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## **Acoustics and Vibration in Mass Timber Structures: Design & Performance**

Photo: Kaiser+Path

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.



#### **Course Description**

In addition to visual appeal, the relative light weight of an exposed timber structure is a driving factor for the use of mass timber in many buildings. However, mass of structure has an impact on two design criteria that often dictate assembly thickness and floor build-up components: acoustics and vibration. This presentation will present design processes and resources available to designers to aid in the minimization of noise and vibration-related complaints in mass timber buildings. The first portion will review options for mass timber floor/ceiling and wall assemblies from a new inventory of acoustically-tested mass timber assemblies created by WoodWorks. Vibration design parameters and strategies will then be discussed, followed by a preview of a document in development that will provide designers with a complete set of vibration design methods and examples.

#### Learning Objectives

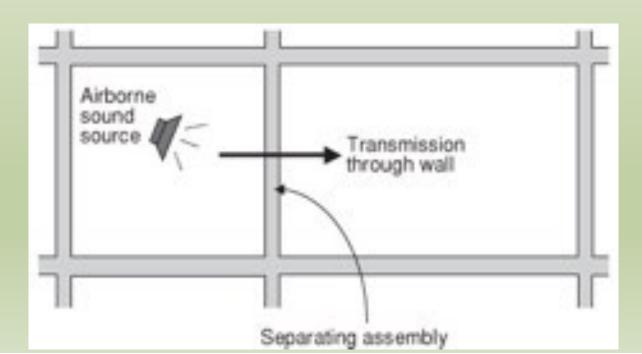
- 1. Highlight the fundamental differences between mass timber and other construction materials in terms of their acoustical performance.
- 2. Review acoustically-tested mass timber assemblies and resources available to designers.
- 3. Review floor vibration design parameters through a systems rather than product-based approach.
- 4. Demonstrate methods of designing mass timber floors for vibration and highlight appropriate design methods for different system characteristics.

## Acoustical Design

#### **Air-Borne Sound:**

#### **Sound Transmission Class (STC)**

- Measures how effectively an assembly isolates air-borne sound and reduces the level that passes from one side to the other
- Applies to walls and floor/ceiling assemblies



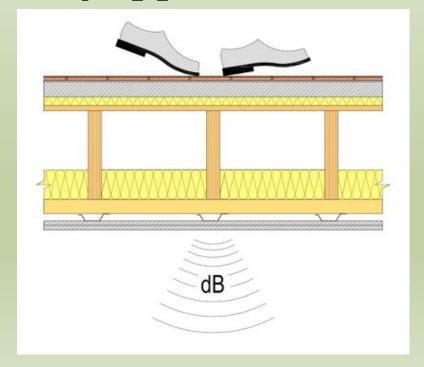


## Acoustical Design

#### **Structure-borne sound:**

#### **Impact Insulation Class (IIC)**

- Evaluates how effectively an assembly blocks impact sound from passing through it
- Only applies to floor/ceiling assemblies





# Acoustical Criteria IBC 1207

Code requirements only address residential occupancies:

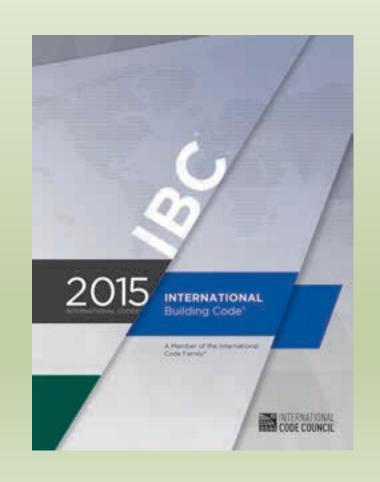
For unit to unit or unit to public or service areas:

#### Min. STC of 50 (45 if field tested):

 Walls, Partitions, and Floor/Ceiling Assemblies

#### Min. IIC of 50 (45 if field tested) for:

Floor/Ceiling Assemblies

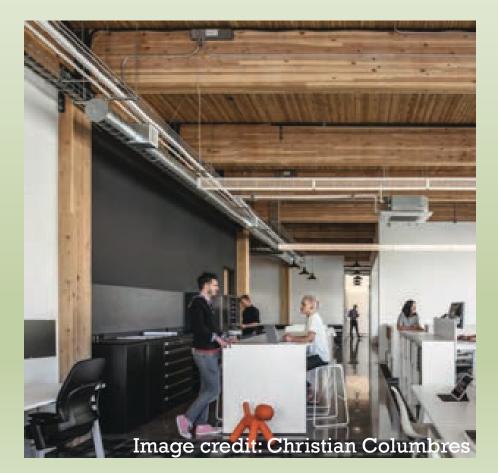


## Acoustical Criteria

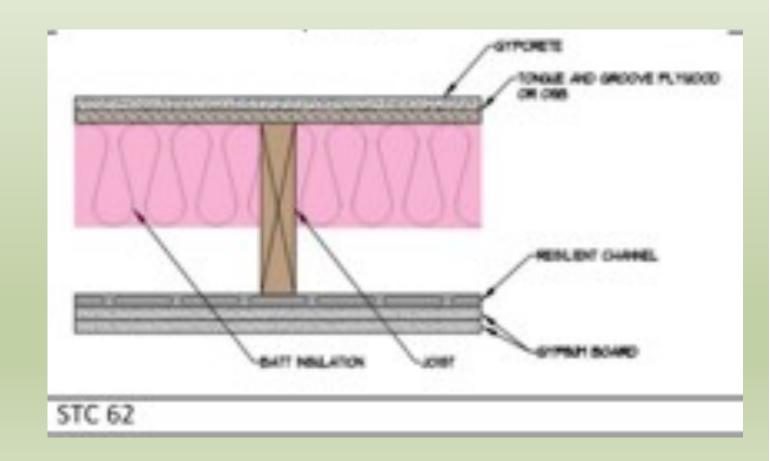
STC	What can be heard
25	Normal speech can be understood quite easily and distinctly through wall
30	Loud speech can be understood fairly well, normal speech heard but not understood
35	Loud speech audible but not intelligible
40	Onset of "privacy"
42	Loud speech audible as a murmur
45	Loud speech not audible; 90% of statistical population not annoyed
50	Very loud sounds such as musical instruments or a stereo can be faintly heard; 99% of population not annoyed.
60+	Superior soundproofing; most sounds inaudible

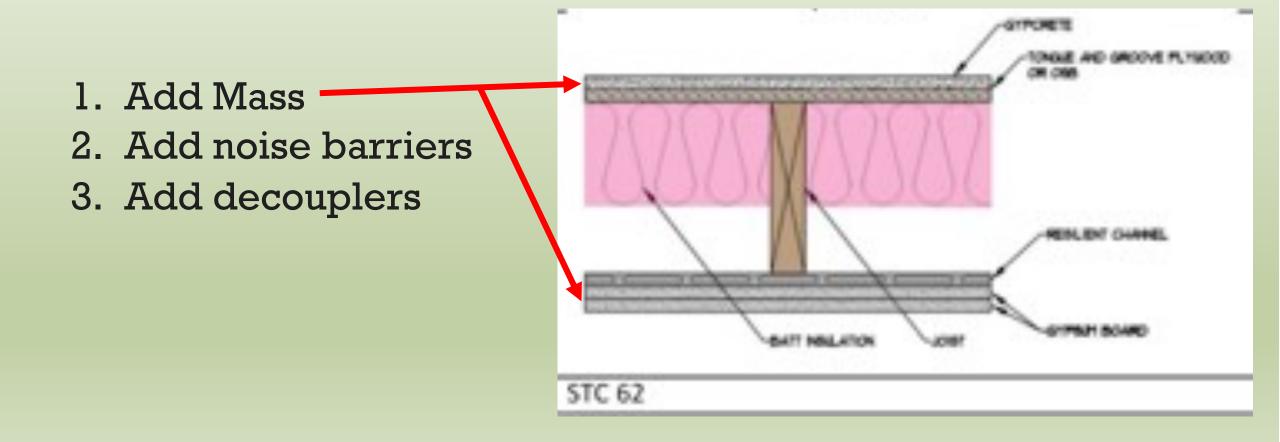
Regardless of the structural materials used in a wall or floor ceiling assembly, there are 3 effective methods of improving acoustical performance:

- 1. Add Mass
- 2. Add noise barriers
- 3. Add decouplers

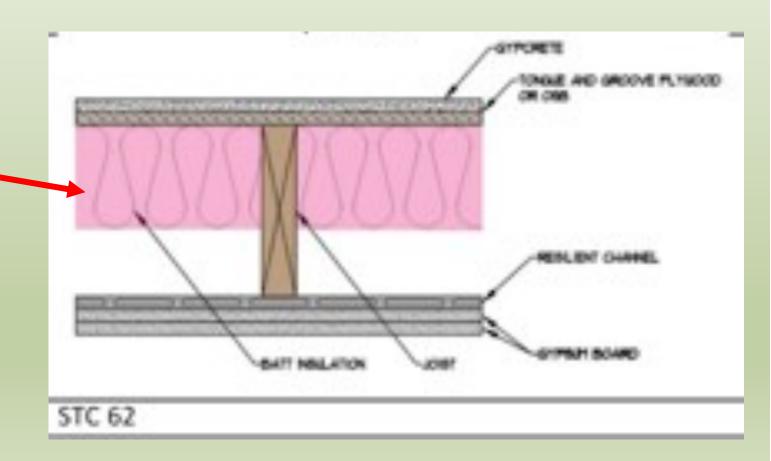


- 1. Add Mass
- 2. Add noise barriers
- 3. Add decouplers

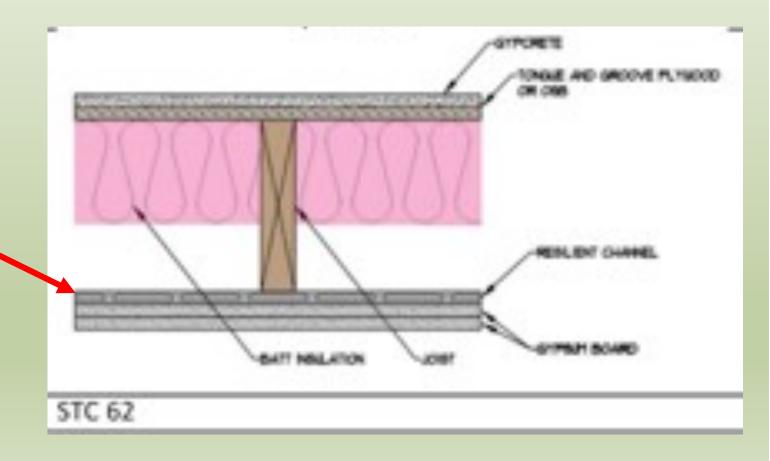




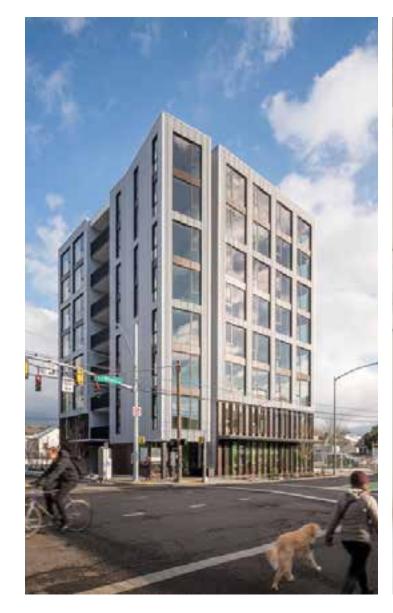
- 1. Add Mass
- 2. Add noise barriers
- 3. Add decouplers



- 1. Add Mass
- 2. Add noise barriers
- 3. Add decouplers



### Mass Timber: Structure Often is Finish







Photos: Baumberger Studio/PATH Architecture/Marcus Kauffman | Architecture

## But by Itself, Not Adequate for Acoustics





TABLE 1: Examples of Acoustically-Tested Mass Timber Panels

Mass Timber Panel	Thickness	STC Rating	IIC Rating
3-ply CLT wall <sup>4</sup>	3.07"	33	N/A
5-ply CLT wall <sup>4</sup>	6.875*	38	N/A
5-ply CLT floor <sup>5</sup>	5.1875*	39	22
5-ply CLT floor <sup>4</sup>	6.875*	41	25
7-ply CLT floor4	9.65"	44	30
2x4 NLT wall <sup>6</sup>	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 <sup>6</sup>	5-1/2" bare NLT 6-1/4" with 3/4" plywood	22 bare NLT 31 with 3/4" plywood	N/A
x6 NLT floor + 1/2" plywood?	6" with 1/2" plywood	34	33

Source: Inventory of Acoustically-Tested Mass Timber Assemblies, WoodWorks7

# One of the main reasons is "mass" Recall the three ways to increase acoustical performance:

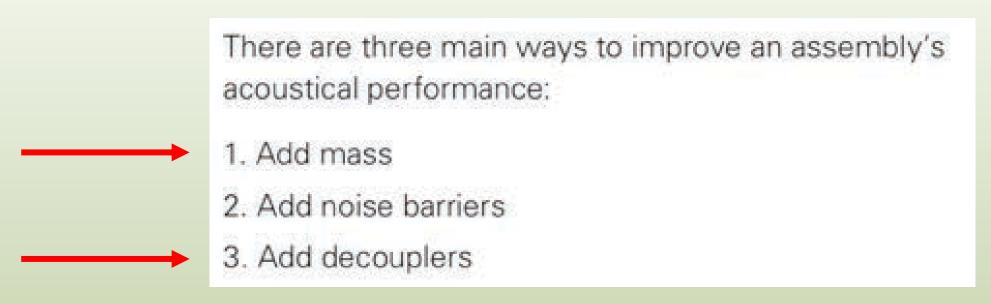
- 1. Add Mass
- 2. Add noise barriers
- 3. Add decouplers

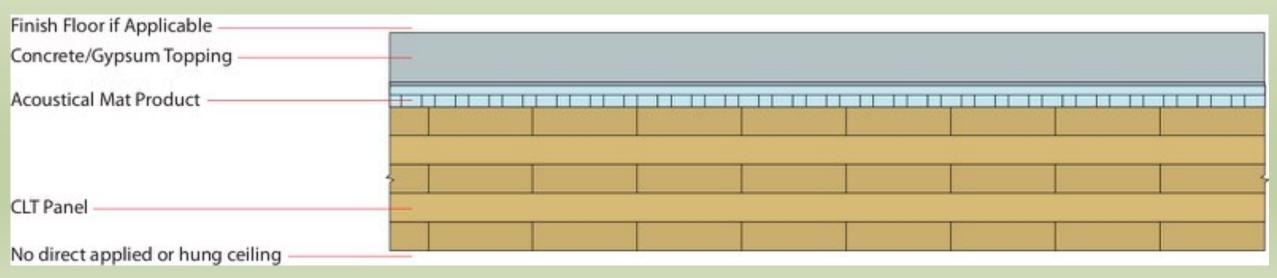












There are three main ways to improve an assembly's acoustical performance:

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

#### **Acoustical Mat:**

- Typically roll out or board products
- Thicknesses vary: Usually
   1/4 "to 1"+













# Common mass timber floor assembly:

- Finish floor (if applicable)
- Underlayment (if finish floor)
- 1.5" to 4" thick concrete/gypcrete topping
- Acoustical mat
- WSP (if applicable)
- Mass timber floor panels



#### Where can you find acoustically tested assemblies?

#### **CLT Floors in CLT Handbook**

End view of cross-section	Floor detail	FSTC	FIIC
	1 = Carpet, or floating flooring about 2/5" on 1/8" resilient underlayment of 0.16 to 0.37 lb./ft. <sup>2</sup> 2 = At least 5.12 lb./ft. <sup>2</sup> dry topping, e.g. 0.8-1" gypsum board, cement fibreboard 3 = Resilient underlayment, e.g. 2/5" rubber mat of 0.84 lb./ft. <sup>2</sup> , <sup>3</sup> / <sub>4</sub> " texture felt of 0.27 lb./ft. <sup>2</sup> , <sup>1</sup> / <sub>2</sub> " low density wood fibreboard of 0.73lb./ft. <sup>2</sup> 4 = 5-layer CLT of 6-7/8"	~45	~45
	- Replace the dry topping by wet topping, e.g. 1.5" concrete of at least 15.6 lb./ft. <sup>2</sup>	~50	~50







To Help Designers Navigate Options for Mass Timber Acoustically Tested Assemblies, WoodWorks Created 2 New Resources

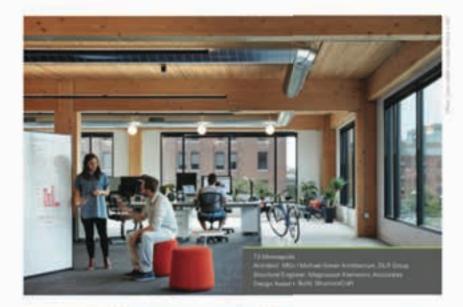
#### Solutions Paper

## Mass Timber Acoustics



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

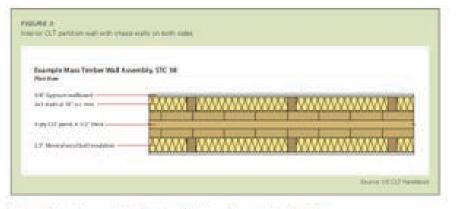
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The growing auxiliability and scote ecceptains of mass trotals—i.e., large bold input jamel products such as prosessment (mater (CLT) and rule terminated trotals 79.7)—for fision wall and soid constructor has given designent a law safters attenuation to Meet, converte, and massively for mass applications. His vivies, the sale of trade trotals in most family and commercial buildings presents unlocal about the history and commercial buildings presents unlocal about the history and commercial buildings presents unlocal

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http://www.woodworks.org/wp-content/uploads/wood\_solution\_paper-MASS-TIMBER-ACOUSTICS.pdf



#### Mass Timber Assembly Options: Walls

Measterder pateit can also be used for interior and extensi wate-hoth bearing and non-bearing. For intenor wate, the result to conceal services such as electrical and oturning. is an added consideration. Common approaches include: facilities a chase widt a front of the trace, timber wall or reduling oversion coefficient in resilient channels that are attached to the mass lowber well. As with time mass trober Noor pursels, have made further walls don't hypically provide: adequate noise control, and chara walk also function as accoption improvements, for example, a 3-pt- Q.T wall parel. with a thickness of 3.07" has an STC rating of 3.07 in colonial. Figure 3 shows at interest CLT partition wall with chase wells. no both sales. This assembly achieves an STC rating of SR. ancienting the IBC's accountrial requirements for multi-family. construction. Other married are installed in the eventury of finished assertation retail above.

#### Acoustical Differences between Mass Timber Panel Options

The majority of assuming hydrodist mass frester assumbtion include CLT. However, hearts have also been opine on other mass familiar pained options such as first, and donest temporal temporal (DLT), as well as tradelonial feasing times options such as targue and grower facilities, Mass facts have constituted that CLT acquists as performance in sightly better than that of other mass timber options, single because the price or western or facilities of contraction of familiations in a CLT panel limits sound flanking.

For those interested in companing similar assentitives and make similar panish types and thick/esseet, the inventory noted above contains tosted assentitive using CLT, NLT, global amounted timber panels (SLT), and kingue and grave declare).

#### Improving Performance by Minimizing Flanking

Even when the assembles in a building one painfully designed and ine talled for high according performance, consideration of familing paths—in areas such as assembly strengthestors—in necessary for a building to meet overall according to meet overall according to the formation of the country of the strength of the second o

One way to minimize fanting paths at these connections and interfaces in to use resident connection solidion and seasing struct. These products are consistent of recising structural basis or congression between structural intertibuts and connections while providing leadable, and basising hard, directions of between management, but the context of

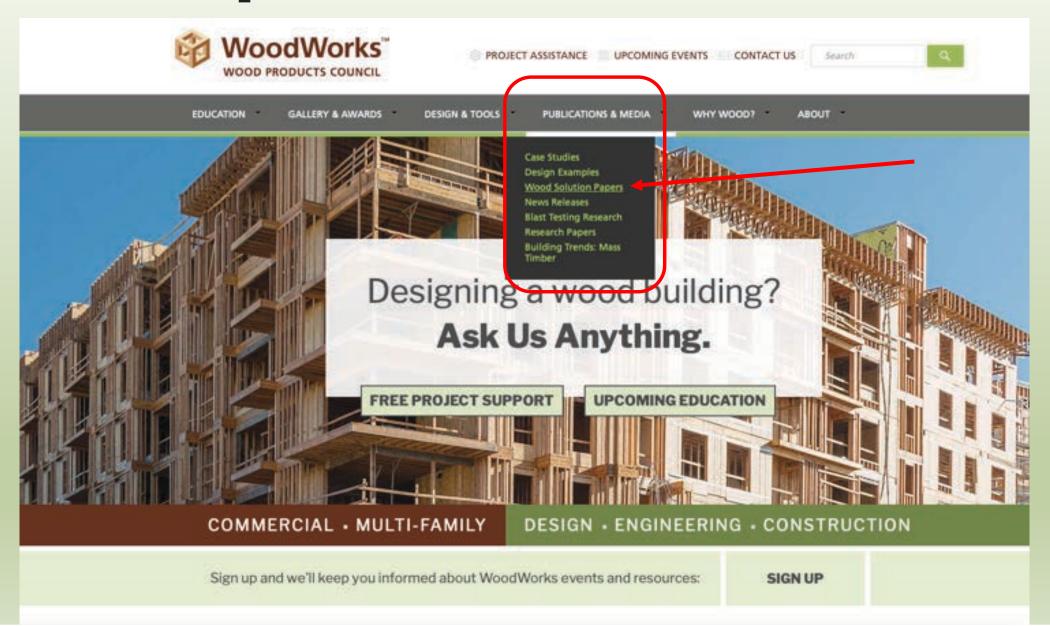
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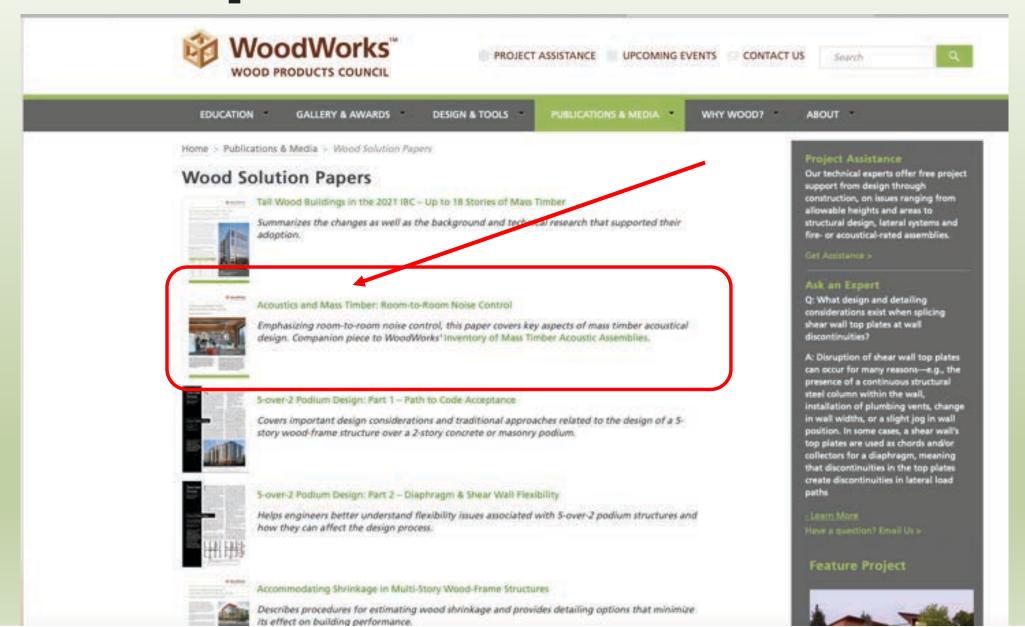
#### Solutions Paper

## Mass Timber Acoustics



#### Solutions Paper

## Mass Timber Acoustics



Inventory of Tested Assemblies

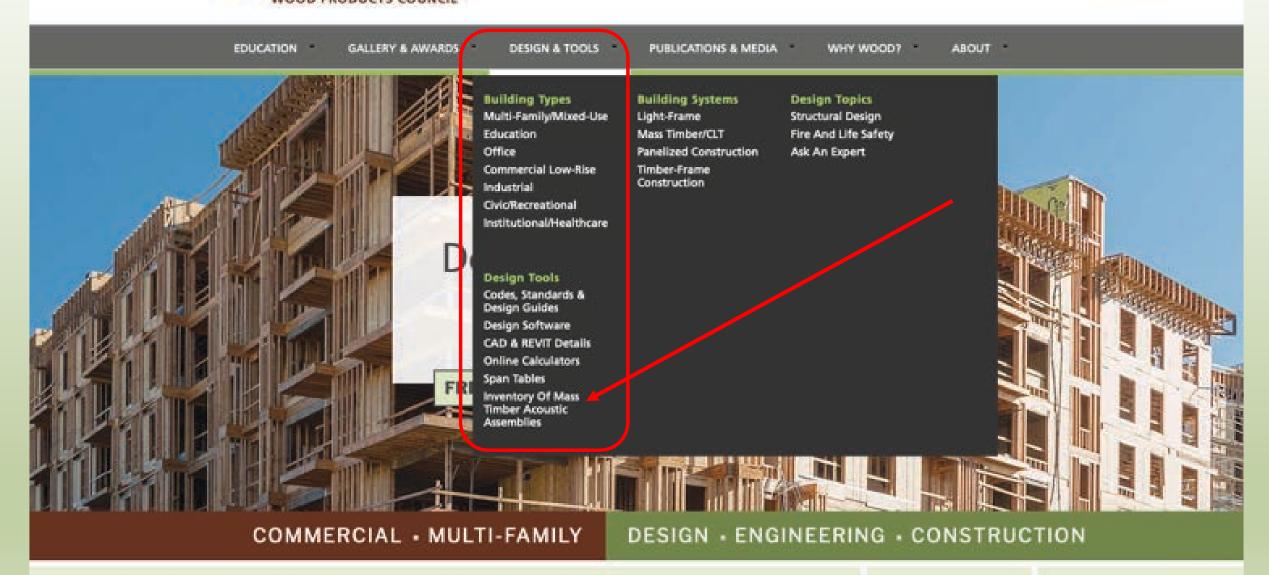


#### **Acoustically-Tested Mass Timber Assemblies**

Following is a list of mass timber assemblies that have been acoustically tested as of January 23, 2019. Sources are noted at the end of this document. For free technical assistance on any questions related to the acoustical design of mass timber assemblies, or free technical assistance related to any aspect of the design, engineering or construction of a commercial or multi-family wood building in the U.S., email help@woodworks.org or contact the WoodWorks Regional Director nearest you: http://www.woodworks.org/project-assistance

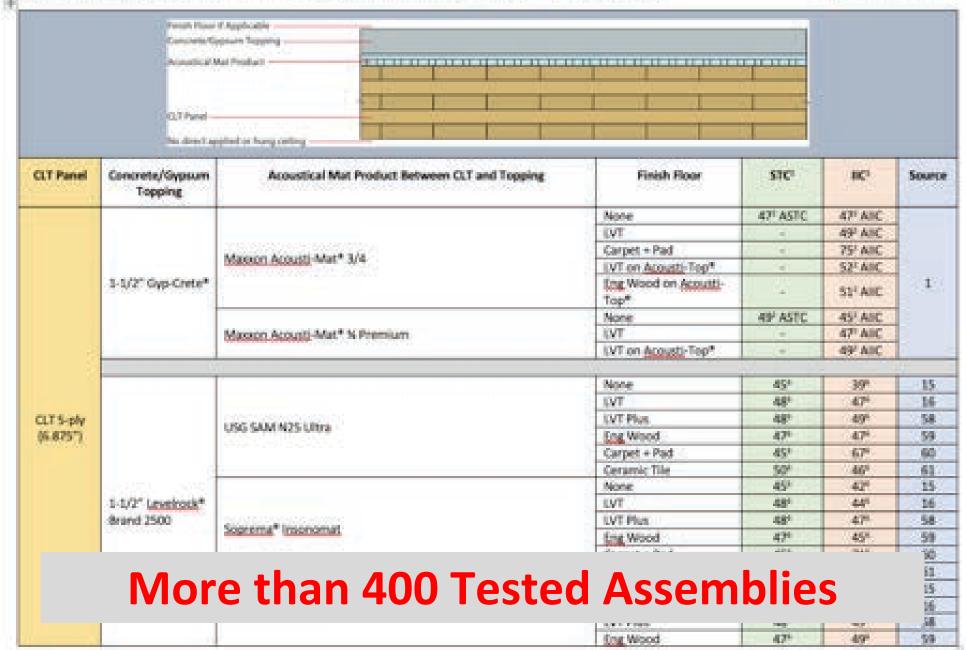
#### Contents:

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Table 2: CLT Floor Assemblies without Concrete/Gypsum Topping, Ceiling Side Exposed	
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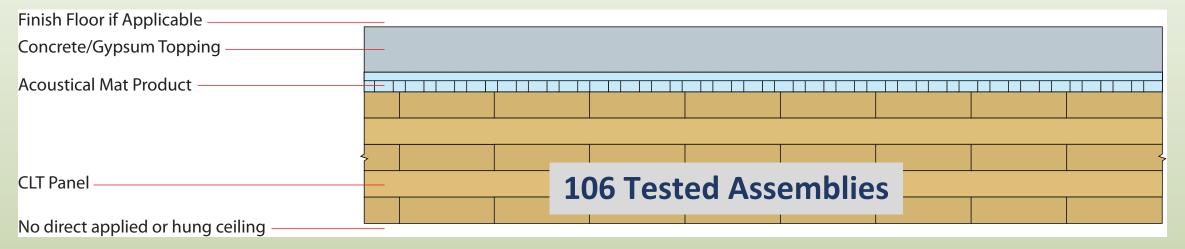


#### Table 1: CLT Floor Assemblies with Concrete/Gypsum Topping, Ceiling Side Exposed





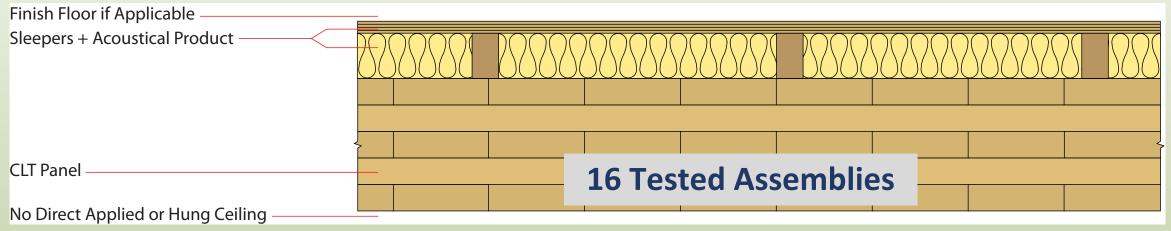
#### Table 1: CLT Floor Assemblies with Concrete/Gypsum Topping, Ceiling Side Exposed



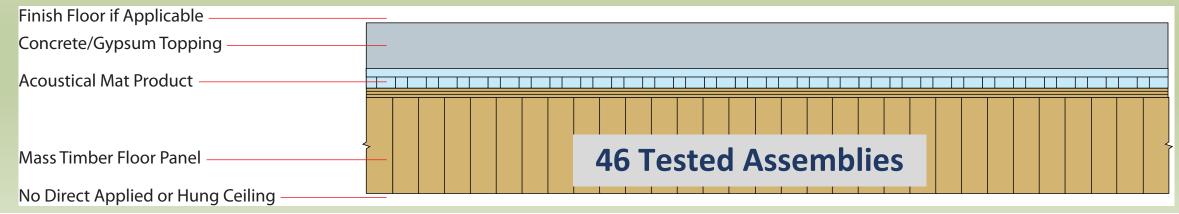
#### Table 2: CLT Floor Assemblies without Concrete/Gypsum Topping, Ceiling Side Exposed



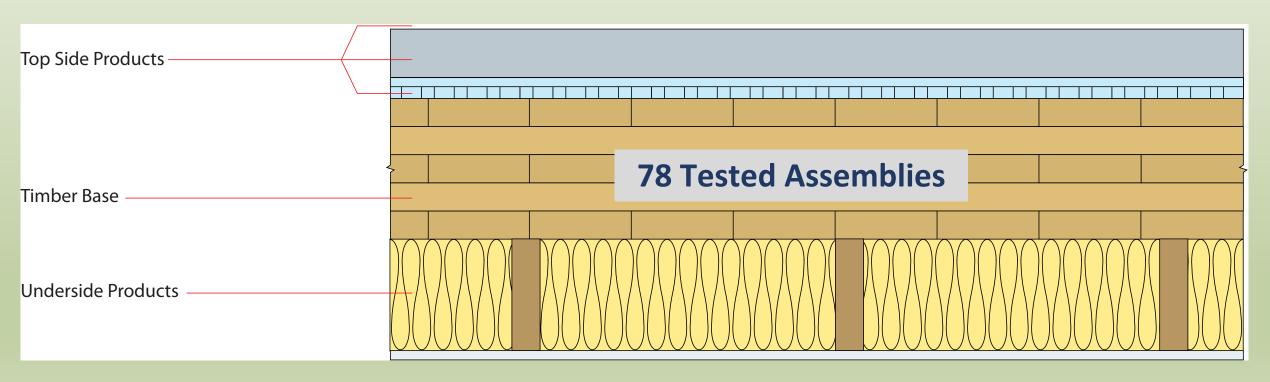
Table 3: CLT Floor Assemblies without Concrete/Gypsum Topping, with Wood Sleepers, Ceiling Side Exposed



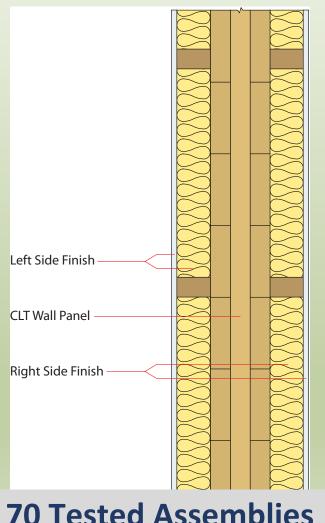
#### Table 4: NLT, GLT & T&G Decking Floor Assemblies, Ceiling Side Exposed



**Table 5: Mass Timber Floor Assemblies with Ceiling Side Concealed** 

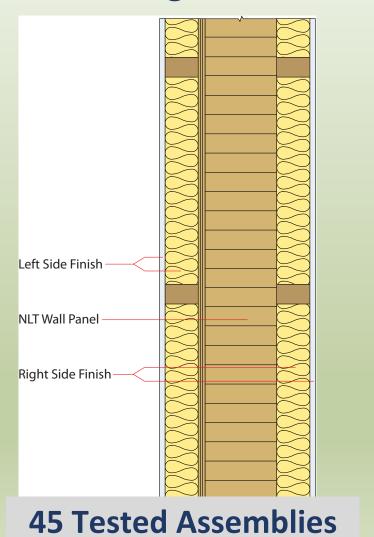


**Table 6: Single CLT Wall** 



**70 Tested Assemblies** 

**Table 7: Single NLT Wall** 

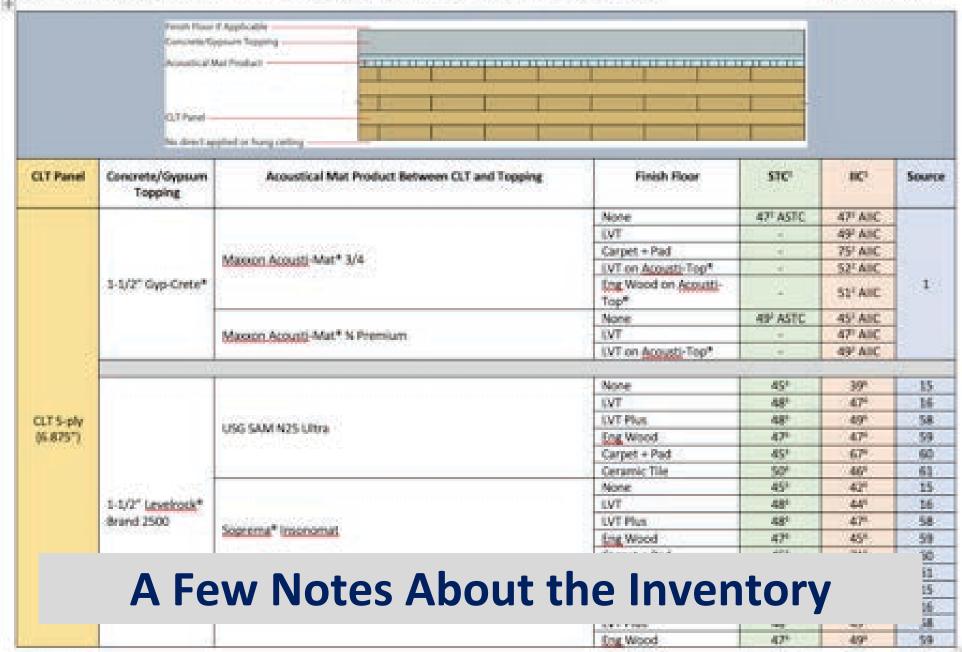


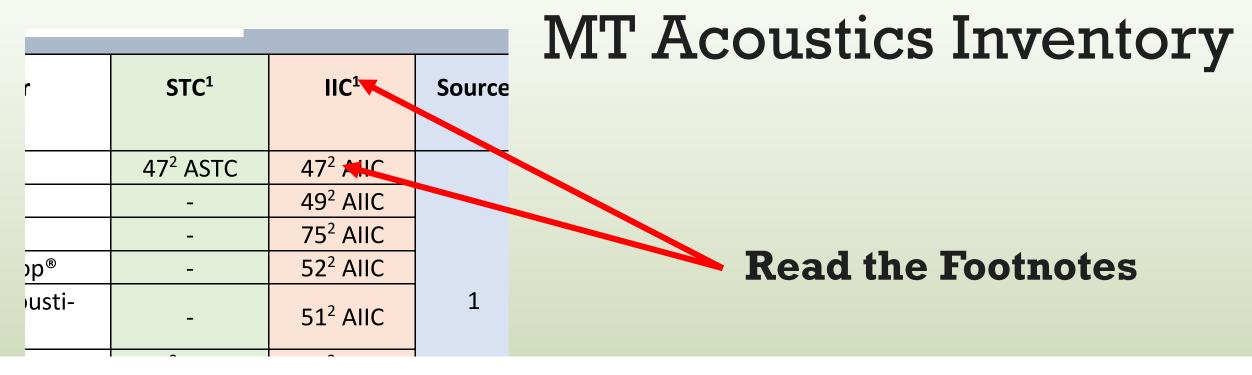
**Table 8: Double CLT Wall** Left Side CLT + Finish Between CLT Panels Right Side CLT + Finish

**32 Tested Assemblies** 

#### Table 1: CLT Floor Assemblies with Concrete/Gypsum Topping, Ceiling Side Exposed





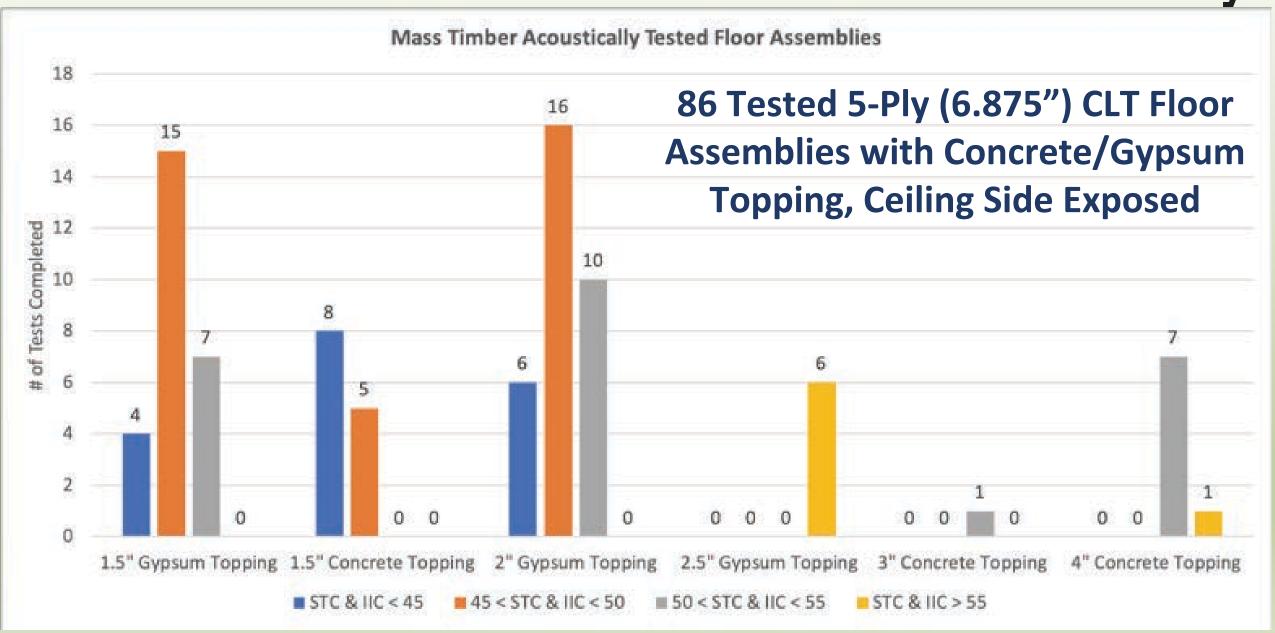


#### **Table 1 Notes:**

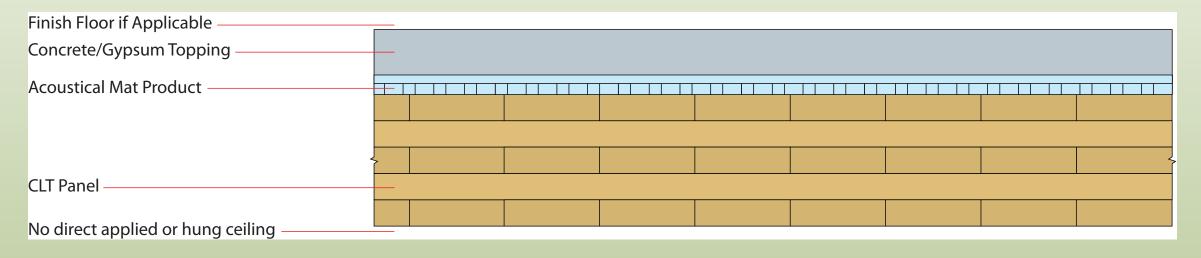
- 1. All STC tests performed in accordance with ASTM E 90 unless otherwise noted below. All IIC tests performed in accordance with ASTM E 492 unless otherwise noted below. See end of document for sources and referenced test reports.
- 2. ASTC field tests performed in accordance with ASTM E 336. AIIC field tests performed in accordance with ASTM E 1007.
- 3. IIC tests not performed in accordance with a singular test standard. Test measurement method used a combination of ASTM E492 and ASTM 1007 per acoustical mat product manufacturer.
- 4. FSTC field test performed in accordance with ASTM E 336. AIIC field test not performed in accordance with ASTM E 1007 (inadequate number of measurements).
- 5. STC and IIC noted is a prediction based on the ISO 15712-1 prediction method as noted in the referenced test report.
- 6. STC and IIC noted is based on floor zone testing procedures that are modifications of ASTM E90 and E492 test and do not fully conform with these test standards per acoustical mat product manufacturer and as noted in the referenced test report.
- 7. Actual thickness of CLT in this test was 6.3" (160 mm)
- 8. Assemblies included in the 1<sup>st</sup> edition of the CLT Handbook are included herein due to their legacy use. However, the testing standards used for these assemblies are European and direct correlation to IBC-referenced ASTM standards is not currently available.
- 9. STC and IIC noted is a based on the ISO 12354 model as noted in the referenced manufacturer's literature

1206.2 Airborne sound. Walls, partitions and floor-ceiling assemblies separating dwelling units and sleeping units from each other or from public or service areas shall have a sound transmission class of not less than 50, or not less than 45 if field tested, for airborne noise where tested in accordance with ASTM E90. Alternatively, the sound transmission class of walls, partitions and floor-ceiling assemblies shall be established by engineering analysis based on a comparison of walls, partitions and floor-ceiling assemblies having sound transmission class ratings as determined by the test procedures set forth in ASTM E90. Penetrations or openings in construction assemblies for piping; electrical devices; recessed cabinets; bathtubs; soffits; or heating, ventilating or exhaust ducts shall be sealed, lined, insulated or otherwise treated to maintain the required ratings. This requirement shall not apply to entrance doors; however, such doors shall be tight fitting to the frame and sill.

1206.3 Structure-borne sound. Floor-ceiling assemblies between dwelling units and sleeping units or between a dwelling unit or sleeping unit and a public or service area within the structure shall have an impact insulation class rating of not less than 50, or not less than 45 if field tested, where tested in accordance with ASTM E492. Alternatively, the impact insulation class of floor-ceiling assemblies shall be established by engineering analysis based on a comparison of floor-ceiling assemblies having impact insulation class ratings as determined by the test procedures in ASTM E492.



# 5-Ply (6.875") CLT Floor Assemblies with Concrete/Gypsum Topping, Ceiling Side Exposed

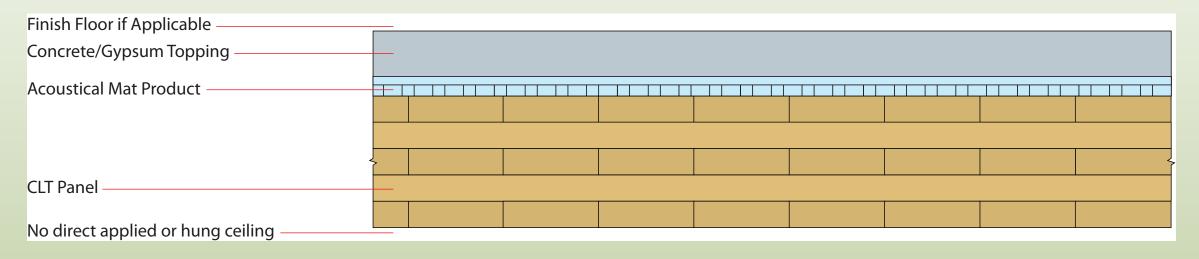


86 Tests Completed. Of these:

32 Have STC & IIC 50 or greater

7 Have STC & IIC 55 or greater

### **Topping Thickness Effect on 5-Ply (6.875") CLT Floor Assemblies**



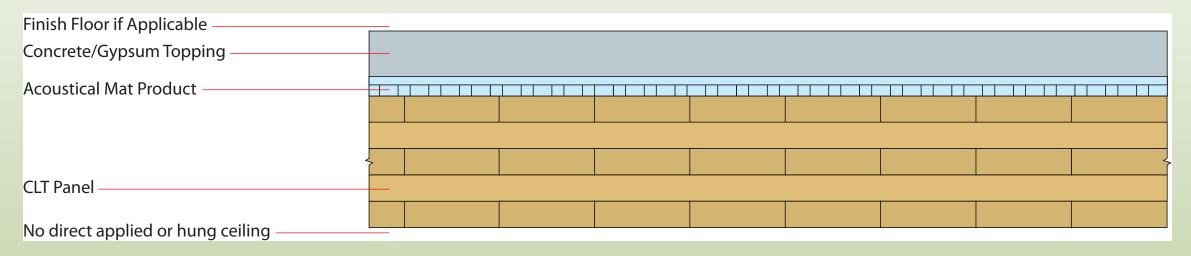
#### 32 Have STC & IIC 50 or greater

7 Include 1.5" Gypsum Topping10 Include 2" Gypsum Topping6 Include 2.5" Gypsum Topping

1 Includes 3" Concrete Topping

8 Include 4" Concrete Topping

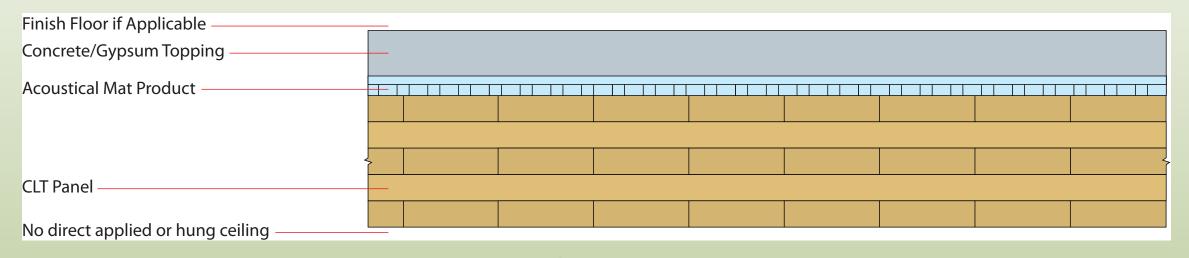
### **Topping Thickness Effect on 5-Ply (6.875") CLT Floor Assemblies**



7 Have STC & IIC 55 or greater

6 Include 2.5" Gypsum Topping 1 Includes 4" Concrete Topping

## Acoustical Mat (AM) Thickness Effect on 5-Ply (6.875") CLT Floor Assemblies



32 Have STC & IIC 50 or greater

3 Include AM  $\leq 0.25$ "

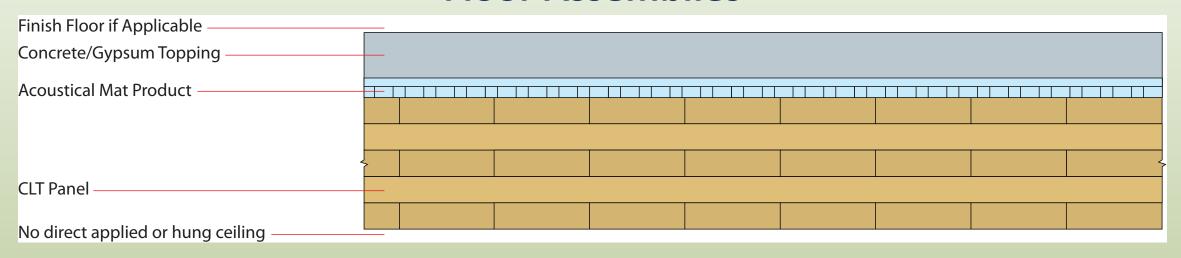
4 Include AM 0.75" < AM ≤ 1"

6 Include AM 0.25" < AM ≤ 0.5"

10 Include AM > 1"

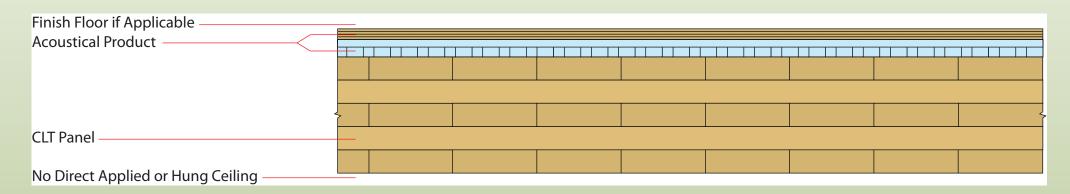
9 Include AM 0.5" < AM ≤ 0.75"

## Acoustical Mat (AM) Thickness Effect on 5-Ply (6.875") CLT Floor Assemblies



7 Have STC & IIC 55 or greater
All 7 Include AM > 1"

Dry Systems → No Concrete/Gypsum Topping
5-Ply (6.875") CLT Floor Assemblies with Ceiling Side Exposed



**21 Tested Assemblies** 

2 Have STC & IIC 50 or greater

Combination of WSP, Cement board type products, Acoustical Mat, Eng. Wood or LVT finish floor



Finish Floor if Applicable						
Concrete/Gypsum Topping —————						
Acoustical Mat Product  Mass Timber Floor Panel						
No Direct Applied or Hung Ceiling						
2x6 NLT + ½" plywood	None	None	None	34	33	55
		Structural concrete panels on track and rim system		54	45	27
	2" Gyp-Crete®	3/" this is a managinate management and management	None	47 <sup>2</sup> ASTC	-	9
		3/4" thick proprietary acoustical mat	LVT on Acousti- Top®	-	47 <sup>2</sup> AIIC	28
	2-1/2" concrete		None	56	48	23
		1" thick proprietary acoustical mat	Engineered Hardwood	56	52	24
			LVT	55	57	25
	4" concrete	None		51	36	8
		1/4" thick proprietary acoustical mat		51	44	7
			Carpet	51	58	49
		1" thick proprietary acoustical mat	None	54	50	50
		2" thick proprietary acoustical mat	-	56 56	52 53	51 52
		3" thick proprietary acoustical mat		50	55	52



Inventory also contains tests conducted on NLT, GLT, T&G Decking



### Mass Timber Acoustics

#### A Solved Challenge?

Still exploring further tests:

- 3-ply CLT floor assemblies
- New product assemblies (MPP)
- More dry systems (no poured toppings)
- Tall wood code-compliant floor assemblies
- Others what challenges do you face when designing mass timber for acoustics? Let us know.
- Are these resources helpful? Let us know.







### > QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

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