Floor vibration control challenges

THE PROBLEM :

Floor vibration control challenges

1) Existing buildings with vibration issues

2) Building conversions and upgrades

3) New builds

"Office Vacancy Rate **Nears 20%** to **Set Fresh Record**, Moody's Says"
(Bloomberg, April 2024)

"**Exodus from Canary Wharf** leaves it at its emptiest for 18 years"
(Telegraph, July 2023)

"What to Do With a 45-Story Skyscraper and **No Tenants**"
(Bloomberg, August 2023)

"US commercial-property **crisis deepens** with office **vacancy rate** topping 2008 highs to hit a **new record**"
(Insider, September 2023)

“How **Adaptive Reuse** Can Help Life Sciences Labs Make the Move to Urban Centers”

(3BL CSR Wire, October 2022)

“**Repurposing existing buildings** into high-tech labs”

(PBC Today, July 2023)

“Life sciences **offer an alternative future** for some of London’s offices”

(London Evening Standard, August 2023)

“Office Developments **Pivoting To Lab Space** As Demand Dwindles”

(Toronto Storeys, July 2023)

THE PROBLEM :

Floor vibration challenges

CALMFLOOR ACTIVE VIBRATION CONTROL

CALMFLOOR
active mass dampers

CALMFLOOR ACTIVE VIBRATION CONTROL

Game-changing CALM®FLOOR active mass damping (AMD) technology

1. Patented solution – no direct competition
2. Instant installation with no structural intervention
3. Step change in performance over older technologies
4. Try-before-you-buy
5. CALM®CONNECT portal for performance monitoring
6. Zero maintenance with CALM®CARE for peace of mind

THE SOLUTION :

CALMFLOOR active mass dampers (AMDs)

Click here to view video

Why use active mass damping?

Problematic floors?
Instant **out-of-the-box** solution

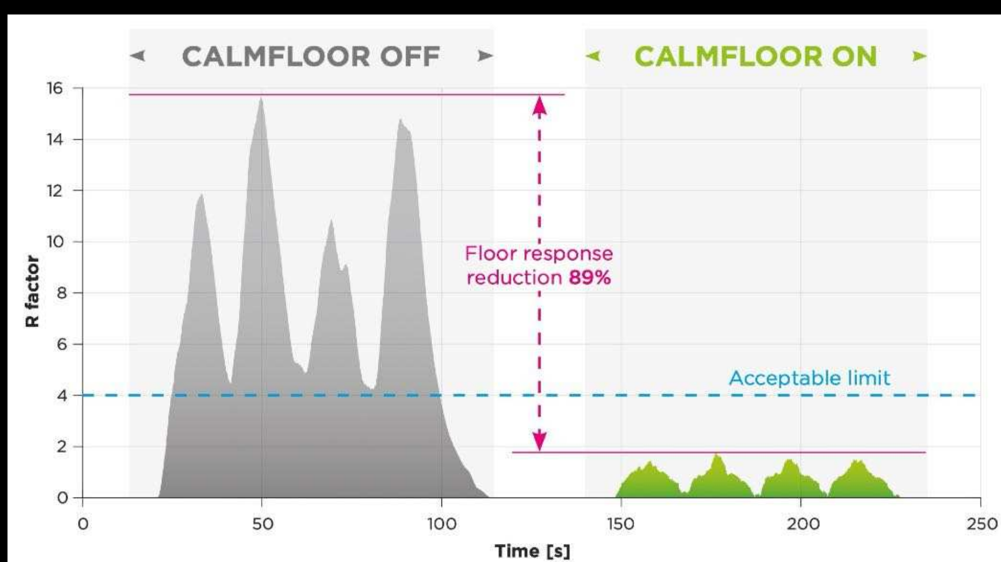
Repurposed floors?
Upgrade performance with no structural intervention

New builds?
Revolutionise construction to achieve Net Zero ambitions

WHY USE ACTIVE MASS DAMPING?

Proven performance

CALMFLOOR in an office building in the UK.

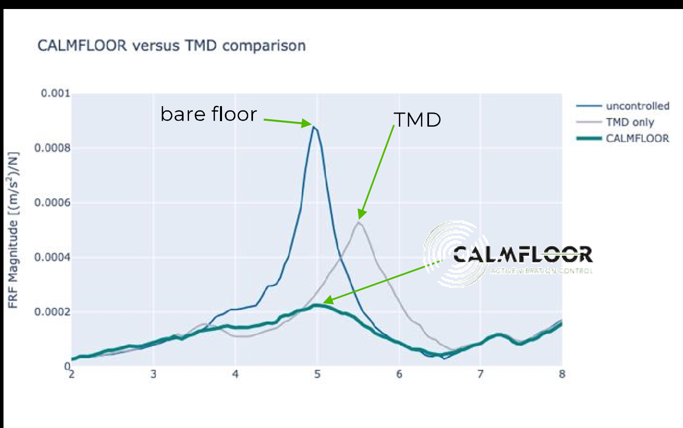


A single AMD reduced vibrations by 89% - the only minimally invasive technology than can deliver this improvement.

WHY USE ACTIVE MASS DAMPING?

Step change over older technologies

67 kg CALMFLOOR unit delivers better performance than **1500 kg** tuned mass damper



CALMFLOOR
ACTIVE VIBRATION CONTROL

“Try before you buy!”

Boston, USA, September 2022

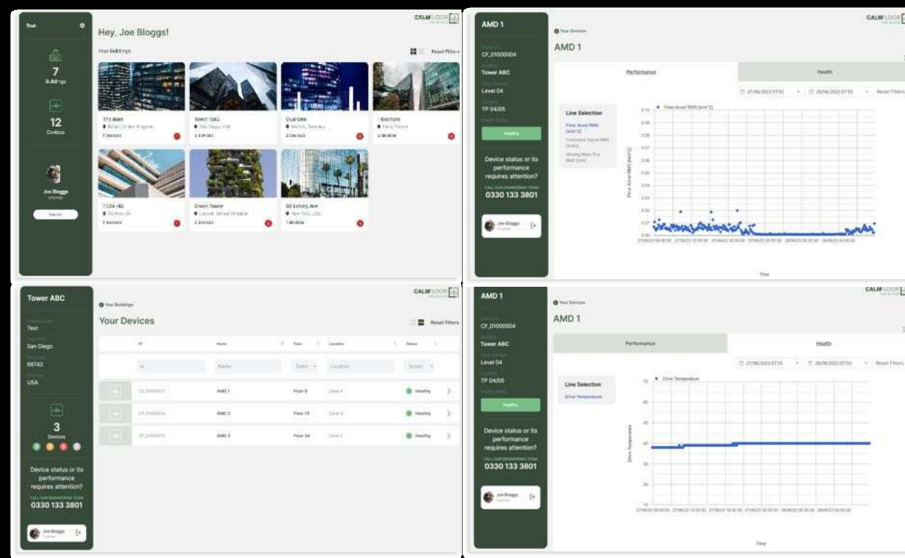
WHY USE ACTIVE MASS DAMPING?

CALMFLOOR
ACTIVE VIBRATION CONTROL

CALM CONNECT

VIBRATION CONTROL PORTAL

1. Secure login portal. Encrypted connection with AMD units.
2. Provides customers with 24/7 status and health of all installed units
3. 24/7 performance data of floor and CALMFLOOR unit
4. Maintenance free by design. CALMCARE for peace of mind



WHY ADOPT CALMFLOOR?

CALMFLOOR
ACTIVE VIBRATION CONTROL

CALM CONNECT

VIBRATION CONTROL PORTAL

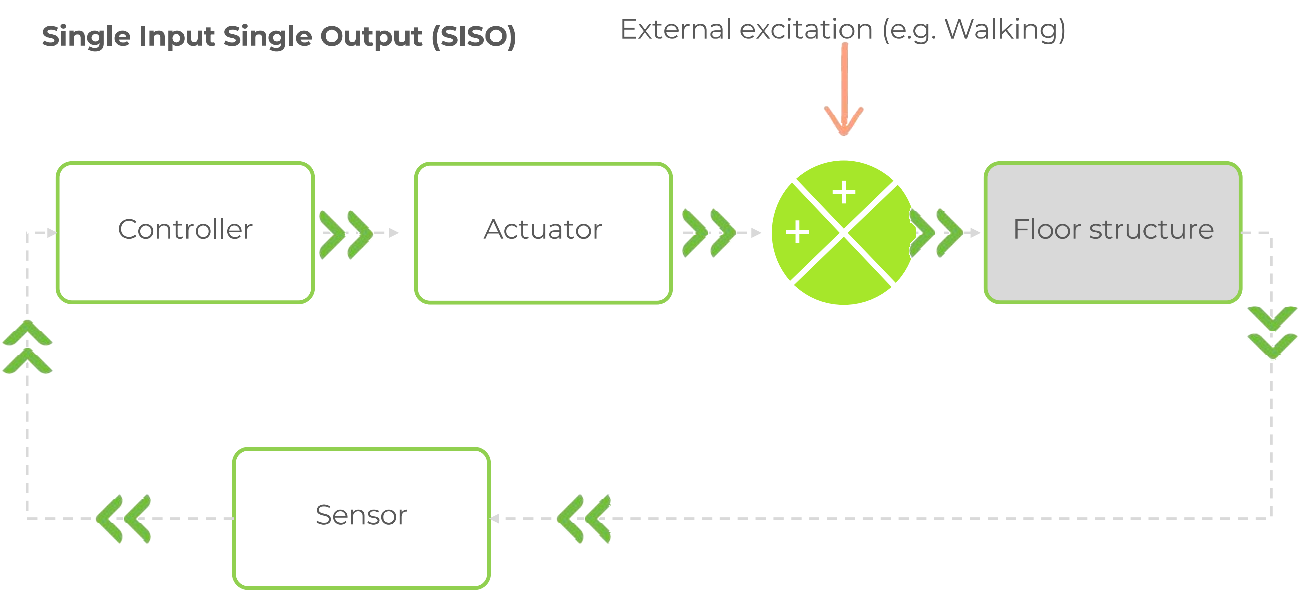
1. Secure login portal. Encrypted connection with AMD units.
2. Provides customers with 24/7 status and health of all installed units
3. 24/7 performance data of floor and CALMFLOOR unit
4. Maintenance free by design. CALMCARE for peace of mind

Analysis and specification of CALMFLOOR for floor structures

ANALYSIS AND SPECIFICATION :

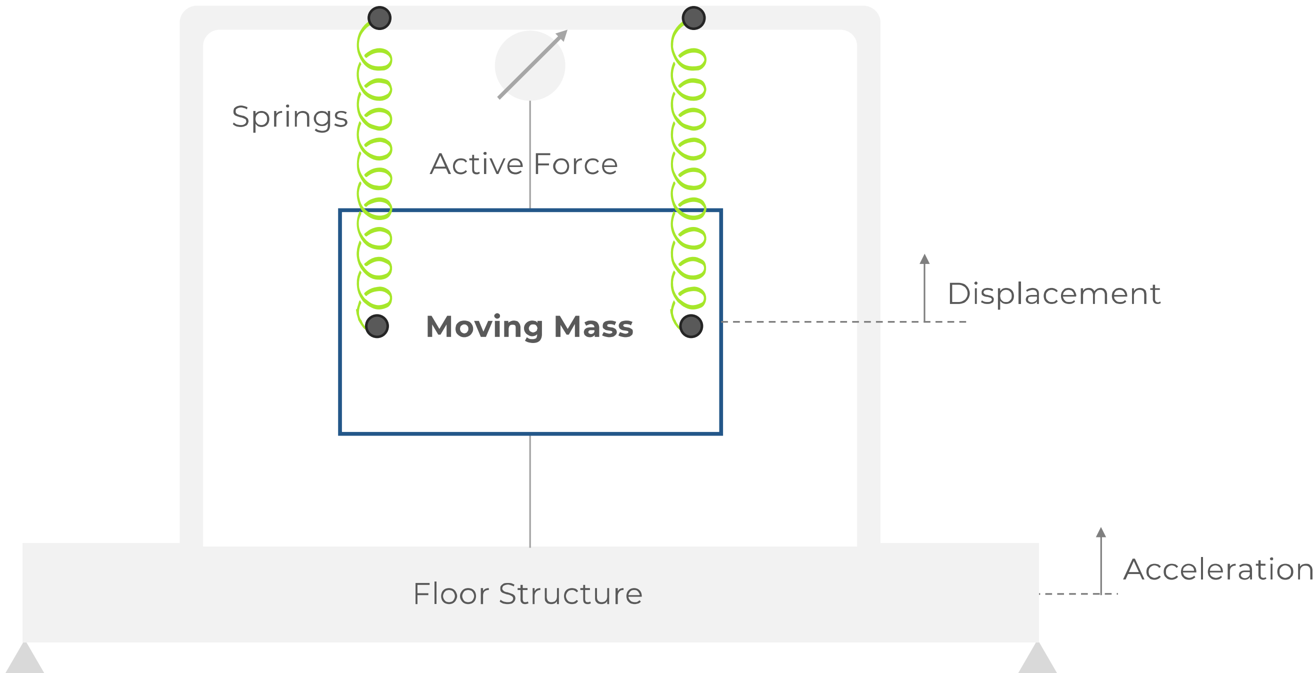
Active vibration control: the concept

Single Input Single Output (SISO)



ANALYSIS AND SPECIFICATION :

Active mass damper **schematic**



ANALYSIS AND SPECIFICATION :

Vibration analysis including CALMFLOOR

- Carry out footfall analysis as usual using appropriate structural analysis software.
- Initial estimate of likely performance may be obtained by assuming damping ratio of 10% in modes which are targeted by AMDs
- More rigorous analysis can be carried out by sending modal properties to CALMFLOOR for further analysis
- Example overleaf

ANALYSIS AND SPECIFICATION :

Typical office floor: footfall analysis

CALMFLOOR ACTIVE VIBRATION CONTROL

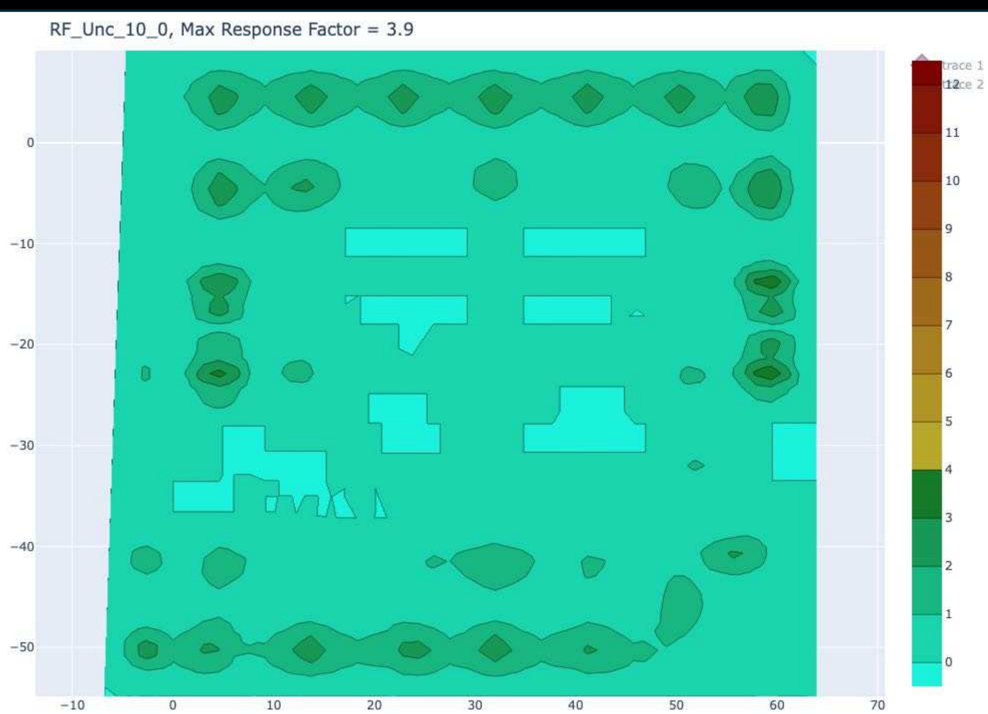
Damping ratio = 2.0%

ANALYSIS AND SPECIFICATION :

Typical office floor: footfall analysis

CALMFLOOR ACTIVE VIBRATION CONTROL

Damping ratio = 10.0%

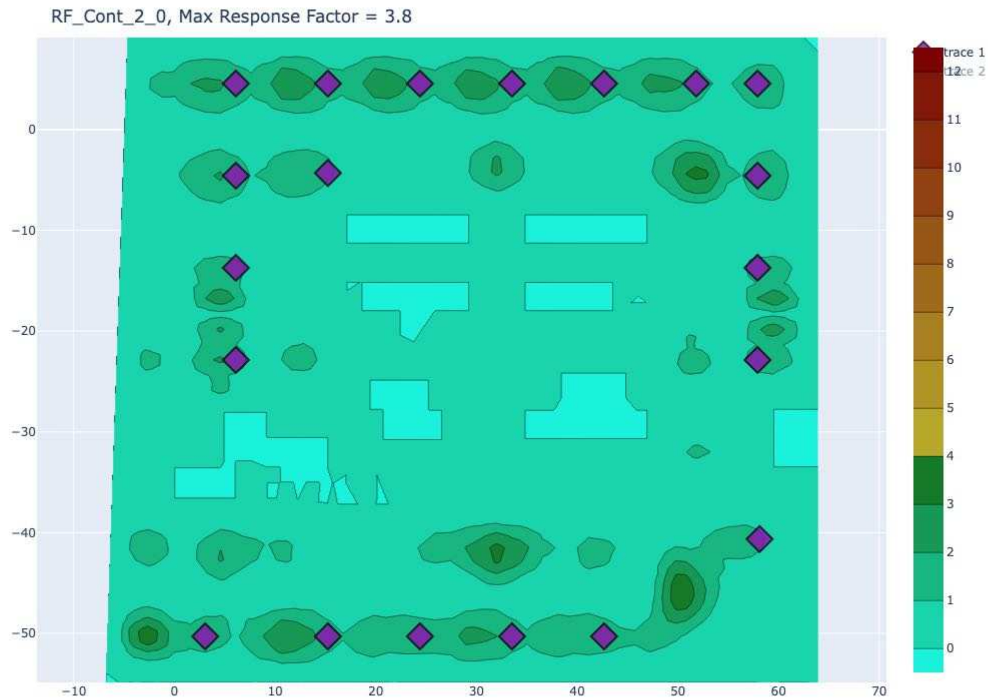


ANALYSIS AND SPECIFICATION :

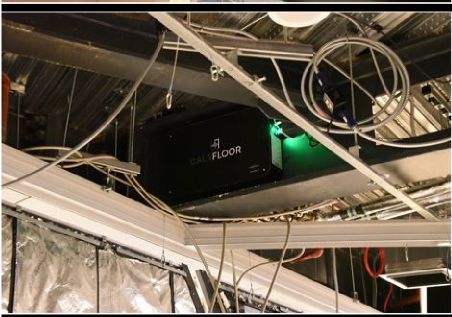
Typical office floor: footfall analysis

Damping ratio = 2.0%

CALMFLOOR modelled explicitly

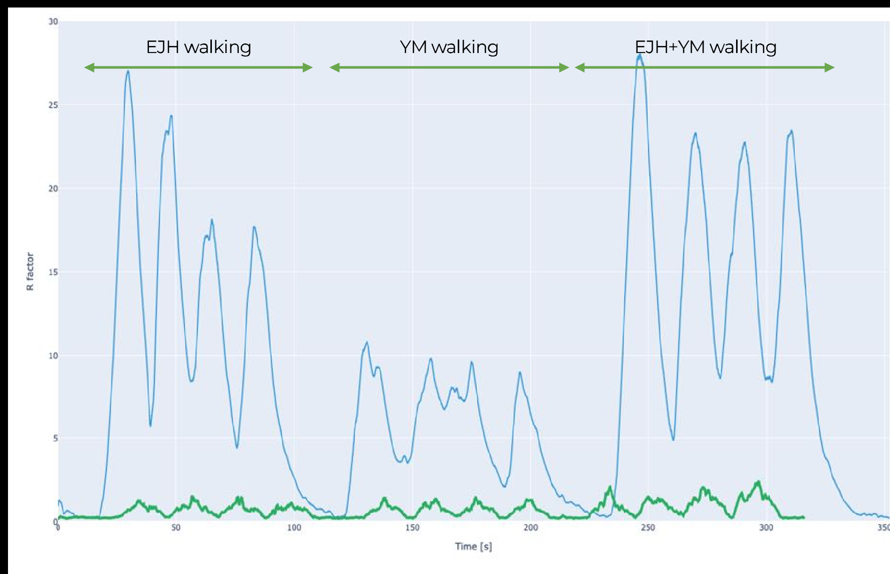


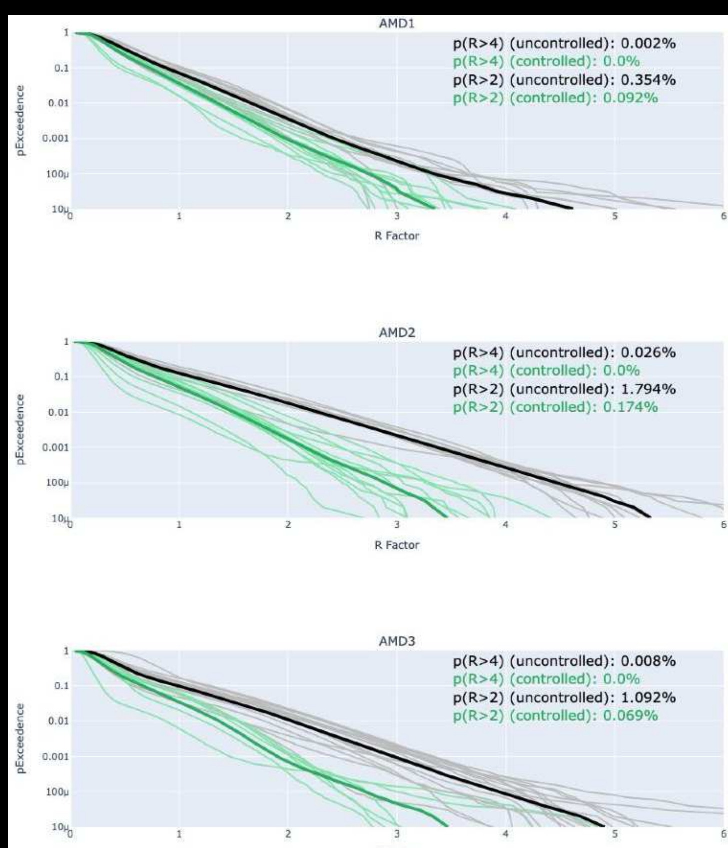
Implementation case studies



CASE STUDY :

Office building in London





CASE STUDY :

Switzerland Office building

CASE STUDY :

F1 ARCADE (Boston)

CALMFLOOR
ACTIVE VIBRATION CONTROL

The challenge: 69 F1 simulators on 2nd floor of tall building. Huge problematic vibration.

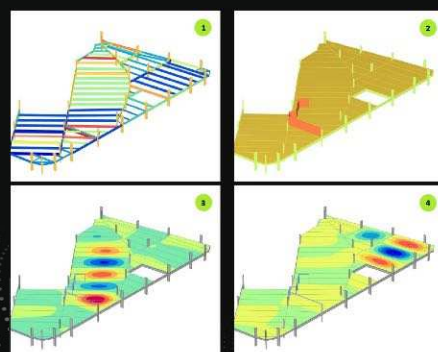
The solution: Simulations showed 11 CALMFLOOR AMDs would resolve issue.

The response time: Initial contact to installation – 15 weeks.

The result: 76% reduction in vibration. 2 new project referrals.

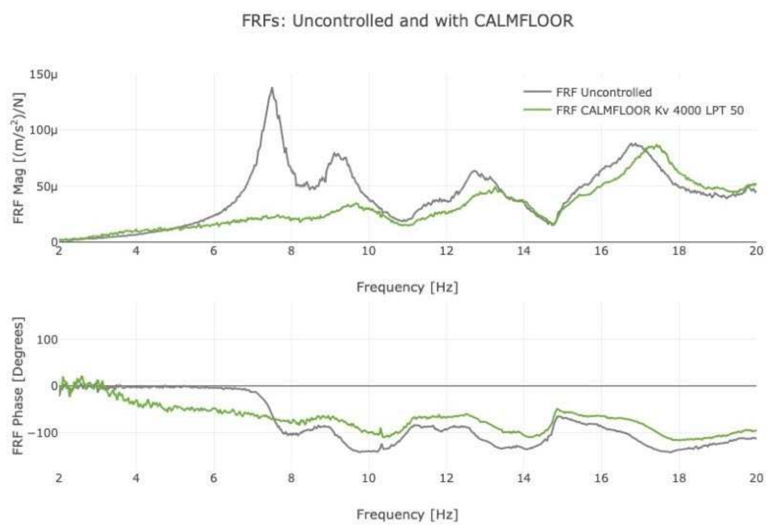
“…a huge win!” – the client

“…the F1 Arcade project was a great success!” – the structural engineer



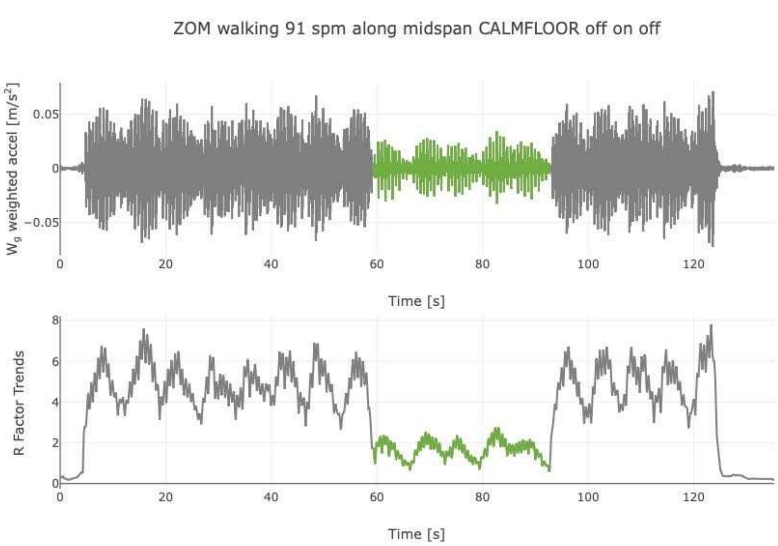
PHYSICAL TEST CASE STUDY :

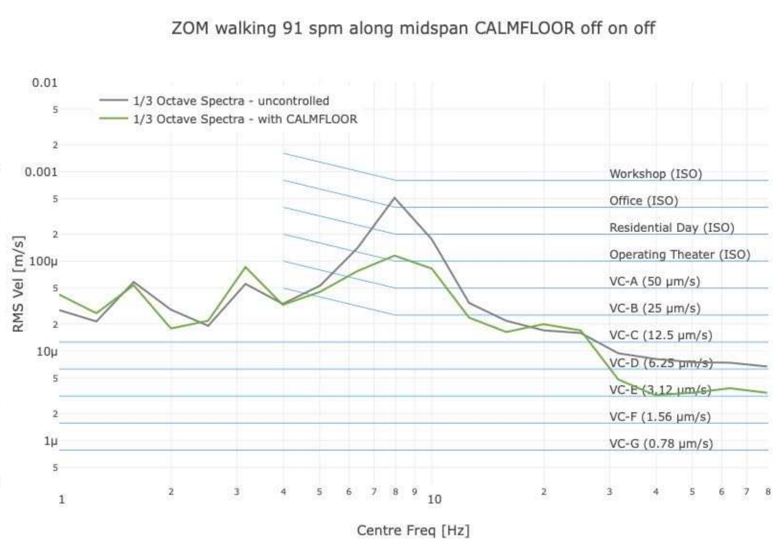
UK office to lab conversion



PHYSICAL TEST CASE STUDY :

UK office to lab conversion

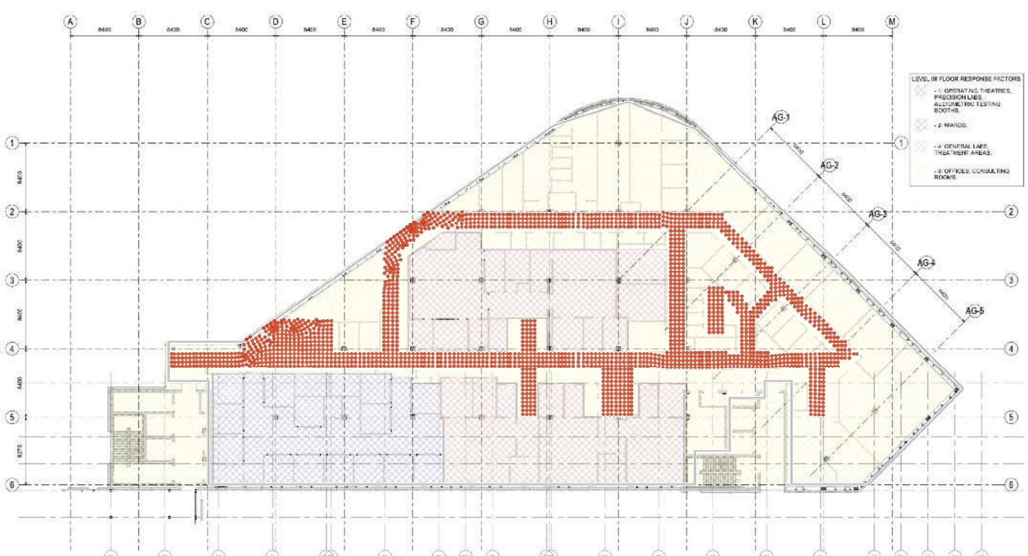




Impact on New Building Design

SIMULATION STUDY :

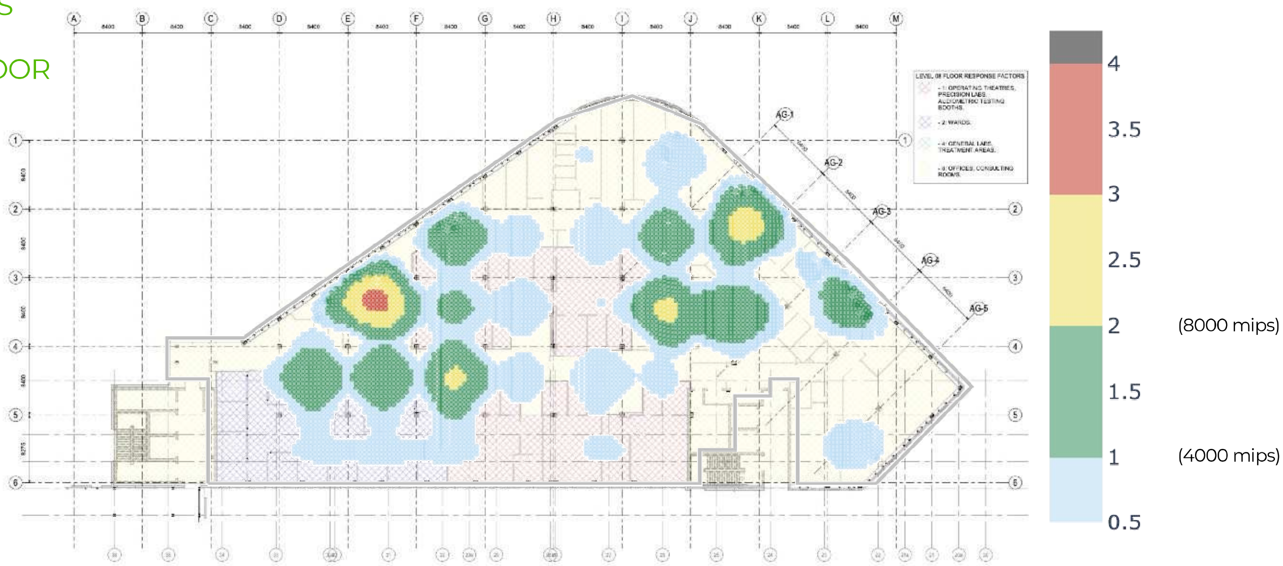
Hospital operating rooms and wards



SIMULATION STUDY :

Hospital operating rooms and wards

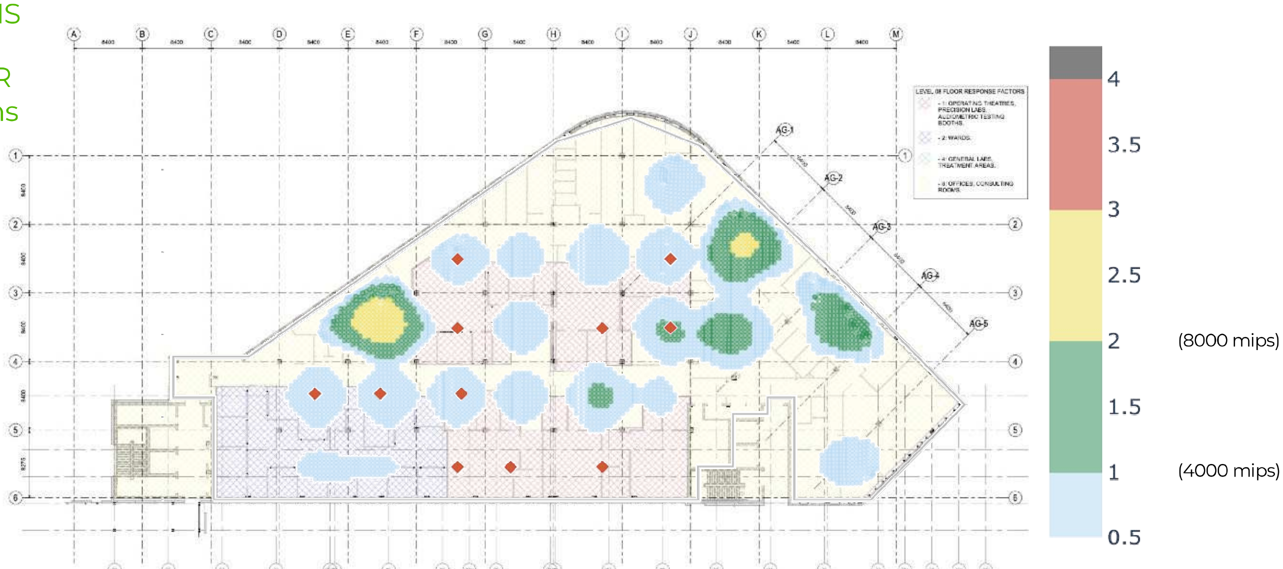
Wg weighted RMS responses: without CALMFLOOR



SIMULATION STUDY :

Hospital operating rooms and wards

Wg weighted RMS responses: with CALMFLOOR units at ◆ locations



SIMULATION STUDY :

Hospital operating rooms and wards

CALMFLOOR ACTIVE VIBRATION CONTROL

Results summary

- Strategic deployment of CALMFLOOR to achieve good performance in all vibration sensitive areas
- Reduction in slab thickness from 400mm to 300mm enabled by CALMFLOOR
- Carbon savings:
  - **~ 1000 tonnes concrete over three floors**
  - **~ 280 tonnes CO_2e**
  - 22 No CALMFLOOR units ~ 11 tonnes CO_2e
  - additional savings when considering structural frame and foundations

Zone	Max RF without CALMFLOOR	Max RF with CALMFLOOR
CT Scanner (R<0.5)	n/a	n/a
OTs & Prec Labs (R<1)	2.6	1.2
Wards (R<2)	2.2	1.0
Offices (R<8)	3.6	3.0

CALMFLOOR ACTIVE VIBRATION CONTROL

Summary

Summary

CALMFLOOR
ACTIVE VIBRATION CONTROL

Advantages of active mass dampers:

1. There's no structural intervention – save time, save carbon, save cost.
2. Net Zero targets and architectural ambitions are more readily achieved.
3. You want to be able to trial the world's only instant, out-of-the-box solution prior to marking a purchasing decision.
4. You want a secure portal that monitors real-time performance.
5. CALMFLOOR is a proven solution - evidence from installations worldwide is overwhelming.

CALMFLOOR is already changing industry perceptions with the one tool in the box you've been missing.
Until now.

CALMFLOOR
ACTIVE VIBRATION CONTROL

The game-changing, patented technology that controls floor vibration – this is the world's only out-of-the-box floor vibration control

SAVES MONEY – SAVES CARBON – SAVES TIME - IMPROVES BUILDING PERFORMANCE

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