Acoustics and Mass Timber: Room-to-Room Noise Control

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Photo: Corey Gaffer courtesy Perkins + Will

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The growing availability and code acceptance of mass timber—i.e., large solid wood panel products such as cross-laminated timber (CLT) and nail-laminated timber (NLT)—for floor, wall and roof construction has given designers a low-carbon alternative to steel, concrete, and masonry for many applications. However, the use of mass timber in multi-family and commercial buildings presents unique acoustic challenges.

While laboratory measurements of the impact and airborne sound isolation of traditional building assemblies such as light wood-frame, steel and concrete are widely available, fewer resources exist that quantify the acoustic performance of mass timber assemblies. Additionally, one of the most desired aspects of mass timber construction is the ability to leave a building's structure exposed as finish, which creates the need for asymmetric assemblies. With careful design and detailing, mass timber buildings can meet the acoustic performance expectations of most building types.

Emphasizing room-to-room noise control, this paper covers key aspects of mass timber acoustical design, including rules of thumb for optimal design, common assemblies and where to find them, detailing strategies, and options for eliminating flanking paths. It is not intended to be an exhaustive review of building code requirements and principles of acoustics design. Several existing resources, such as the WoodWorks publication, *Acoustical Consideration for Mixed-Use Wood-Frame Buildings,* the *US CLT Handbook,*[1] and the *Nail-Laminated Timber: US Design and Construction Guide,*[2] discuss particulars of acoustical design in wood-frame structures and considerations associated with a variety of mass timber panel options.

Basics of Acoustics and Code Requirements

Section 1206 of the 2018 International Building Code (IBC) lists requirements for acoustical performance of walls, partitions and floor/ceiling assemblies in multi-family buildings. These assemblies, which separate one dwelling unit from another or from public areas, must have a sound transmission class (STC) rating of 50 and, in the case of floor/ceiling assemblies, an impact insulation class (IIC) rating of 50. (These ratings can be reduced to 45 when field tested.) Note that these code requirements only apply to multi-family construction. Although guidelines related to acoustical performance in occupancies such as offices, schools and hospitals[3] do exist, they are not requirements under the IBC.

STC measures how effectively a wall or floor/ceiling assembly isolates airborne sound and reduces the level that passes from one side to the other. Examples of airborne sound include conversation and music. IIC measures how effectively a floor/ceiling assembly blocks impact sound from passing through a floor/ceiling and only applies to those assemblies. Examples of impact sound include foot falls and a book dropping on the floor.

Unique Mass Timber Acoustics Considerations

Bare mass timber floor/ceiling or wall assemblies are seldom used, in large part due to inadequate acoustical performance. For example, a 5-ply CLT floor with a thickness of 6.875" has an STC rating of 41 and an IIC rating of 25.[4] As such, components are typically added to mass timber assemblies to improve their acoustics. See Table 1 for acoustical properties of bare mass timber panels.

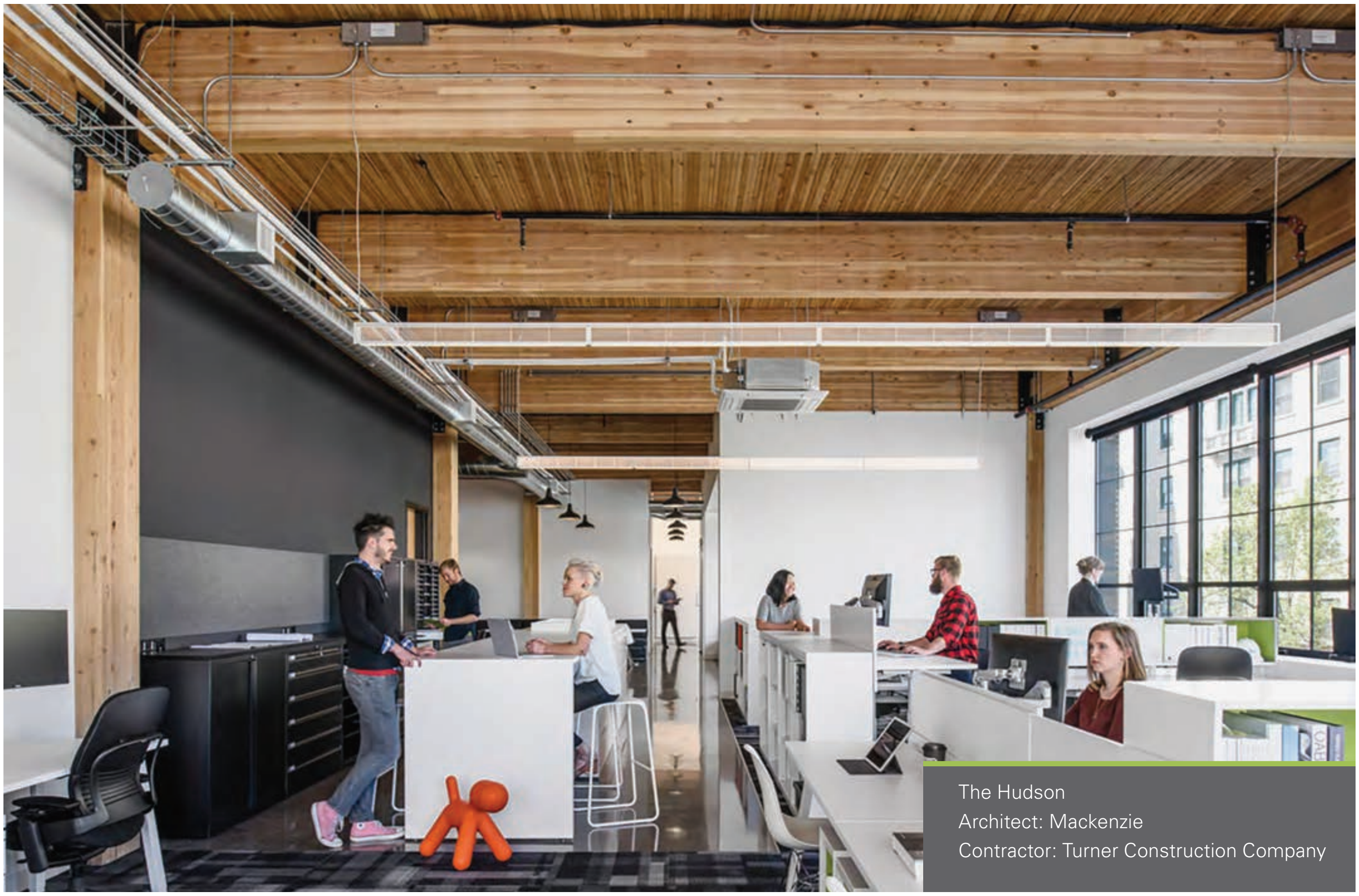
In floor/ceiling applications, owners and design teams often want to expose the ceiling side of mass timber panels for aesthetic reasons, which means that any acoustical components must be installed on top of the assembly. This is one of the main acoustical design distinctions between light wood-frame floor/ceiling assemblies and mass timber floor/ceiling assemblies. In light-frame construction, acoustical components are typically included above, within and below the assembly—e.g., underlayment and/or concrete topping above the framing, batt insulation within the depth of the framing, and resilient channels and gypsum ceiling board underneath.

TABLE 1:

Examples of Acoustically-Tested Mass Timber Panels

Mass Timber Panel	Thickness	STC Rating	IIC Rating
3-ply CLT wall[4]	3.07"	33	N/A
5-ply CLT wall[4]	6.875"	38	N/A
5-ply CLT floor[5]	5.1875"	39	22
5-ply CLT floor[4]	6.875"	41	25
7-ply CLT floor[4]	9.65"	44	30
2x4 NLT wall[6]	3-1/2" bare NLT 4-1/4" with 3/4" plywood	24 bare NLT 29 with 3/4" plywood	N/A
2x6 NLT wall[6]	5-1/2" bare NLT 6-1/4" with 3/4" plywood	22 bare NLT 31 with 3/4" plywood	N/A
2x6 NLT floor + 1/2" plywood[2]	6" with 1/2" plywood	34	33

Source: Inventory of Acoustically-Tested Mass Timber Assemblies, WoodWorks[7]



The Hudson
Architect: Mackenzie
Contractor: Turner Construction Company

Photo: Christian Colombres

There are three main ways to improve an assembly's acoustical performance:

1. Add mass
2. Add noise barriers
3. Add decouplers

One of the characteristics of mass timber is that it has a high strength-to-weight ratio; therefore, when compared to other panel and slab-type construction materials, it weighs significantly less. This reduces building mass, which is beneficial in terms of lower seismic forces, smaller foundation requirements, and soil improvement measures such as pilings or piers. However, with acoustics, more mass typically means better noise control. For comparison, a typical 6"-thick concrete slab weighs approximately 80 pounds per square foot (psf) and has an STC rating of 53[8] while a ~7"-thick CLT panel weighs about 18 psf[9] and has an STC of 41.[4] Due to the lack of mass inherent in the mass timber panel, a common way to improve acoustical performance is to add a poured concrete or gypsum-based topping layer, usually in the range of 1-3" thick.

Concrete floor topping

Photo: Maxxon Corporation

Decouplers are products that decouple, or break direct connections between, finishes on one side of an assembly and the other. This reduces the amount of noise that can directly travel through finish to structure to finish. Common examples in light wood-frame construction include resilient channels and air spaces. In mass timber floor/ceiling systems, the most common decoupling products are underlayments and mats placed between the mass timber panel and concrete or gypsum-based topping. The type and thickness of material varies by product line and manufacturer, but the purpose is the same: to break the direct connection between structure/ceiling finish (the mass timber panel) and the top side finish (topping and/or finish floor). Below are several examples of underlayment products.

Although it is common to add noise barriers within light wood-frame assemblies (e.g., batt insulation in a floor cavity), this method is much less common in mass timber floor/ceiling assemblies. That said, several acoustically-tested mass timber floor assemblies include wood sleepers on top of the panels and noise barriers such as sand or batt insulation between the sleepers. See Figure 1.

Acoustical floor underlayments

Photo: AcoustiTECH [10]

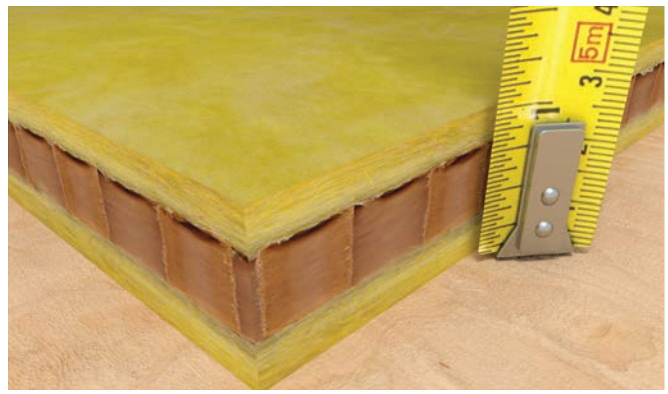


Photo: Kinetics Noise Control, Inc., [11]

Photo: Maxxon Corporation

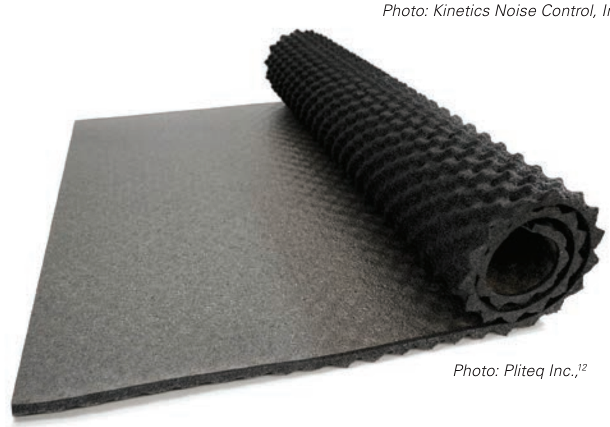
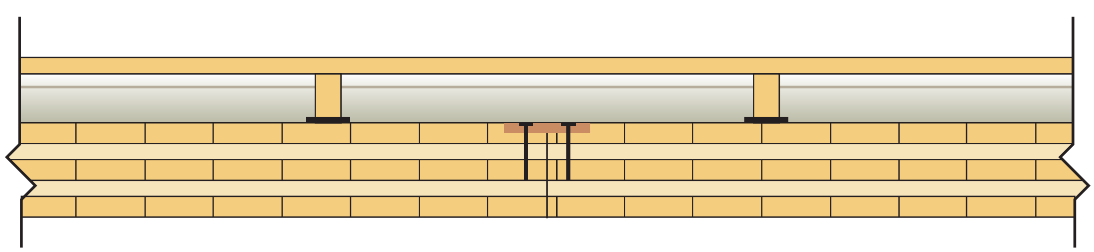


Photo: Pliteq Inc., [12]

FIGURE 1:
CLT floor assembly with wood sleepers and sand topping



Source: Regupol

Mass Timber Assembly Options: Floors

Using the design principles discussed, a common mass timber floor/ceiling assembly includes the following (from top to bottom):

- Finish flooring (if applicable)
- Concrete/gypsum-based topping (usually 1-3" thick)
- Acoustical mat/underlayment
- Mass timber panel

Using a common 5-ply CLT floor panel, STC ratings in the range of 50-59 have been achieved for this common assembly build-up. IIC ratings are greatly influenced by the presence and type of finish flooring. For this build-up with no finish floor (i.e., concrete topping is the exposed floor surface), IIC ratings in the range of 35-60 have been achieved. When finish flooring is added, including luxury vinyl tile, engineered wood flooring, ceramic tile and carpet and pad underlayment, IIC ratings of 60+ have been achieved. Acoustical tests have been completed on variations of this assembly, with the primary variables being the specific acoustical mat product and thickness, and type of poured topping. Tests have also been completed on a number of alternatives, including options that don't involve a poured topping layer. To help designers compare options, WoodWorks has compiled a web-based Inventory of Acoustically-Tested Mass Timber Assemblies, which includes their STC and ICC ratings, plus links to the associated test reports. The inventory is updated as new tests are completed, and can be found at http://bit.ly/mass-timber-assemblies.

Albina Yard
Architect: LEVER Architecture
Structural Engineer: KPFF Consulting Engineers

Photo: LEVER Architecture

Where higher acoustical ratings for floor/ceiling assemblies in mass timber structures are required, installing ceiling gypsum board, either directly attached to the underside of the mass timber panel or hung from resilient channels or similar resilient clip systems, is a viable approach. Although this does conceal the mass timber panel from view, covering all or some of the panels may already be necessary to conceal MEP services and/or the covering material may be part of the floor assembly's fire resistance. Tested floor/ceiling assemblies with applied ceiling and resilient channel/clip systems are included in the inventory noted above.

FIGURE 2:
Mass timber panel

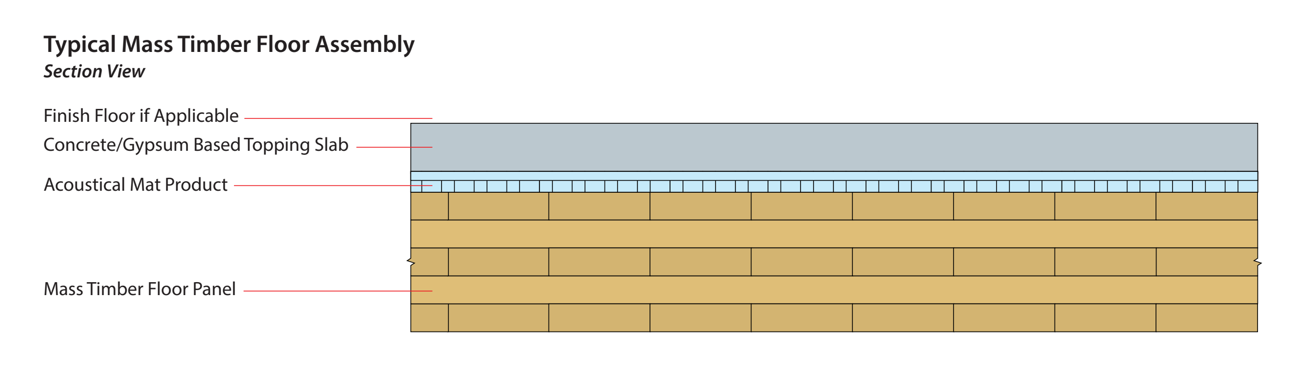
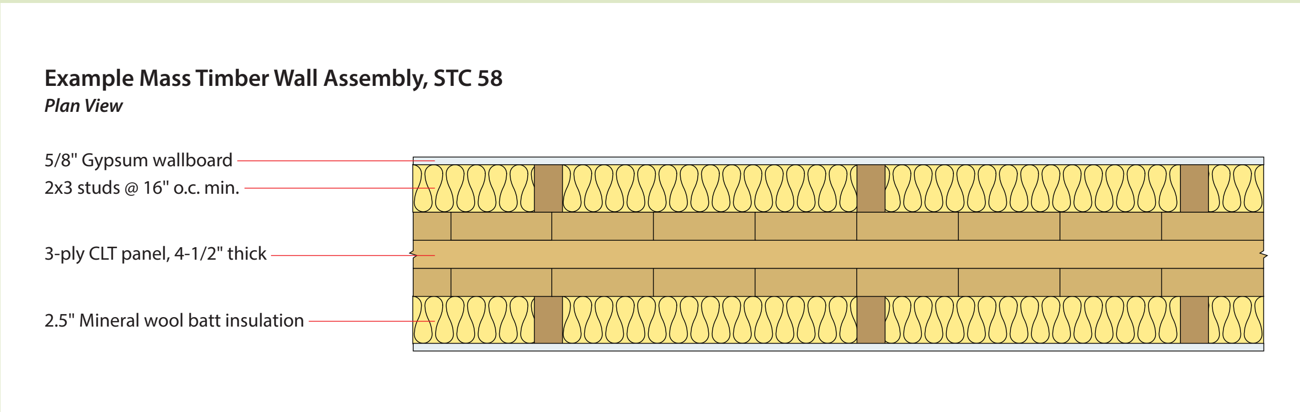


FIGURE 3:
Interior CLT partition wall with chase walls on both sides



Source: US CLT Handbook

Mass Timber Assembly Options: Walls

Mass timber panels can also be used for interior and exterior walls—both bearing and non-bearing. For interior walls, the need to conceal services such as electrical and plumbing is an added consideration. Common approaches include building a chase wall in front of the mass timber wall or installing gypsum wallboard on resilient channels that are attached to the mass timber wall. As with bare mass timber floor panels, bare mass timber walls don't typically provide adequate noise control, and chase walls also function as acoustical improvements. For example, a 3-ply CLT wall panel with a thickness of 3.07" has an STC rating of 33.[4] In contrast, Figure 3 shows an interior CLT partition wall with chase walls on both sides. This assembly achieves an STC rating of 58, exceeding the IBC's acoustical requirements for multi-family construction. Other examples are included in the inventory of tested assemblies noted above.

Acoustical Differences between Mass Timber Panel Options

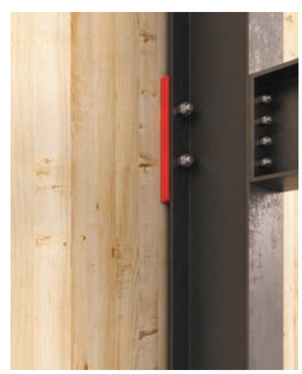
The majority of acoustically-tested mass timber assemblies include CLT. However, tests have also been done on other mass timber panel options such as NLT and dowel-laminated timber (DLT), as well as traditional heavy timber options such as tongue and groove decking. Most tests have concluded that CLT acoustical performance is slightly better than that of other mass timber options, largely because the cross-orientation of laminations in a CLT panel limits sound flanking.

For those interested in comparing similar assemblies and mass timber panel types and thicknesses, the inventory noted above contains tested assemblies using CLT, NLT, glued-laminated timber panels (GLT), and tongue and groove decking.

Improving Performance by Minimizing Flanking

Even when the assemblies in a building are carefully designed and installed for high acoustical performance, consideration of flanking paths—in areas such as assembly intersections, beam-to-column/wall connections, and MEP penetrations—is necessary for a building to meet overall acoustical performance objectives.

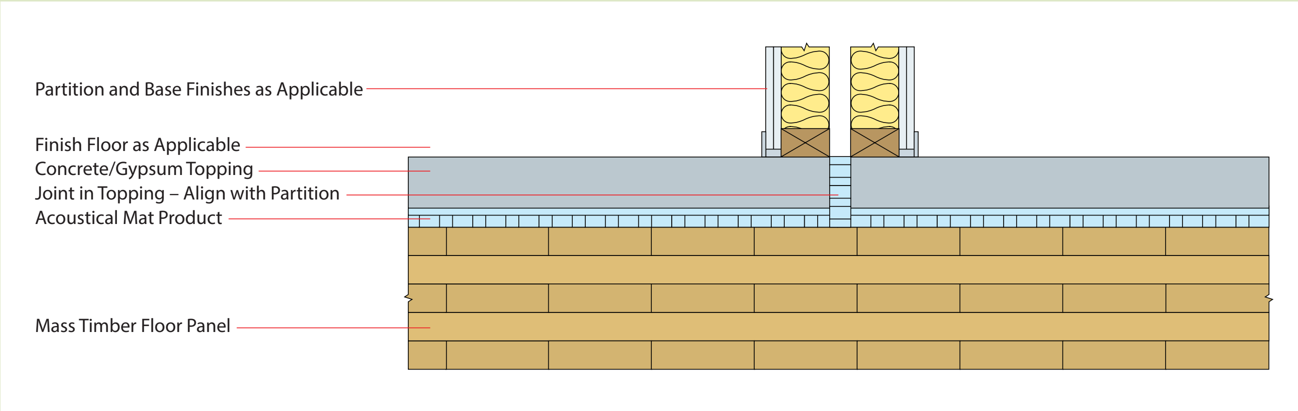
One way to minimize flanking paths at these connections and interfaces is to use resilient connection isolation and sealant strips. These products are capable of resisting structural loads in compression between structural members and connections while providing isolation and breaking hard, direct connections between members. In the context of the three methods for improving acoustical performance noted above, these strips act as decouplers. With airtight connections, interfaces and penetrations, there is a much greater chance that the acoustic performance of a mass timber building will meet expectations.



Acoustical isolation strips

Photos: Rothoblaas

FIGURE 4:
Flanking control detail at floor/wall interface



In multi-family mass timber buildings, where numerous interior partitions exist, there are several detailing and panel layout techniques for minimizing flanking. As noted, a poured topping is common on mass timber floor panels. Breaking the topping at unit separation walls, as illustrated in Figure 4, can help minimize the ability of sound to travel through the topping from one unit to the next. Where further noise control is required, an additional step is to break the mass timber floor panels at each unit wall (if these walls are also bearing locations). While this can be an effective means of enhancing acoustical performance, such a panel layout can create inefficiencies in the manufacturing and erection processes. As such, this approach should be discussed with the manufacturer and installer to evaluate the cost-benefit trade-offs.

Interior partitions in a four-story CLT hotel

Photo: Lendlease

Conclusion

Designing a building for noise control has a tremendous impact on the overall satisfaction of tenants. Laboratory and field tests have already shown that mass timber assemblies can provide satisfactory sound insulation—and this is contributing to the use of mass timber for more projects. A greater number of buildings will generate more knowledge and lead to more field testing, and the result will be an expanding inventory of cost-efficient assemblies and details that perform well acoustically.

Mass timber buildings are unique in that designers often try to maximize the visibility of structural members. This creates the need for unique solutions to address noise control. With appropriate attention to detail in the design and construction of assemblies, as well as consideration of flanking paths and sound isolation in connections and penetrations, mass timber buildings can deliver acoustic high performance.

End Notes:

1. *US CLT Handbook,* www.thinkwood.com/products-and-systems/clt-handbook
2. *Nail-Laminated Timber: US Design & Construction Guide,* v1.0, www.thinkwood.com/products-and-systems/nltguide
3. American Hospital Association (for healthcare facilities); ANSI S12.60 (for K-12 schools); Department of Housing and Urban Development (for multi-family housing); General Services Administration (for federal courthouses and office buildings)
4. *Acoustics Summary: Sound Insulation in Mid-rise Wood Building,* National Research Council Canada, https://nparc.nrc-cnrc.gc.ca/eng/view/fulltext/?id=0dd15eec-b02e-4fb5-b8c6-aca331051d1d
5. *Acoustic Testing of CLT and Glulam Floor Assemblies,* Nordic Engineered Wood Report No. A1-008253.1, National Research Council Canada www.regupol.com/test-reports/pdfs/A1-008253.pdf
6. *Addendum to RR-335: Sound Transmission through Nail-Laminated Timber (NLT) Assemblies,* National Research Council Canada, https://nparc.nrc-cnrc.gc.ca/eng/view/fulltext/?id=9e3b39be-e0ed-415b-9649-3e7ec228f52c
7. *Inventory of Acoustically-Tested Mass Timber Panels,* WoodWorks, http://bit.ly/mass-timber-assemblies
8. *Kinetics Noise Control Test Report #AT001049,* https://kineticsnoise.com/arch/tests/pdf/AT001049.pdf
9. *Nordic X-Lam Design Properties,* Nordic Structures, www.nordic.ca/data/files/datasheet/file/NS-NT601-US-ASD_Design_Properties_Nordic_X-Lam_2018-11-05.pdf
10. AcoustiTECH, a division of the Finitec Group: Sofix system + Soprema InsonoFloor underlayment
11. Ultra Quiet SR, Kinetics Noise Control, Inc.
12. GenieMat® FF, Pliteq Inc., Patents: US 8,240,430, US 8,556,029, CA 2,500,956 and CA 2,503,520