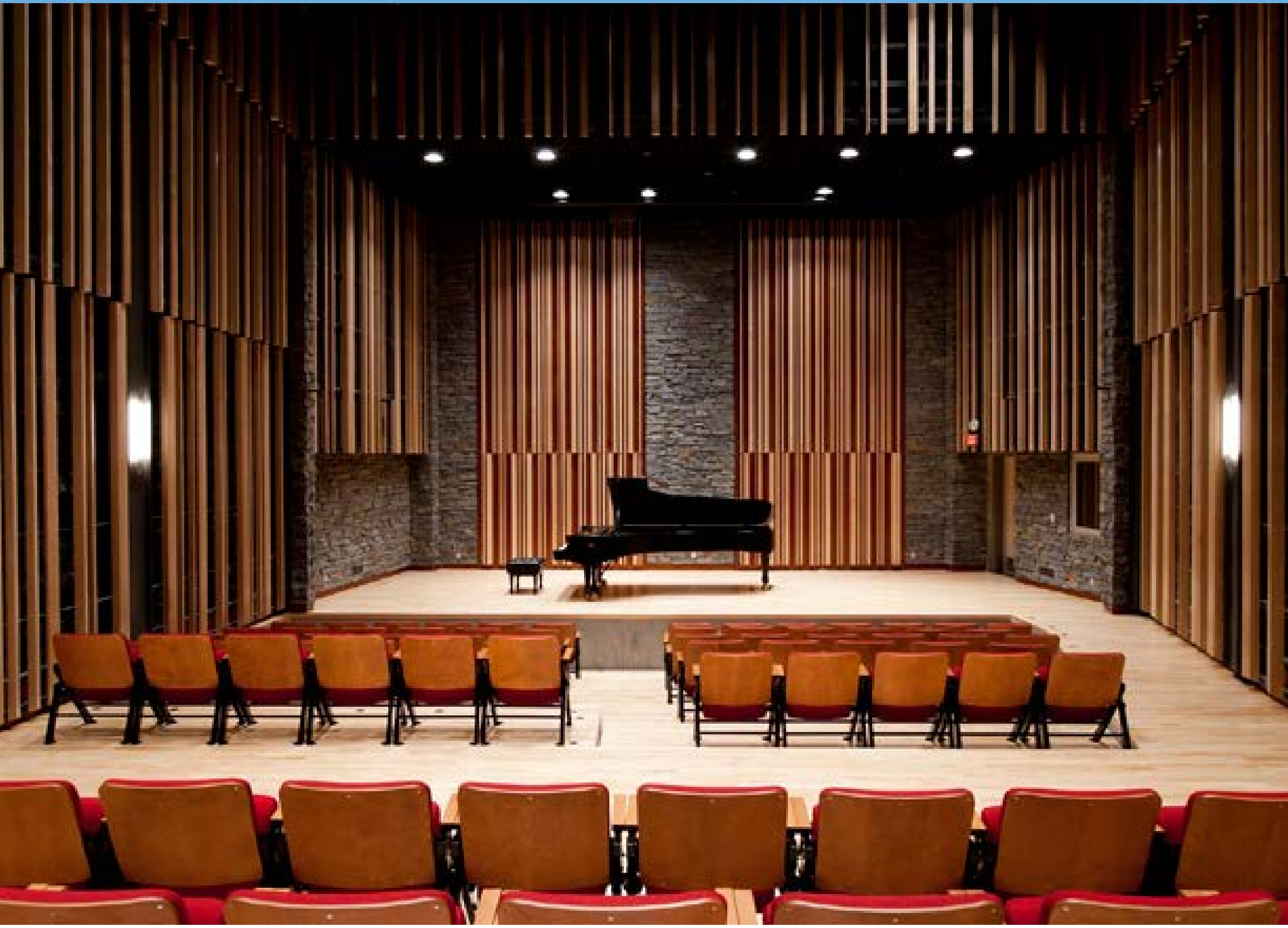
DON'T OSCILLATE ON VIBRATION MANAGEMENT

Vibration needs to be addressed in the design phase



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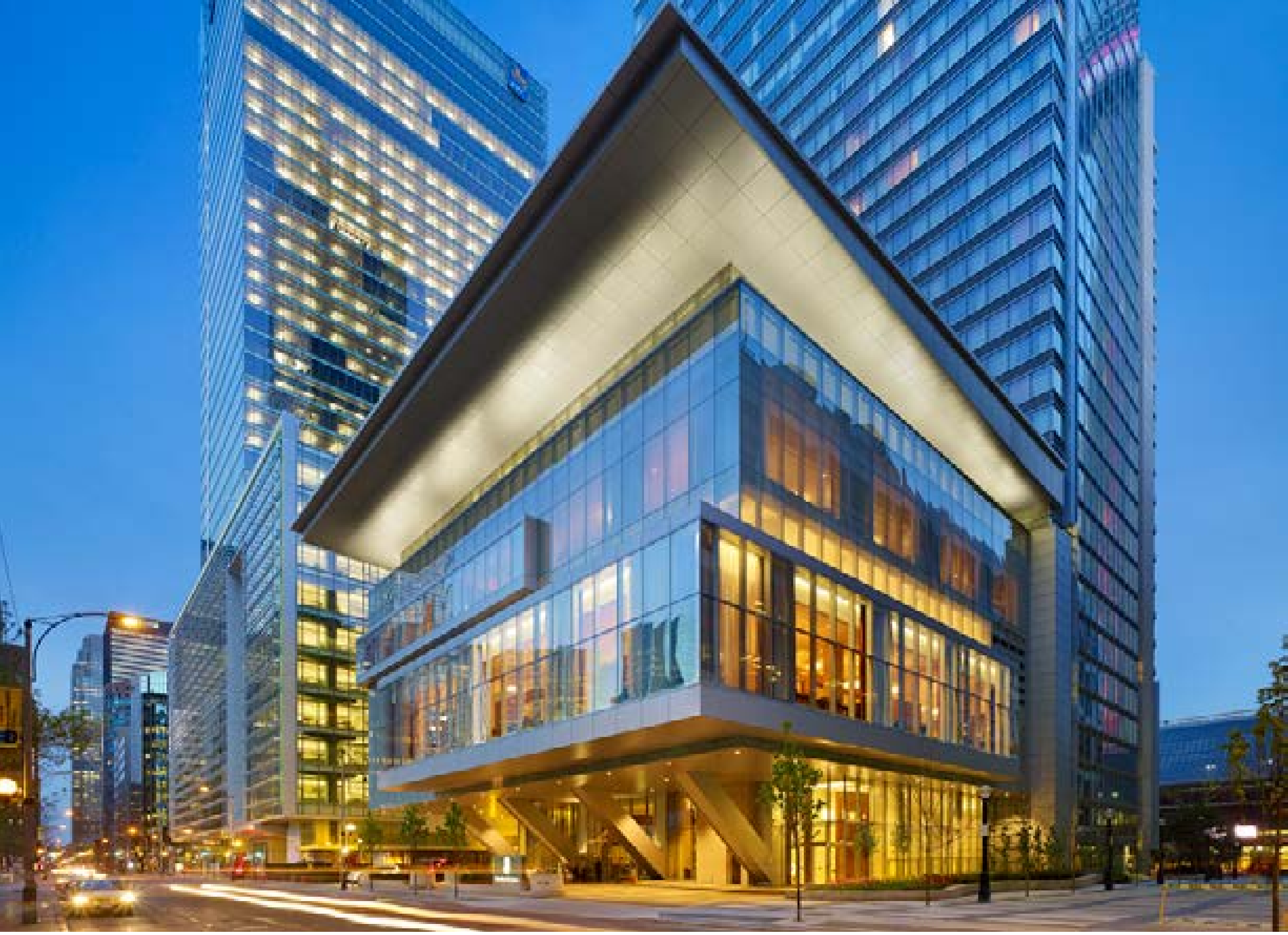

Vancouver is creating a vibrant urban community with creative architecture and buildings. But to really push the boundaries, it is time to rethink the approach to building and vibration. Vibration management can no longer be an afterthought and instead needs to move to the early stages of design. The belief that vibration performance can always be handled by a structural engineer is a mistake.
As buildings evolve, dynamic vibration analysis and understanding requires a specialized skill set. Acoustical engineers have the expertise to ensure vibration is not an issue after the doors open. This key measurement cannot be left to fall through the cracks.

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1 CONNECTING INNOVATION WITH VIBRATION

From heritage building revitalization to new public transit stations to skyscraper growth, Vancouver and the surrounding areas are leaders in innovative architecture and building. They are also trailblazing mass timber structures and continue to push barriers in development and construction.

However, the drive to build creatively can result in new challenges. As structures get taller and lighter, vibration propagation within a structure becomes a greater concern. Vibrations in buildings are usually felt between 0.5 Hz and 80 Hz. A building with a steel floor and concrete deck usually has a natural frequency between 3 Hz and 10 Hz. A single individual walking across a floor with a low natural frequency around 3 to 5 Hz can easily excite this floor to a point where it can create discomfort for others. Mass timber buildings can also experience vibration issues because of a lower mass and the stiffness of the floors.

Dynamic vibration from human activities such as footfalls and rhythmic activities are considerations, as are rail, transit and road vibrations. Long-span floors, tall buildings and mass timber structures are exciting options but they drive a need for more focus on vibration since they are more prone to experiencing vibration concerns than other structures. If you add in variables like fitness classes or dancing in banquet halls, dynamic vibration becomes even more of an issue. When activity such as this occurs and lines up with the natural frequency of the structure, resonance can be experienced where the vibration levels can get amplified and become perceptible and concerning.

2 RETHINKING VIBRATION MANAGEMENT

Buildings that use vibration-sensitive equipment such as MRIs, CT scanners and microscopes, and equipment for microscopic surgery, are particularly vulnerable because they require extremely low floor vibrations to function.

But in many cases, vibration is not initially considered in the design. Many clients will assume that the vibration environment of the building is acceptable - in many cases, without any evidence - or that the structural engineer will provide a design that meets vibration requirements. However, structural engineers may not have sufficient vibration expertise in non-standard situations to provide the best guidance. Structural engineers are required to design the building to ensure seismic conditions are satisfied, and that from a static perspective, the structure can sustain typical vibration levels from occupants as required by building code requirements.

2 RETHINKING VIBRATION MANAGEMENT

As buildings in Vancouver continue to push the envelope, ignoring dynamic vibration impact could be costly. It is necessary to analyze, assess and provide design recommendations to ensure vibrations are managed appropriately.

Trying to fix vibration issues after a building is constructed is expensive. There are significant benefits to using an expert in the early stages to design and model the vibration impact on the floors and building.

Dynamic vibration takes a special skill set to understand, as modeling a structure's response to vibration is key to assessing potential issues.

Without a proper assessment, there is a risk of overdesigning the structure, which not only impacts costs but reduces the sustainability of a building.

A vibration expert will review the impacts of human activity to assess how it excites the structure. For example, banquet halls usually offer a large space to accommodate a group of people. But when dancers excite the natural frequency of the dance floor, that floor can feel like a trampoline. This is not comfortable for users. This is why vibration also needs to be considered in auditoriums, stadiums, and convention centres where other rhythmic activities can happen. There are standards and codes that recommend approaches or provide recommend approaches and limits to vibration levels that are created by this type of activity.

Human activity is only part of the issue. External factors can also add to the vibration equation. For example, a railway can cause a very low frequency propagation into a structure with sensitive uses. So, looking at vibration only in a structure can miss key elements influencing the building from outside.

3 SOLVING THE VIBRATION CHALLENGE

As part of the design process, vibration analysis and prediction are relatively straightforward when conducted by specialists. It includes three steps:

Identifying Potential Issues: This could either involve modelling known sources of vibration in the building or measuring environmental vibration levels that exist near the building.

Modelling the Structure: This modelling would make use of finite element analysis to review a structure's natural frequency and then predict its responses to human activity or external vibration inputs nearby.

Developing Design Recommendations: If the vibration levels exceed the specified limits, get recommendations on how to address the issues. This could include structural modifications or design recommendations for vibration isolation systems and/or tuned mass damper designs.

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4 IDENTIFYING POTENTIAL ISSUES

At the early stages of a project, knowing the vibration threats is an essential component in sizing the problem. If there is a source of the vibration and it is part of the building design, specifications of the equipment and its operations can be used to quantify the vibration input into the building. If the source of the vibration is expected to be human activity such as in the case of walking next to an MRI or microscope, or rhythmic dancing in the case of a long span floor, there are some standards that can be used to identify the vibrational input into the structure. It should be noted, however, that some of the assumptions in standard texts can be overly conservative, and a detailed understanding of the actual vibration inputs would require knowledge and experience to get it right.

For existing sources of external vibration, detailed measurements can often work well in quantifying the vibration source, and the behavior of vibration paths within the source receiver soil path. Measurement methodologies range from direct measurements of rail-based sources such as freight, subway, LRT on the surface, in tunnels, or directly on rail inverts where applicable. They could also include direct measurements in bore holes drilled to get contact with multiple layers of soil and measure the soil propagation properties of the vibration. Testing can also be carried out in the case of a future vibration sources such as a planned transit line. In this case, measurements would involve using a known vibration impulse source to send vibration impulses through the soil and measure at various locations and depths. This would allow for the determination of the vibration transfer characteristics between the future line and the subject property and enable the modelling of vibration impacts from the line.

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5 DEVELOPING DESIGN RECOMMENDATIONS

Once modelling the structure is complete and the inputs of the vibration are modelled, vibration isolation strategies can be developed. While there are a few methods of reducing vibration onto a target surface, at a fundamental level, the interventions seek to achieve a mismatch between the medium that the vibration is travelling through and the one that needs to be isolated. There are examples of this phenomenon in nature as well. When light transitions between air and water, some of that light bounces back up and a certain amount transitions into the water. This is what gives water the appearance of a mirror in scenic photos! Another example is the Hula Hoop: if the vibration of your hips doesn't match the natural frequency of the Hoop, the energy is not transferred and the Hula Hoop falls to the ground to the dismay of the user. The same is true for vibrational waves, where a mismatch in wave speed, natural frequency, and mass can cause portions of the vibrational waves to reflect back and not transmit into the area of interest. This is the fundamental reason spring isolators (i.e. mismatch in natural frequency) are used to reduce vibration from mechanical equipment, and localized slab thickening is often used for reducing vibration levels on MRIs in hospitals (i.e. mismatch in mass and stiffness).

There are design recommendations that can be easily incorporated into the process if they are assessed early on in a project. This could include modifying the structure to change the natural frequency by changing the mass and/or stiffness of the structure. Another potential option would be developing isolation systems for equipment or a tuned mass damper for the structure itself. In any situation, running a vibration assessment on the structure with a specialist can often provide good insight early and reduce trouble for the project later.

ABOUT AERCOUSTICS

Aercoustics Engineering Limited is an acoustics, noise, and vibration consulting engineering firm. We are a trusted provider of specialized services that covers a variety of sectors. We have delivered a multitude of successful and cost-effective medical treatment facilities across Canada and the United States. Our large and technically diverse team, including our new Vancouver office, is not only capable of punctually accomplishing the proposed scope of work, but eager to meet and surpass the work standards of the client.

The success of these spaces depends on a fully integrated design approach. By working closely with the architectural, structural and construction teams, we can bring life to thoughtful, pragmatic solution that can meet the needs of this project. For more information, please visit www.aercoustics.com or contact one of our team members below.

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