If You Build It, Will It Make a Sound? Learning through Acoustic Testing of Mass Timber Floor Assemblies

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A hollow massive timber (HMT) floor system was developed at (Omitted) University to address several overarching objectives: long spans, low-embodied carbon, building systems integration, and end-of-life circularity. One related goal was a departure from concrete toppings, which complicate disassembly and reuse. However, concrete toppings are key contributors to sound attenuation, so the acoustic performance of the HMT system needed rigorous testing in order to determine if it could meet stringent sound rating requirements, particularly for residential and hospitality settings.

Each HMT floor cassette consists of two 3-ply cross-laminated timber flanges and two glulam web members. Designed for spans up to 40 feet, the system reduces the need for interior bearing points, promoting flexibility. The cavities are designed to meet fire compartmentalization requirements and can be used for the passage of MEP systems, with top-down access provided at periodic hatches. A variety of flange-to-web connection methods were explored to ensure both structural integrity and ease of disassembly.

Rather than outsourcing acoustic testing to a commercial facility, our team embraced a hands-on approach to promote iterative design studies while enhancing learning opportunities. With support from a Construction Logistics elective course, plus student research assistants from several disciplines, an acoustic testing chamber was built for measuring sound transmission through floor assemblies. The two-story chamber includes a sound source room (above) and a sound receiving room (below). It was constructed in two halves and with hinged upper walls such that it can collapse down for movement between our low and high-bay lab spaces.

The chamber was designed to support ASTM-compliant testing to demonstrate whether floor assemblies meet the IBC's required sound attenuation standards, including minimum field-test ratings of 45 for airborne sound insulation and impact sound insulation, which are required for residential and hotel applications. Professional acoustic testing equipment was used for generating and measuring sound across the spectrum of discernable frequencies.

Testing began with baseline floor assemblies, placed into the 8'x20' void between source room and receiving room. Results were compared with third-party lab results to validate the sound chamber and test procedures. Testing of the HMT cassette followed, beginning with the bare assembly, and then adding various layers to study their effects. These included carpet tiles, acoustic mats, and OSB subfloor. The addition of cellulose insulation in the HMT cavities was also studied. All versions of the HMT cassette achieved the required airborne sound rating (NNIC > 45), while the versions with carpet or acoustic mat exceeded impact sound requirements (NISR > 50). These results demonstrate that HMT assemblies can meet or exceed the IBC's most stringent acoustic requirements without concrete toppings.

From planning to construction to validation and testing this hands-on study of acoustic behavior and performance provided encouraging data for the all-timber HMT system while also providing valuable educational experiences at multiple levels. Looking ahead, a detailed acoustic testing manual was created to guide future testing and education. The team is ready to examine new floor assemblies while also broadening its studies to include flanking sound above demising walls.

Keywords: building acoustics, mass timber, circularity

IF YOU BUILD IT, WILL IT MAKE A SOUND?

LEARNING THROUGH ACOUSTIC TESTING OF MASS TIMBER FLOOR ASSEMBLIES

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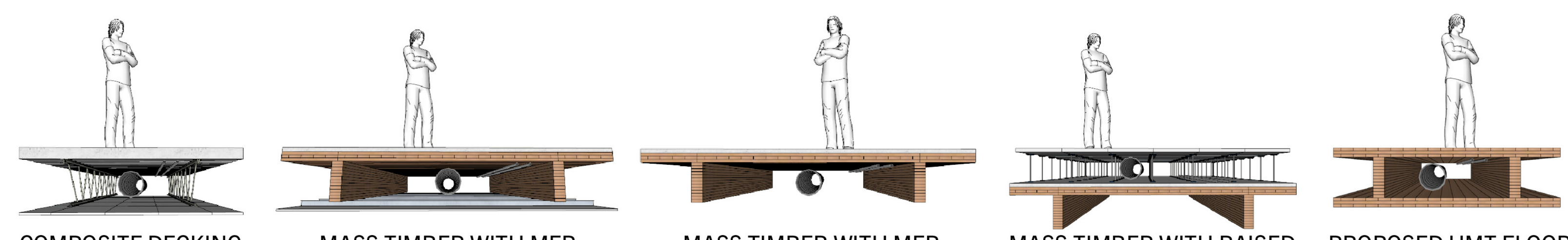
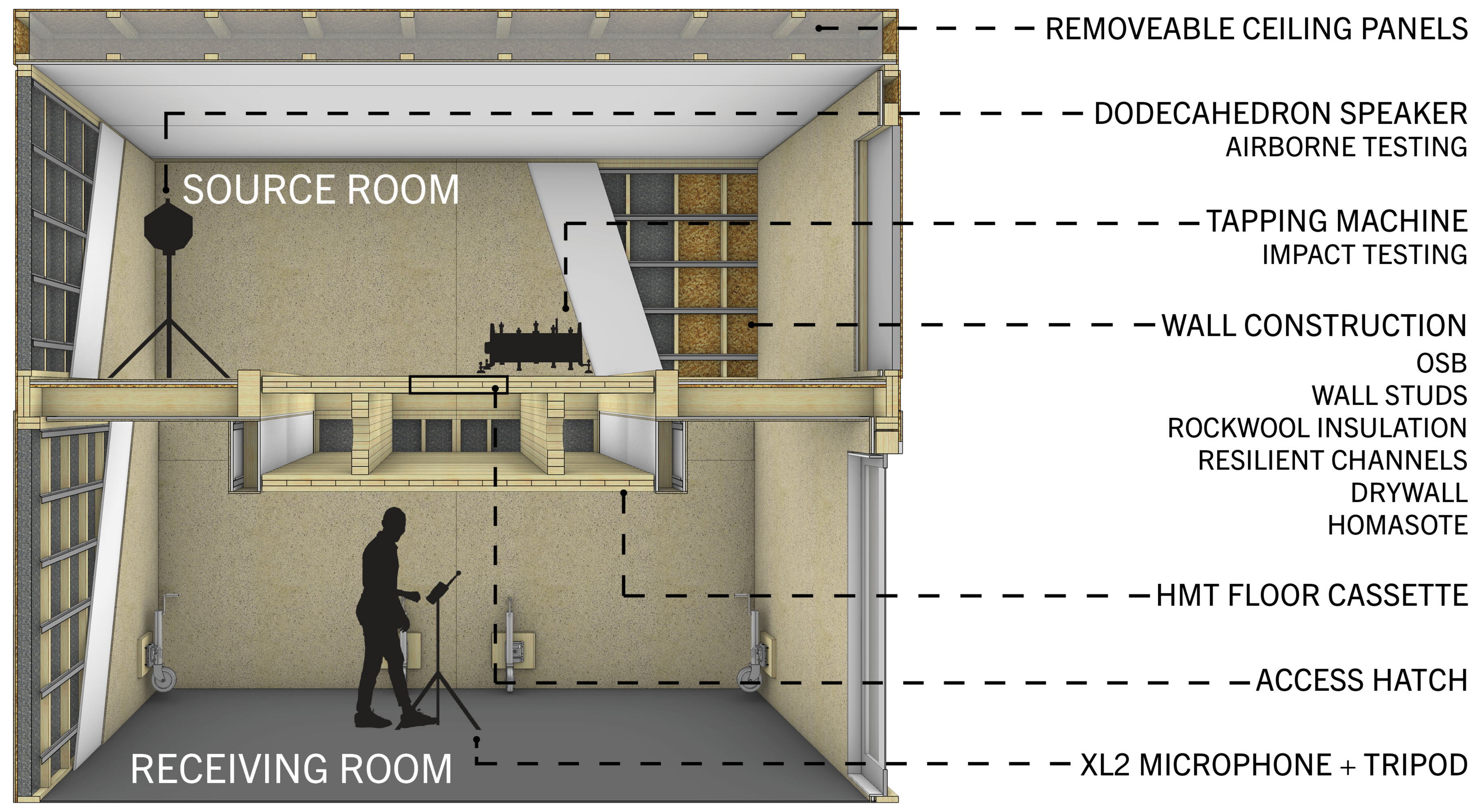
INTRODUCTION

Clemson University has developed a hollow massive timber (HMT) floor system to address several overarching objectives: long spans, low-embodied carbon, building systems integration, and end-of-life circularity. One related goal was a departure from concrete toppings, which complicate disassembly and reuse. However, concrete toppings are key contributors to sound attenuation, so the acoustic performance of the HMT system needed rigorous testing in order to determine if it could meet stringent sound rating requirements, particularly for residential and hospitality settings.

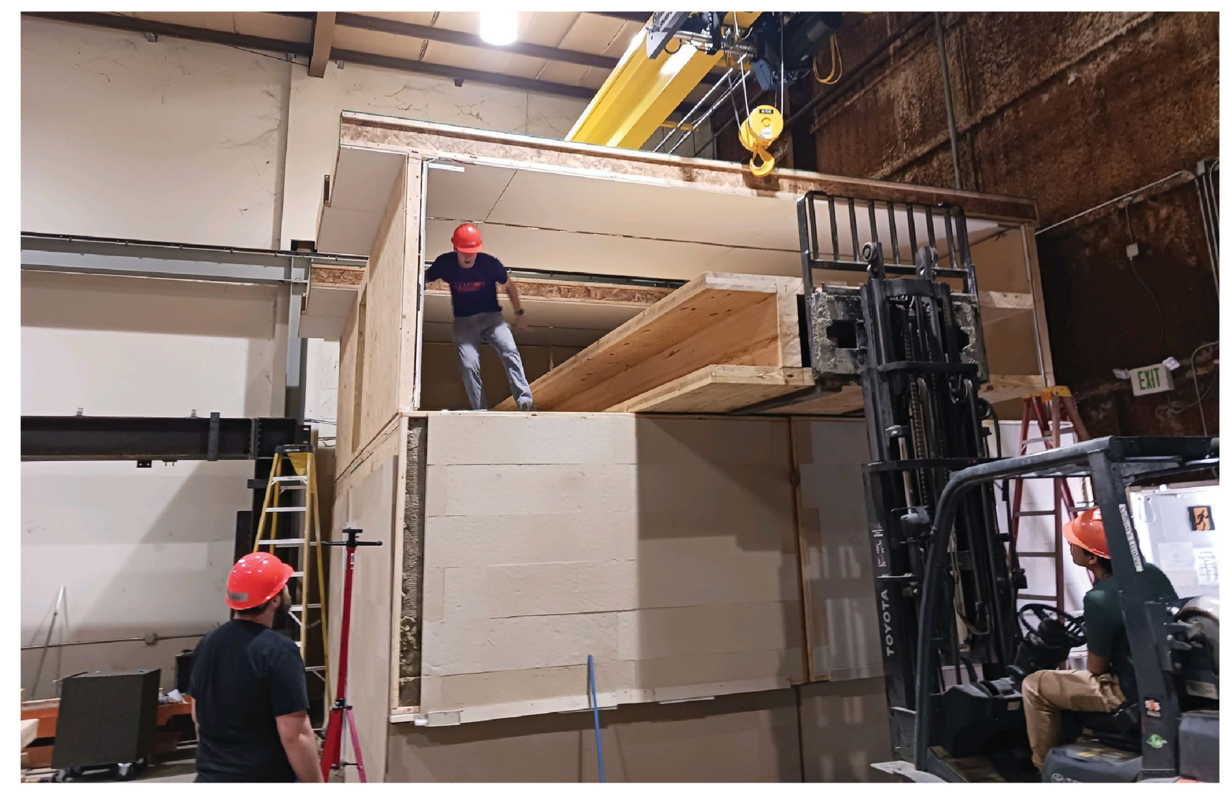


COMPOSITE DECKING OVER STEEL STRUCTURE — MASS TIMBER WITH MEP CONCEALED BY CEILING — MASS TIMBER WITH MEP SYSTEMS EXPOSED — MASS TIMBER WITH RAISED ACCESS FLOORING — PROPOSED HMT FLOOR CASSETTE SYSTEM



Each HMT cassette consists of two 3-ply CLT flanges and two glulam web members. Designed for spans up to 40 feet, the system reduces the need for interior bearing points. The cavities are designed to meet fire compartmentalization requirements and can be used for the passage of MEP systems, with top-down access provided at periodic hatches. A variety of flange-to-web connection methods were explored to ensure both structural integrity and ease of disassembly.

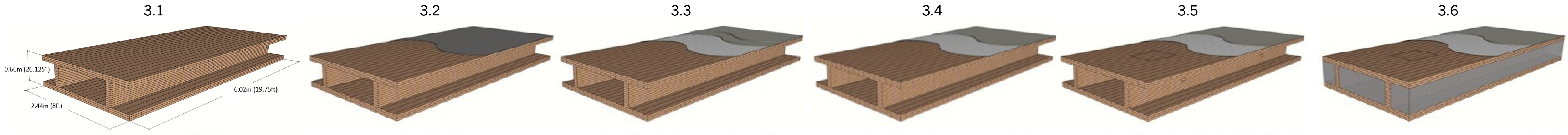
With support from a Construction Logistics elective course, plus student research assistants from several disciplines, an acoustic testing chamber was built for measuring sound transmission through floor assemblies. The two-story chamber includes a sound source room and a receiving room. It was constructed in two halves and with hinged upper walls such that it can collapse down for movement between our low and high-bay lab spaces.



METHODOLOGY AND TESTED ASSEMBLIES

The chamber was designed to support ASTM E336-20 and ASTM E1007-21 compliant testing to demonstrate whether floor assemblies meet the IBC's required sound attenuation standards. Those standards include minimum field-test ratings of 45 for both airborne and impact sound insulation in the case of residential and hotel applications. Professional acoustic testing equipment was used for generating and measuring sound across the spectrum of discernable frequencies.

Testing began with two different control floor assemblies, placed into the 8'x20' void between source room and receiving room. Control test results were compared with third-party lab results to validate the sound chamber and test procedures. Testing of the HMT cassette came next, beginning with the bare assembly, and then adding various flooring and insulation layers to study their effects.



3.1 BARE HMT CASSETTE — 3.2 w/ CARPET TILES — 3.3 w/ ACOUSTIC MAT + 2 OSB LAYERS — 3.4 w/ ACOUSTIC MAT + 1 OSB LAYER — 3.5 w/ HATCHES + DUCT PENETRATIONS — 3.6 FILLED w/ CELLULOSE INSULATION

Test No.	Condition	NNIC (Airborne)	NISR (Impact)
-	**Target**	≥ 45	≥ 45
3.1	Bare HMT Cassette	45	37
3.2	w/ Carpet Tile	45	51
3.3	w/ Acoustic Mat + 2 Layers OSB Subfloor	50	52
3.4	w/ acoustic mat + 1 Layer OSB Subfloor	47	50
3.5	3.4 w/ Hatches + Duct Penetrations (no insulation)	49	50
3.6	3.5 w/ Cellulose Insulation	49	51

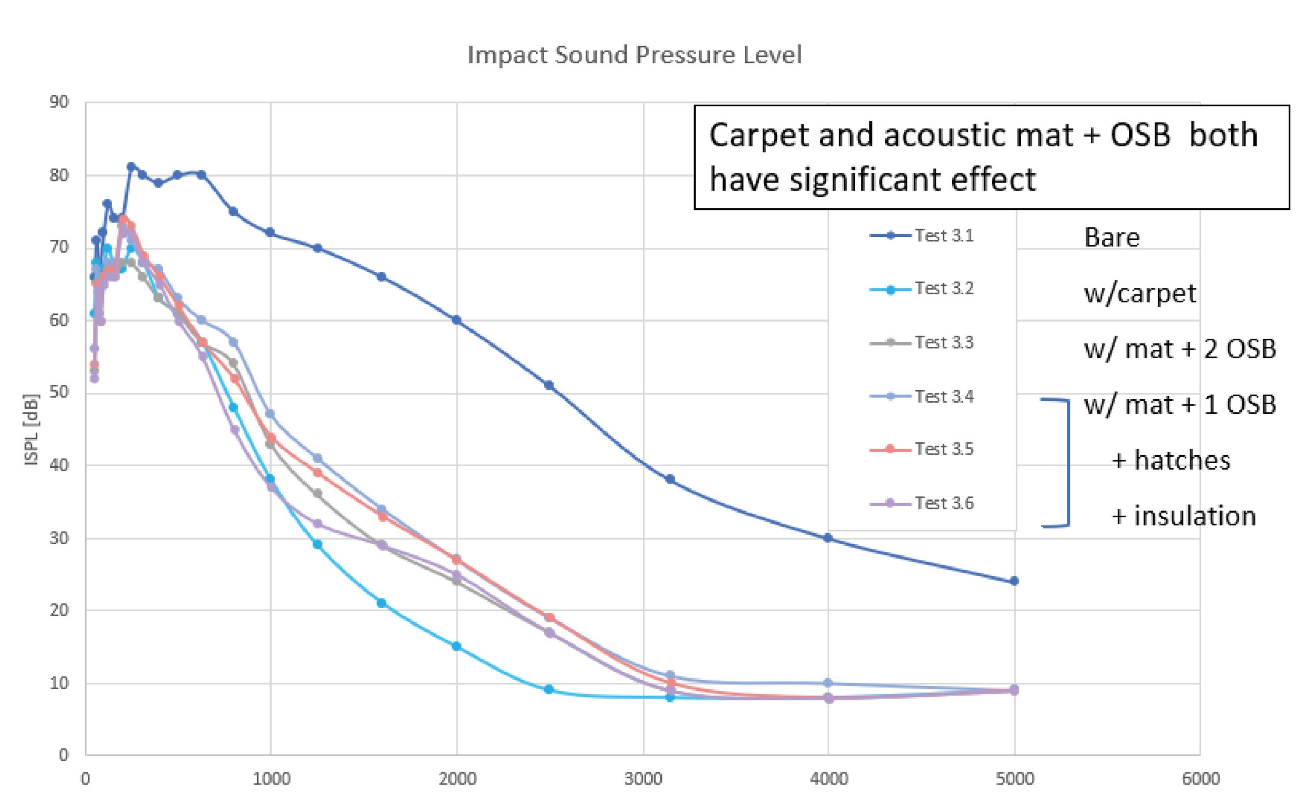
RESULTS AND DISCUSSION

The table above details the various tested floor assemblies using the experimental HMT floor system. In addition to the baseline bare assembly, other variations were tested including carpet tiles, acoustic mats, and layers of OSB subfloor. The addition of cellulose insulation in the HMT cavities was also studied. All versions of the HMT cassette achieved the required airborne sound rating (NNIC ≥ 45). This likely results from the overall mass and geometry of the HMT floor sytsem itself. The tested assemblies that used carpet or acoustic mat exceeded impact sound requirements (NISR ≥ 45). This is because these layers served to decouple the impact sound from the structure of the floor assembly.

These test results are encouraging and demonstrate that HMT assemblies can meet or exceed the IBC's most stringent acoustic requirements without concrete toppings. The resulting elimination of cementitious material lowers carbon footprint and promotes circularity for the HMT components themselves.

Impact Sound Pressure Level (dB)

Frequency (Hz)	Test 3.1	Test 3.2	Test 3.3	Test 3.4	Test 3.5	Test 3.6
50	66	61	53	56	54	52
63	71	68	65	67	65	64
80	67	63	61	63	60	60
100	72	67	66	66	66	65
125	76	70	67	68	67	66
160	74	67	66	68	67	66
200	74	67	68	73	74	72
250	81	70	68	71	73	72
315	80	68	66	68	69	68
400	79	63	63	67	66	65
500	80	61	61	63	62	60
630	80	57	57	60	57	55
800	75	48	54	57	52	45
1000	72	38	43	47	44	37
1250	70	29	36	41	39	32
1600	66	21	29	34	33	29
2000	60	15	24	27	27	25
2500	51	9	17	19	19	17
3150	38	8	9	11	10	9
4000	30	8	8	10	8	8
5000	24	9	9	9	9	9
NISR Rating	**37**	**51**	**52**	**50**	**50**	**51**



Airborne Transmission Loss (dB)

Frequency (Hz)	Test 3.1	Test 3.2	Test 3.3	Test 3.4	Test 3.5	Test 3.6
50	20	24	21	21	-	22
63	22	23	23	21	24	24
80	26	25	27	25	29	29
100	28	29	29	29	31	32
125	26	28	32	32	32	34
160	31	31	35	34	33	36
200	35	34	38	34	34	36
250	34	35	41	37	37	37
315	33	34	41	35	36	37
400	38	37	43	40	42	44
500	39	38	45	44	45	46
630	40	39	45	45	46	46
800	42	41	45	44	46	46
1000	44	42	47	47	47	47
1250	47	46	48	48	49	49
1600	49	49	51	50	50	50
2000	53	53	55	53	54	54
2500	57	58	59	58	59	58
3150	60	61	63	62	63	63
4000	63	65	66	65	66	66
5000	65	68	70	69	69	69
NNIC Rating	**45**	**45**	**50**	**47**	**49**	**49**