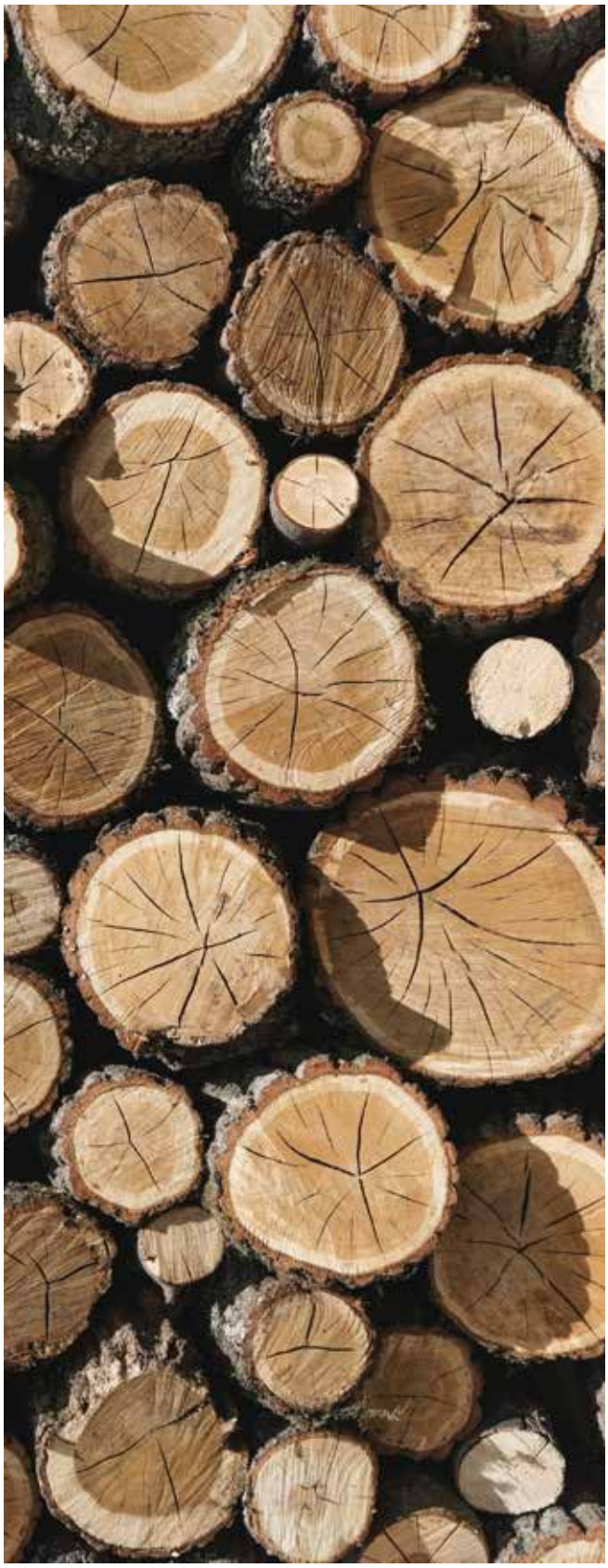

photo credit: rawpixel on unsplash.com

Acoustic Lab Testing (ASTM E492-2016, ASTM E90-2016) of CLT and MPP Wall and Floor Assemblies for Multi-Family Residential Application

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Acoustic Lab Testing (ASTM E492-2016, ASTM E90-2016) of Multi-Family Residential CLT and MPP Wall and Floor Assemblies

Prepared for:

Iain Macdonald
Director, TallWood Design Institute
Oregon State University

Prepared by:

Energy Studies in Buildings Laboratory
Department of Architecture
University of Oregon
Eugene, Oregon | Portland, Oregon

Research Team:

Kevin Van Den Wymelenberg (PI)
Dale Northcutt
Mark Fretz
Jason Stenson
Ethan Zagorec-Marks

March, 2019

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1.0 INTRODUCTION

The use of mass timber panels is becoming a popular choice for construction due to concerns about climate change, resource sustainability, the need for construction efficiencies and the human biophilic affinity for wood. Developed about three decades ago in Austria, panelized mass timber products have been used in Europe for some time but are now gaining market traction across North America and represent an opportunity for designers, developers, engineers and contractors.

With this new design opportunity in North America comes jurisdictional code performance requirements that need to be demonstrated to building authorities in the United States. Among these are requirements for fire, seismic and acoustic testing. Acoustics standards in the United States are prescribed by various organizations, such as the International Code Council (ICC), Housing and Urban Development (HUD), American Nation Standards Institute (ANSI), American Society for Testing and Materials (ASTM) and Facility Guidelines Institute (FGI) and are codified by jurisdiction based on building typology.

In addition to code requirements, the economics of occupant satisfaction and well-being play a role in project development. Economic studies have shown that consumers value spaces with higher acoustic quality and display a willingness to pay for the relief from unwanted noise.[1] Furthermore, noise intrusion in places where people spend a majority of their time has been shown in a body of literature to affect cognitive function, disrupt sleep patterns, promote irritability, and provoke heart conditions.[2] Therefore, in order for a housing project to perform, it must not only meet code requirements but also market expectations for high quality, acoustically separated living spaces.

The acoustic performance of mass timber panels is measured by two metrics: STC (sound transmission class) and IIC (impact insulation class). STC, for example, is how well a wall assembly acoustically separates two spatial volumes. IIC is a measurement of how well a floor dampens the sound transmission of an impact between two adjacent spatial volumes, be that a dropped object or footstep. For multifamily housing, the International Code Council (ICC) prescribes a wall and floor assembly performance standard to meet or exceed a STC rating of 50 in a lab test (ASTM E 90)or 45 in field tests (ASTM E 336) and IIC rating of 50 in a lab test (ASTM E 492) or 45 in field tests (ASTM E 1007).[3]

Using industry standards such as ICC, HUD, ANSI, FGI as a starting point for designing a series of floor and wall assemblies we hope to find high performing cost-effective acoustic solutions for mass timber assemblies that can be readily adopted by design teams and jurisdictional authorities . In addition, this study aims to provide more third-party verified data on CLT + MPP acoustic performance and disseminate it into the public sphere.

1. Fahrländer, Stefan Sebastian; Gerfin, Michael; Lehner, Manuel (2015) : The influence of noise on net revenue and values of investment properties: Evidence from Switzerland, Discussion Papers, Universität Bern, Department of Economics, No. 15-02
2. Jarosińska, D., Héroux, M., Wilkhu, P., Creswick, J., Verbeek, J., Wothge, J., & Paunović, E. (2018). Development of the WHO Environmental Noise Guidelines for the European Region: An Introduction. *International Journal of Environmental Research and Public Health*, 15(4), .
3. International Code Council. (2010). *ICC G2-2010 Guideline for Acoustics.*

2.0 PROPOSED WALL AND FLOOR ASSEMBLIES

The following section illustrates the resulting CLT and MPP wall and floor assemblies that are proposed for acoustic testing based on market feedback. The wall and floor assemblies are optimized with careful consideration to the economics, aesthetics (desire for occupants to see mass timber in assembly construction), wellness (IAQ of material emissions), and acoustic viability that can be afforded by mass timber construction.

One grouping of floor assemblies is a structural composite and features a 2-1/4" concrete slab mechanically bonded to a 5-lam (6-7/8") CLT or 6" MPP base. The base assembly (F01) was developed by Oregon State University and SOM for use in regions of high seismic activity.[1] Due to the requirement for concrete to be bonded to wood, the dense concrete topping is not acoustically decoupled from the wood panel as is customarily the case. Therefore, lab testing data is needed to understand this structural composite acoustic behavior.

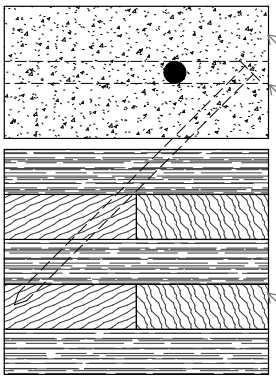
The second grouping of floor assemblies uses a construction sequence that does not require wet trades. To do this, three layers of cement board are bonded together for a 1-1/2" topping in place of a poured concrete topping. This floor assembly was developed from feedback that design teams wanted to increase construction speed by eliminating the need for concrete to be poured, formed, and cured. The use of a dry mineral aggregate, such as sand or gravel, was investigated as an option since this is used in Europe; however, an additional consideration from contractors is that they preferred a material that crews were already familiar using, such as cement board.

Currently, many mass timber buildings constructed or under construction are employing framed exterior walls. However, the potential for cost savings from using mass timber panels in shaft walls or as pre-manufactured off-site assemblies exists; therefore, influenced the final selections for testing. The wall assemblies utilize a prototypical exterior rainscreen assembly while maintaining the aesthetics of a natural CLT finish. Furthermore, the outboard insulation levels are sized to meet energy code requirements of most U.S. climate zones.

1. Skidmore, Owings, and Merrill. Timber Tower Research Project. Oregon State University. December 2017.

PROPOSED FLOOR ASSEMBLIES FOR TESTING - STRUCTURAL COMPOSITE

F01

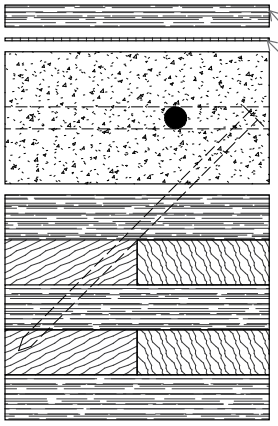


2-1/4" concrete slab @ 145 pcf density (as-tested density in lab report)

#3 rebar @ 6" o.c. in direction of span, 12" o.c. (maximum) perpendicular to span direction, pre-drill screw hole 1" to assure screw geometry, 8mm x 220mm ASSY VG CYL type shear fastener, position @ 12" o.c. field spacing, angle screw 45 degrees to surface of CLT, screw penetrates 5-1/4" into CLT leaving 1-1/2" of screw exposed (measured on vertical) to receive slab

5-Lam CLT or 6" MPP provided by TallWood, half lap panel to panel joint with ASSY VG CSK type shear fastener screw 8mm x 140mm or 160mm depending on material (see CD drawings), 12" o.c. spacing, single bead of construction adhesive, Wood sealer applied to all top surfaces and end-grain before pouring concrete slab

F02

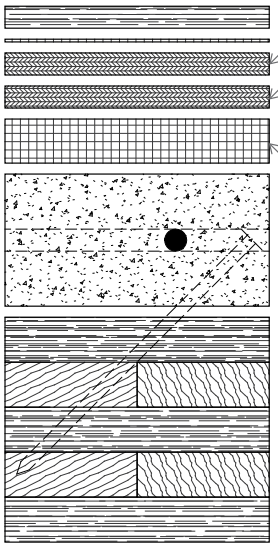


6-1/2" wide x 1/2" thick random length pine engineered floating floor, sanded, naturally oiled, T&G planks locked together

1/8" acoustic underlayment

* F02 - DEVELOPED BUT NOT TESTED AFTER VALUE ENGINEERING

F03



48"x 96"x 5/8" OSB nailed T&G sub-floor, stagger seams, adhered with construction adhesive, apply acoustic sealant to gaps (see CD drawings for orientation)

1" of acoustic underlayment, installed in opposite direction to hardwood flooring

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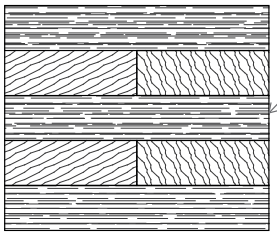
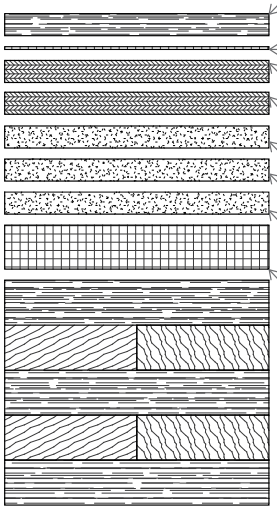
PROPOSED FLOOR ASSEMBLIES FOR TESTING - DRY ASSEMBLY

F04



5 lam CLT or 6" MPP, half lap panel to panel joint with ASSY VG CSK screw 8mm x 140mm or 160mm depending on material (see CD drawings), 12" o.c. spacing, single bead of construction adhesive

F05



6-1/2" wide x 1/2" thick random length pine engineered floating floor, sanded, naturally oiled, T&G planks locked together

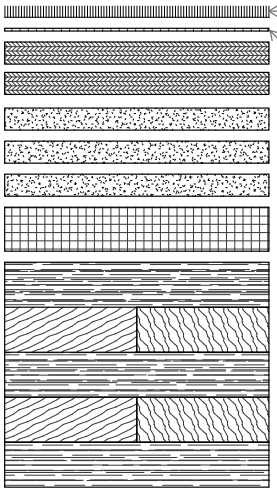
1/8" acoustic underlayment

48"x 96"x 5/8" OSB glued T&G sub-floor, stagger seams, adhere with construction adhesive, OSB stack adhered to cement board stack with construction adhesive

1/2" cement board, stagger board joints per CD drawings, adhere panels with construction adhesive, apply acoustic sealant to gaps

1" of acoustic underlayment, installed in parallel direction to hardwood flooring

F06

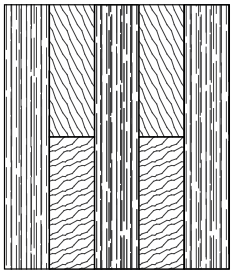


1/2" pile nylon carpet, 3343 oz/cb.yd. pile density, 97.5oz/sq.yd face weight

3/8" 8lb carpet pad

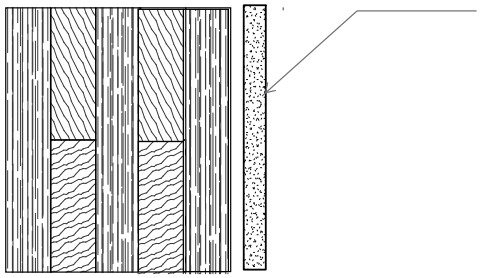
PROPOSED WALL ASSEMBLIES FOR TESTING

W07



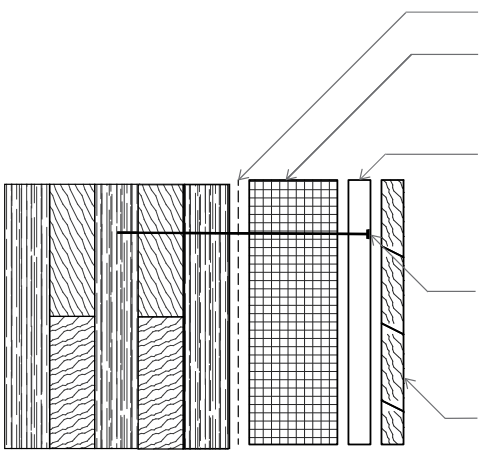
Specified mass timber. Half lap panel joint with single bead of construction adhesive. Joint fastened with 8mm x 140mm or 160mm ASSY VG CSK fastener depending on material (see CD drawings), 12” o.c. spacing

W08



5/8” gyp. bd. with 1-1/4" Type W fastener, field screw 16” spacing all directions, tape all joints

W09



weather barrier and primer

4” mineral wool insulation

1” x 4” wood battens @ 24“ o.c.

Wood batten therm fasteners, 8mm x 200mm 12” o.c.

1” x 6” T&G cedar siding,1-1/4" drywall fastener centered at batten

3.0 CLT + MPP FLOOR TESTS

The following section shows the process of testing CLT and MPP floor assemblies for sound transmission at **Riverbank Acoustical Laboratories (Alion Science + Technology)** in Geneva, Illinois. CLT and MPP samples were shipped to the lab wrapped and covered during transport.

Above: calibrated impact sound generator used for IIC testing. Image Credit: Evan Schmidt, OSU TallWood Design Institute

CLT FLOOR TESTING PROCESS

Images depict the process of moving CLT panels into testing chamber and securing joint. Note the size of door opening and the need for a joint in the mass timber base floor.

Credit for all images on this page: Evan Schmidt, OSU TallWood Design Institute

CLT FLOOR TESTING PROCESS

Images depict the process of sealing perimeter of floor CLT using sand and acoustic putty.

Credit for all images on this page: Evan Schmidt, OSU TallWood Design Institute

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CLT FLOOR TESTING PROCESS

Images depict the process of assembling the layers of the dry floor construction.

Credit for all images on this page: Dale Northcutt, ESBL

CLT FLOOR TESTING PROCESS

Images depict the process of assembling the structural composite floor and IIC base testing.

Credit for all images on this page: Dale Northcutt, ESBL

MPP FLOOR TESTING PROCESS

Images this page: the process of MPP installation into the chamber.
Images following page: MPP dry and structural composite assembly build up.

Credit for all images on this page: Dale Northcutt, ESBL

MPP FLOOR TESTING PROCESS

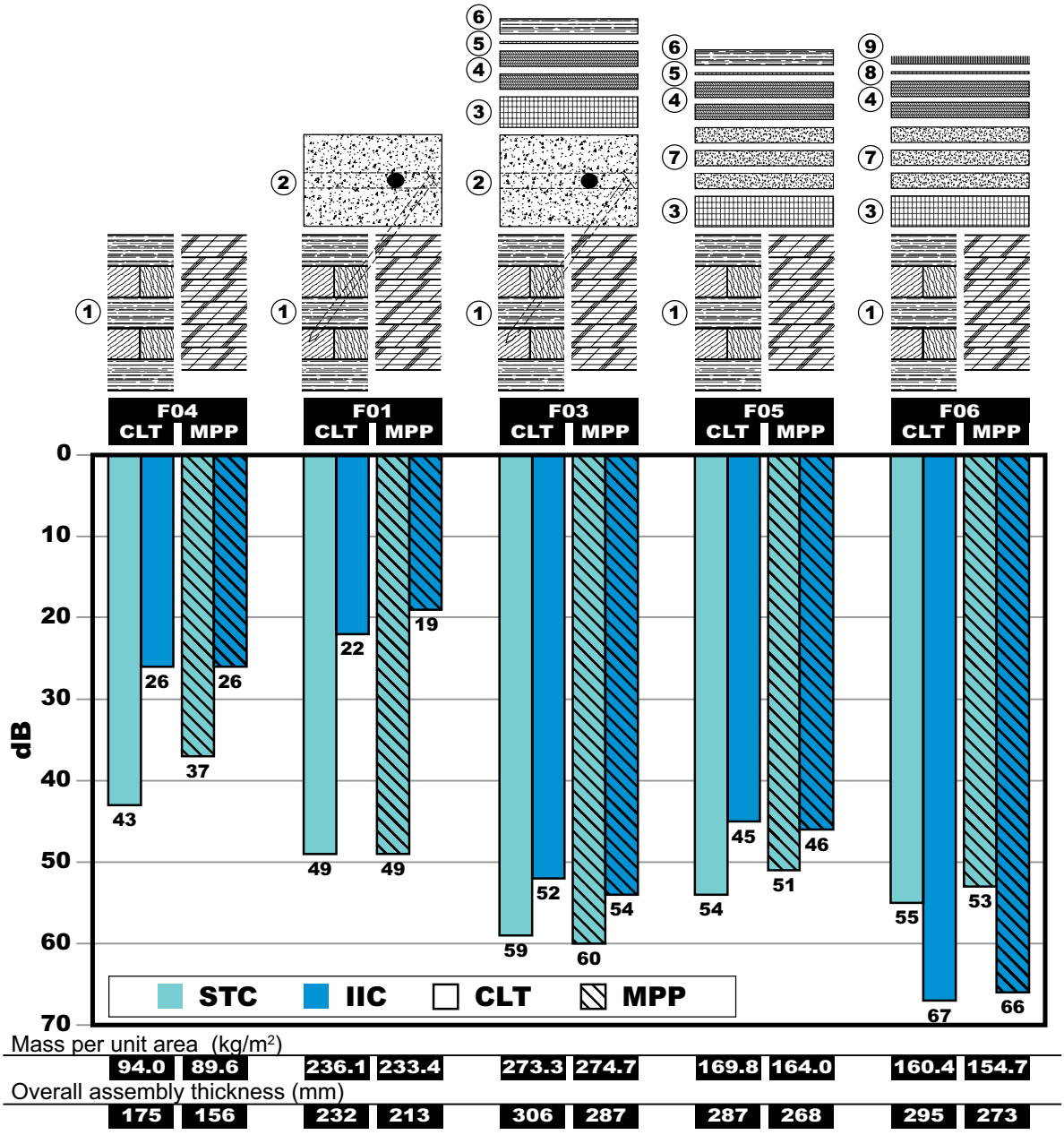








CLT + MPP FLOOR TESTING RESULTS



1. Mass timber panel, 6-7/8" 5-lam CLT or 6-1/8" MPP, single half-lap joint in direction of span
2. 2-1/4" concrete slab @ 145 pcf density, #3 rebar, 6" o.c. in span direction, 12" o.c. perpendicular to span, 8mm x 220mm shear fastener, 12" o.c. field spacing @ 45º
3. 1" acoustic underlayment, install in opposing direction to flooring
4. 5/8" OSB, 2 layers, glued in direction of span, stagger seams, adhere with construction adhesive
5. 1/8" acoustic underlayment
6. 6-1/2" x 1/2" random length engineered pine floating floor, T&G, sanded, oiled
7. 1/2" cement board, 3 layers, stagger seams, adhere with construction adhesive
8. 3/8" 8lb carpet pad
9. 1/2" pile nylon carpet, 97.5 oz/sq.yd face weight

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4.0 CLT + MPP WALL TESTS

The following section shows the process of testing CLT and MPP wall assemblies at **USG Testing Services, Corporate Innovation Center** in Libertyville, Illinois.

Below: fitting CLT panel into wall test opening. Image Credit: Dale Northcutt, ESBL

CLT WALL TESTING PROCESS

Images this page: the process of receiving the CLT at testing lab, sealing in test opening and assembly build up.

Credit for all images on this page: Dale Northcutt, ESBL

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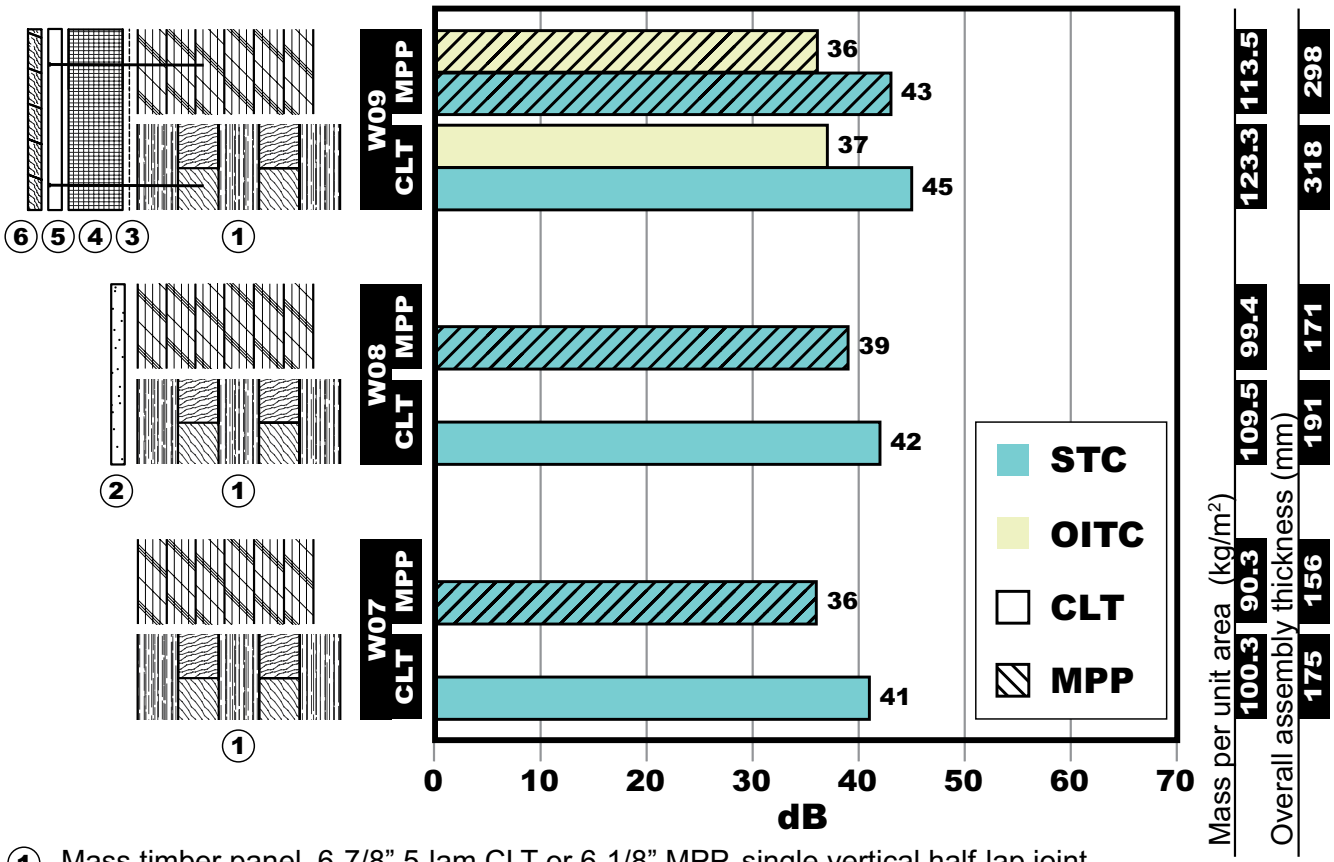
MPP WALL TESTING PROCESS

Images this page: the process of receiving the MPP at testing lab, installing and sealing in test opening and assembly build up.

Credit for all images on this page: Dale Northcutt, ESBL

CLT + MPP FLOOR TESTING RESULTS



1. Mass timber panel, 6-7/8” 5-lam CLT or 6-1/8” MPP, single vertical half-lap joint
2. 5/8” gypsum wall board, field screw 16” spacing all directions, tape all joints
3. Self-adhered waterproofing membrane
4. 4” mineral wool insulation
5. 1” x 4” wood battens @ 24“ o.c., 8mm x 200mm fasteners with secondary thread, 12” o.c.
6. 1” x 6” T&G cedar siding

5.0 DISCUSSION

Through the process of developing and acoustic testing mass timber wall and floor assemblies, there were some lessons learned that will be documented in this section. There was tremendous enthusiasm from industry to have more tested and verified assemblies at their disposal so that design teams can be flexible when bidding projects, such as having alternate assemblies with comparable performance available that can be substituted based on market conditions. The general summary of feedback that we received included a desire for generic materials, less wood fiber in the base construction, speed of assembly and visibility of the mass timber substrate.

During testing, both laboratory facilities were very helpful, educational, and accommodating to our research team. Being on-site during tests was an advantage to quickly understand and resolve issues that develop. A few of the considerations from testing include:

1. Although the same assemblies were used for both CLT and MPP, test results are not directly comparable since the mass timber substrates used are different thickness. 5-lam CLT was 6-7/8" and MPP was 6-1/8"
2. Original construction drawings needed updating for as-built due to some clarification. For instance, 145 pcf concrete was specified; however, available concrete used for testing was 151 pcf.
3. Some of the CLT had holes in an exterior layer where knots may have fallen out leaving 1-1/2" deep holes in the face and reducing the sound path distance through these areas.
4. In one location, the MPP panel had 1" plywood laminations with an air gap at the butt joint and those gaps lined up on every other layer; thereby, effectively reducing the sound path through this section. However, this was an early production panel donated for testing and the manufacturer has informed us that this has since been corrected in production.

ACKNOWLEDGMENTS

The research team from the Energy Studies in Buildings Laboratory would like to acknowledge and thank the following individuals and organizations for contributing to the successful completion of this project:

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Industry Advisors

Tobin Cooley, Listen Acoustics

Jake Ross, Creative Acoustics NW

Dean Lewis, DCI-Engineers

Erica Fischer, Oregon State University, School of Civil and Construction Engineering

Alex Zelaya, Hacker

Denis Blount, Arup

Matt Mahon, Arup

Zach Brehm, Swinerton James Woods, Glumac

Peter Allen, ABD Engineering

Evan Stravers, Scott Edwards Architecture

Juliette Grummon-Beale, FFA

Randy McGee, ZGF Architects

Eric McDonnell, KPFF

Riverbank Acoustical Laboratories

USG Testing Services, Corporate Innovation Center

6.0 APPENDICIES

6.1 PREVAILING CODES AND INDUSTRY STANDARDS

IBC
International Building Code

DESCRIPTION	*IIC | STC*
MULTI-FAMILY DWELLING	50* | 50*

* 45 if field tested

ICC
International Code Council

DESCRIPTION	*IIC | STC*
GRADE A	60 | 60
GRADE B	55 | 55

HUD
Housing and Urban Development

DESCRIPTION	*IIC | STC*
MINIMUM	58 | 52
AVERAGE	62 | 56
LUXURY	65 | 60

ANSI/ ASA
American National Standards Institute

DESCRIPTION	*IIC | STC*
ENCLOSED AREA, THERAPY ROOM, HEAL CARE ROOM, HIGH ACOUSTICAL PRIVACY ROOM	na | 50
COMMON USE AND PUBLIC USE RESTROOMS	na | 53
CORRIDOR, STAIRCASE, OFFICE, OR CONFERENCE ROOM	na | 45
MUSIC ROOM, MUSIC PERFORMANCE SPACE, AUDITORIUM, MECHANICAL EQUIPMENT ROOM, CAFETERIA, GYMNASIUM, INDOOR POOL	na | 60

GSA
General Services Administration

DESCRIPTION	*IIC | STC*
OFFICE PARTITIONS	na | 45
HIGH ISOLATION OFFICE	na | 53
STANDARD OFFICE	na | 40
TELECONFERENCE ROOMS	na | 53

FGI
Facility Guidelines Institute

DESCRIPTION	*IIC | STC*
PATIENT ROOM NEXT TO PATIENT ROOM (WALL-SAME FLOOR)	na | 45
PATIENT ROOM NEXT TO PATIENT ROOM (FLOOR-TO-FLOOR)	na | 50
PATIENT ROOM NEXT TO CORRIDOR	na | 35
PATIENT ROOM NEXT TO PUBLIC SPACE	na | 50
NICU NEXT TO PUBLIC SPACE	na | 50
RESTROOM NEXT TO PUBLIC SPACE	na | 45
PUBLIC SPACE NEXT TO MRI ROOM	na | 50

6.2 ACOUSTIC SURVEY ISSUED TO INDUSTRY LEADERS

The following section shows wall and floor assemblies with known acoustical performance identified from published sources, such as *Think Wood's CLT Handbook* or acoustic product manufacturers. The goal of this survey was to document known assembly performance data and identify desirable CLT and MPP assemblies based on construction technique, performance, aesthetics and cost. Some of the assemblies are developed by us to gauge new directions that industry might consider and flag immediate needs due to a paucity of published data in order to reduce market barriers by providing the needed testing. The results from these tests will be disseminated to the building industry to facilitate mass timber construction projects by reducing market barriers.

These identified assemblies were compiled into a document which was sent out to twenty-three different developers, engineers, acousticians, architects, and contractors as a market climate field survey. Of the twenty-three surveys sent out, twenty were returned. By crowd-sourcing our efforts we were able to optimize two wall assemblies and two floor assemblies to provide value to the building industry.

CLT ACOUSTIC WALL AND FLOOR ASSEMBLY SURVEY

UNIVERSITY OF OREGON ENERGY STUDIES IN BUILDING LAB + TALL WOOD DESIGN INSTITUTE

Thank you for taking some time to provide feedback for a cross laminated timber acoustic study.

We need your input and comments on a series of floor and wall assemblies in order to deterimine which assemblies to initially test. Each assembly will include a diagram, some relevant information and a few fields for you to complete in a fillable PDF.

This survey is aimed at helping the ESBL better anticipate the needs and desires of the industry for CLT assemblies for acoustic performance. Your knowledge of CLT assemblies including aesthetics, cost, and constructability will inform the lab testing of 2 - 3 CLT based wall and floor assemblies.

After going throught this survey please save your resulting PDF and send it back to the address below.

mfretz@uoregon.edu

your information

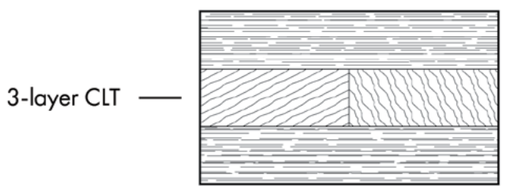
name :

email :

phone :

organization :

thank you!

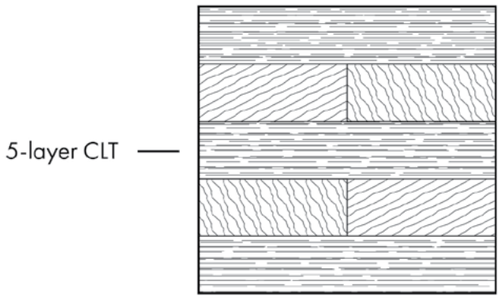


base assembly floor assembly wall assembly suggest an assembly

assembly description (top layer - base layer)	3-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	4.5
sound transmission class rating (STC code minimum 52)	32
impact isolation class (IIC code minimum 52)	23.1
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**

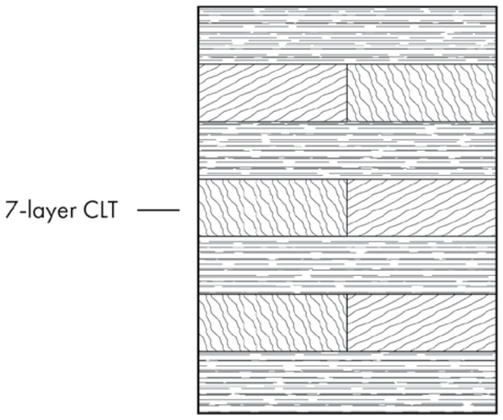
comments
(please feel free to share
comments, thoughts, questions,
reccomendations, etc.)

sources AcoustiTECH Acoustical Guide PDF, WoodWorks CLT Solutions



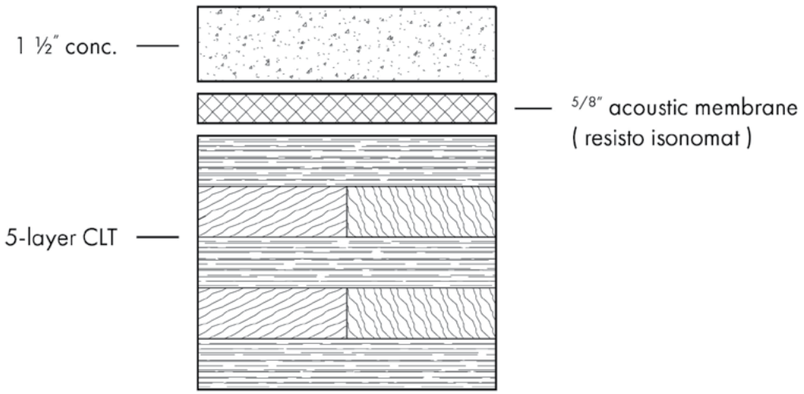
base assembly floor assembly wall assembly suggest an assembly

assembly description (top layer - base layer)	5-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	5.8
sound transmission class rating (STC code minimum 52)	39
impact isolation class (IIC code minimum 52)	24
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	CLT Handbook FPInnovations PDF



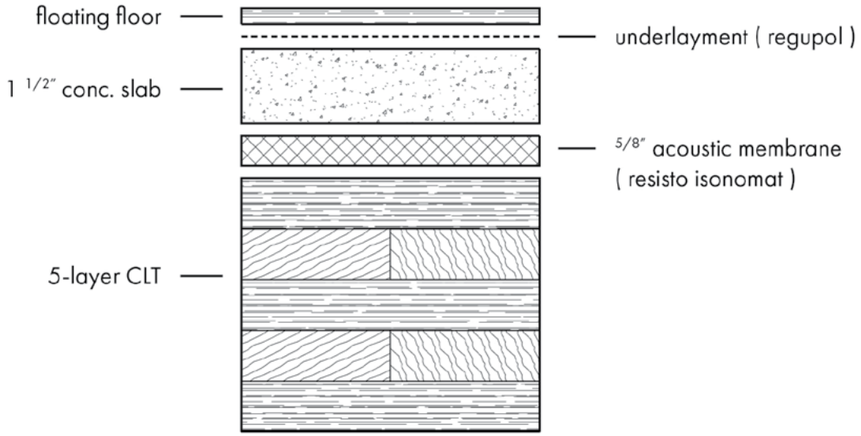
base assembly floor assembly wall assembly suggest an assembly

assembly description (top layer - base layer)	7-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	8.3
sound transmission class rating (STC code minimum 52)	(untested)
impact isolation class (IIC code minimum 52)	25
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	WoodWorks CLT Soulutions



base assembly **floor assembly** wall assembly suggest an assembly

assembly description (top layer - base layer)	1 1/2" conc., 5/8" acoustic membrane (Resisto Isonomat), 5- layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	7.3
sound transmission class rating (STC code minimum 52)	(untested)
impact isolation class (IIC code minimum 52)	44
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	AcoustiTECH Acoustical Guide PDF



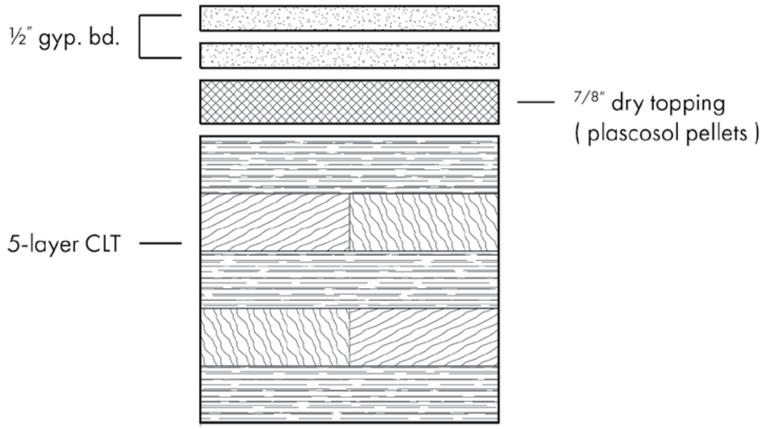
base assembly **floor assembly** wall assembly suggest an assembly

assembly description (top layer - base layer)	floating floor, 1 1/2" conc., 5/8" acoustic membrane (Resisto Isonomat), 5-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	7.3
sound transmission class rating (STC code minimum 52)	(untested)
impact isolation class (IIC code minimum 52)	49
availible in the U.S. (y / n)	**Y N**

would you reccomend this assembly?
(y / n) **Y N**

comments
(please feel free to share
comments, thoughts, questions,
reccomendations, etc.)

sources AcoustiTECH Acoustical Guide PDF

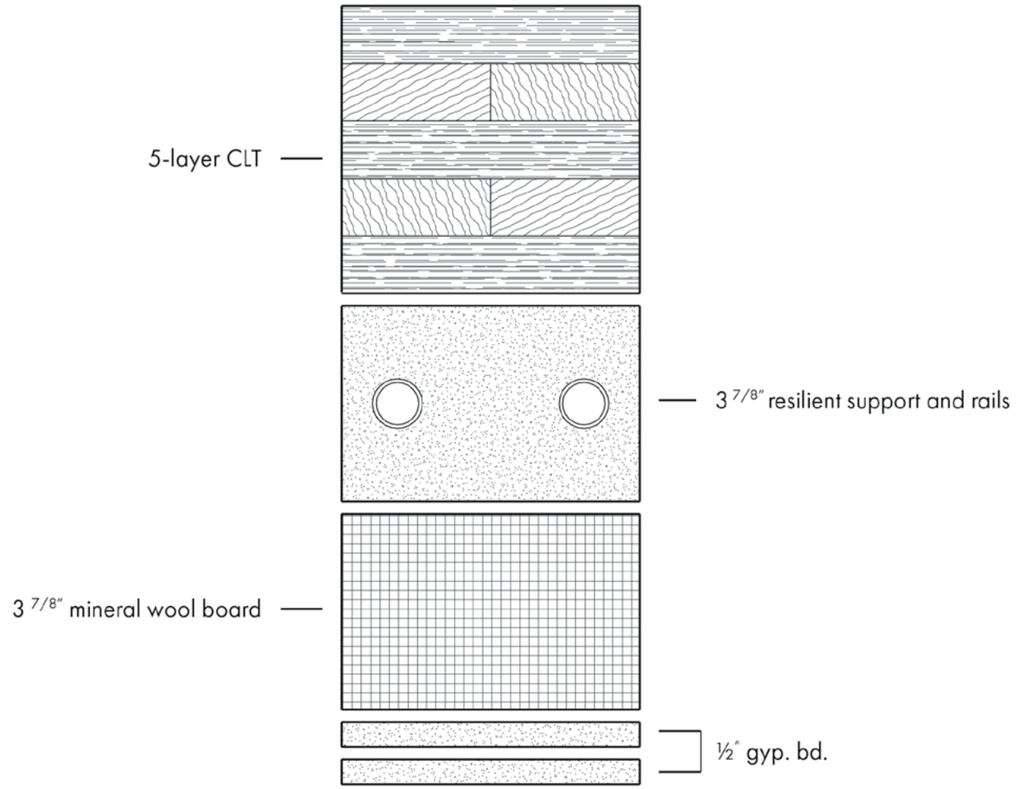


base assembly **floor assembly** wall assembly suggest an assembly

assembly description (top layer - base layer)	(x2) 1/2" gyp. bd., 7/8" dry topping (PLACOSOL pellets), 5-layer CLT		
cost (material, labor, installed , time)	**$**	**$$**	**$$$**
constructability (1 - 3) easy - complex	**1**	**2**	**3**
aesthetic (! - !!!)	**!**	**!!**	**!!!**
thickness (inches)	7.7		
sound transmission class rating (STC code minimum 52)	45		
impact isolation class (IIC code minimum 52)	35		
availible in the U.S. (y / n)	**Y**	**N**	
would you reccomend this assembly? (y / n)	**Y**	**N**	

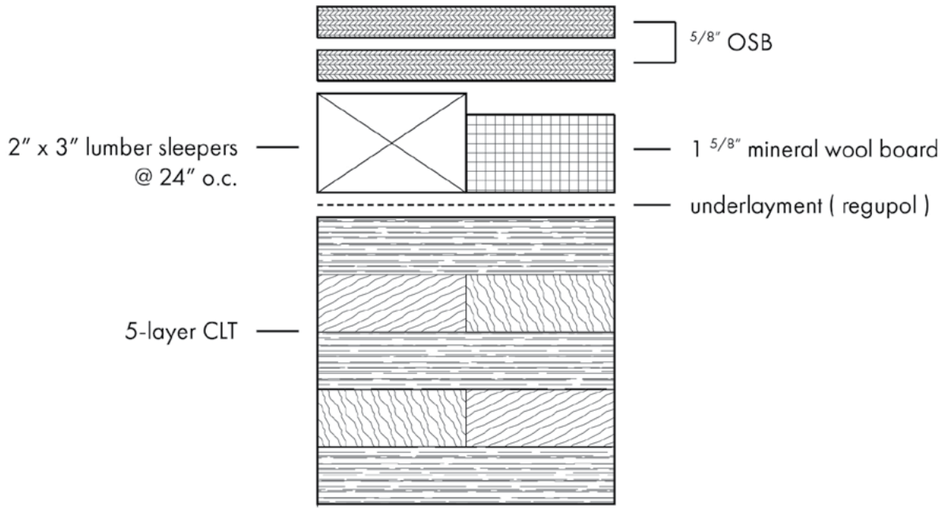
comments
(please feel free to share
comments, thoughts, questions,
reccomendations, etc.)

sources AcoustiTECH Acoustical Guide PDF



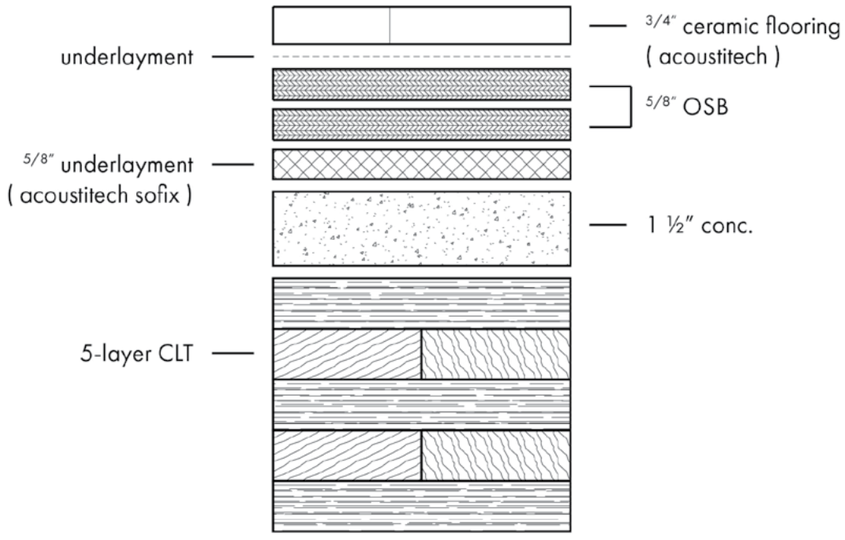
base assembly **floor assembly** wall assembly suggest an assembly

assembly description (top layer - base layer)	5-layer CLT, resilient supports and rails, 7/8" mineral wool, (x2) 1/2" gyp. bd.
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	14.8
sound transmission class rating (STC code minimum 52)	64
impact isolation class (IIC code minimum 52)	59
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	AcoustiTECH Acoustical Guide PDF



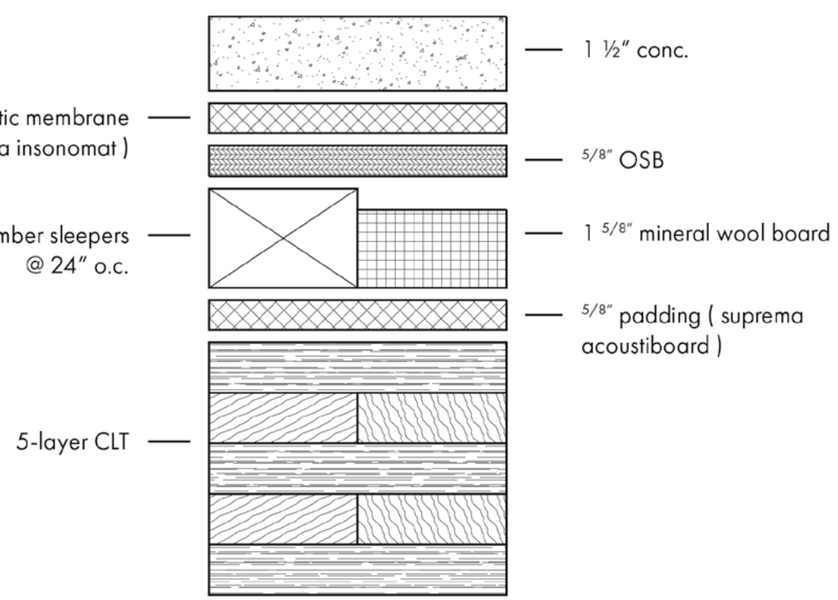
base assembly **floor assembly** wall assembly suggest an assembly

assembly description (top layer - base layer)	(x2) 5/8" OSB, 1 5/8" mineral wool board, lumber sleepers (2" x 3" @ 24" o.c.), underlayment (REGUPOL), 5-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	11.1
sound transmission class rating (STC code minimum 52)	53
impact isolation class (IIC code minimum 52)	45
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	CLT Handbook FPInnovations PDF



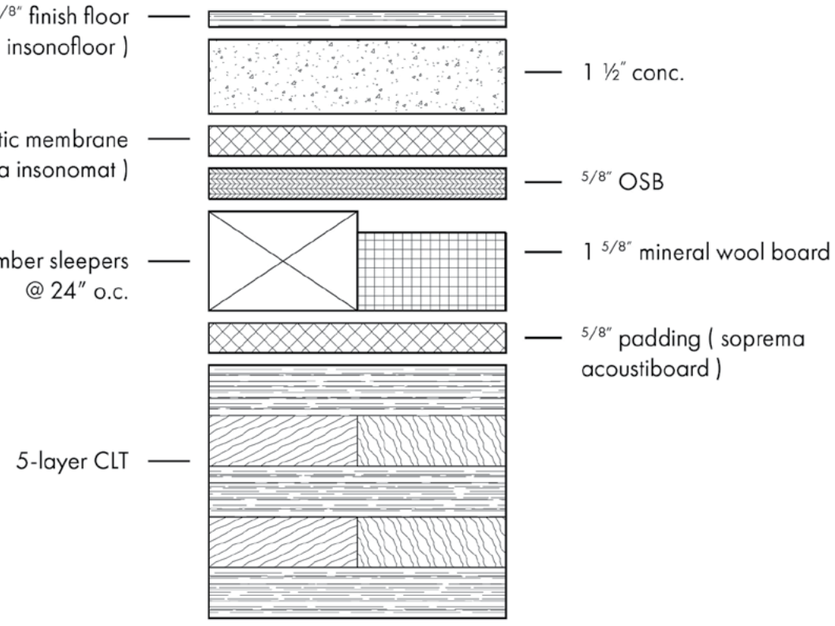
base assembly **floor assembly** wall assembly suggest an assembly

assembly description (top layer - base layer)	3/4" ceramic flooring (acoustiTECH), (x2) 5/8" OSB, 5/8" underlayment (AcoustiTECH SOFIX), 1 1/2" conc., 5-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	9.5
sound transmission class rating (STC code minimum 52)	(untested)
impact isolation class (IIC code minimum 52)	60.1
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	AcoustiTECH Acoustical Guide PDF



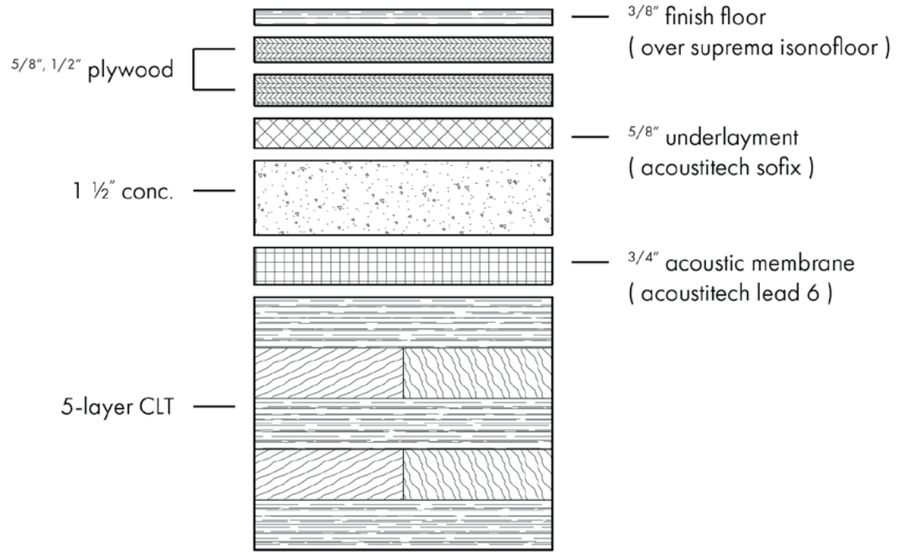
base assembly **floor assembly** wall assembly suggest an assembly

assembly description (top layer - base layer)	1 1/2" conc., 5/8" acoustic membrane (Soprema Insonomat), 5/8" OSB, lumber sleepers (2" x 3" @ 24" o.c.) 1 5/8" mineral wool board, 5/8" padding (Soprema Acoustiboard), 5-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	11.2
sound transmission class rating (STC code minimum 52)	(untested)
impact isolation class (IIC code minimum 52)	56
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	AcoustiTECH Acoustical Guide PDF

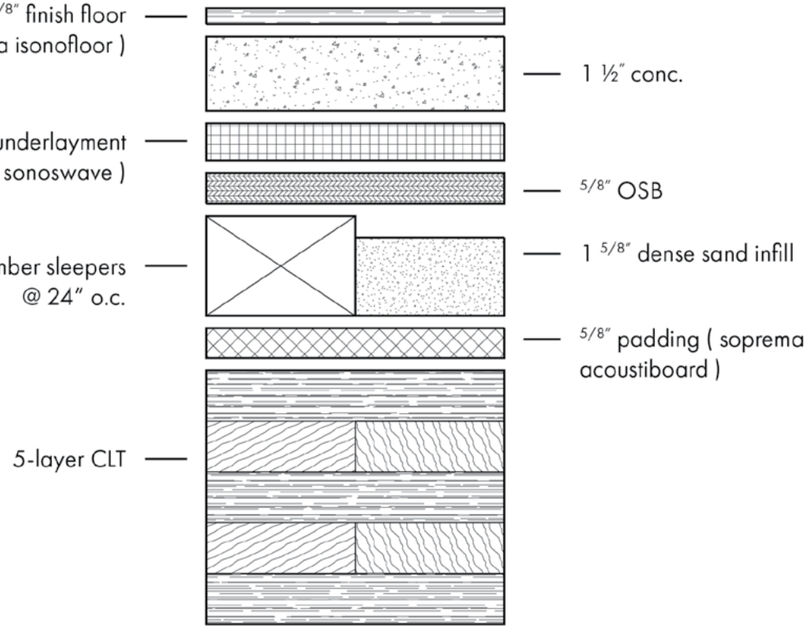


base assembly **floor assembly** wall assembly suggest an assembly

assembly description (top layer - base layer)	3/8" finish floor, acoustic membrane (Soprema Insonofloor), 1 1/2" conc., 5/8" acoustic membrane (Soprema Insonomat), 5/8" OSB, lumber sleepers (2" x 3" @ 24" o.c.) 1 5/8" mineral wool board, 5/8" padding (Soprema Acoustiboard), 5-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	11.4
sound transmission class rating (STC code minimum 52)	(untested)
impact isolation class (IIC code minimum 52)	61
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	AcoustiTECH Acoustical Guide PDF

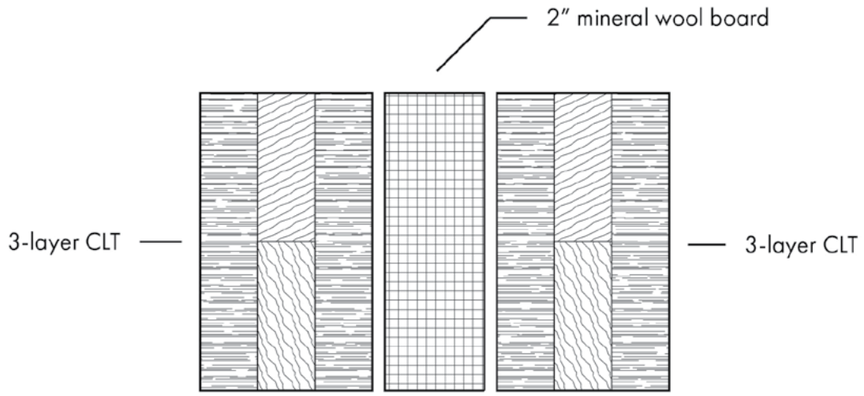


assembly description (top layer - base layer)	3/8" finish floor, acoustic membrane (Soprema Insonofloor), 1/2" plywood, 5/8" plywood, 5/8" underlayment (AcoustiTECH SOFIX), 1 1/2" conc., 3/4" acoustic membrane (AcoustiTECH LEAD 6), 5-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	9.4
sound transmission class rating (STC code minimum 52)	(untested)
impact isolation class (IIC code minimum 52)	58
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	AcoustiTECH Acoustical Guide PDF



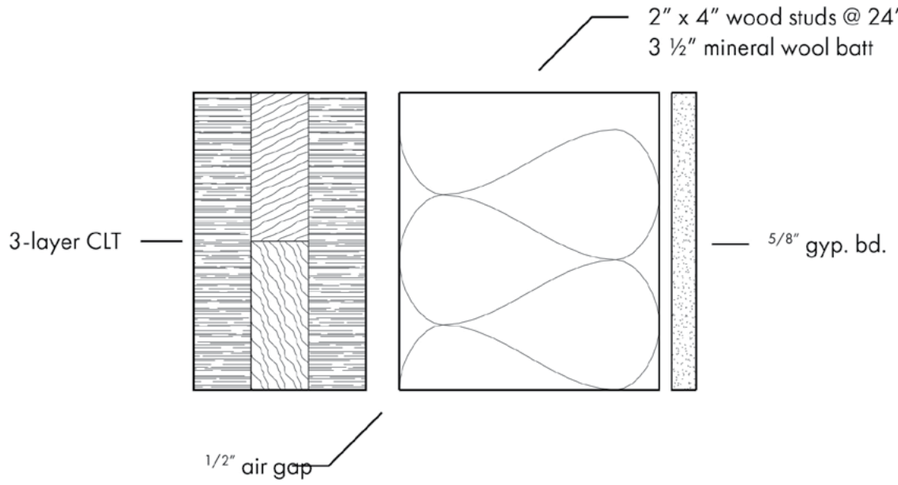
base assembly **floor assembly** wall assembly suggest an assembly

assembly description (top layer - base layer)	3/8" finish floor, acoustic membrane (Soprema Insonofloor), 1 1/2" conc., 3/4" underlayment (Regupol Sonuswave), 5/8" OSB, lumber sleepers (2" x 3" @ 24" o.c.) w/ sand infill, 5/8" padding (Soprema Acoustiboard), 5-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	11.4
sound transmission class rating (STC code minimum 52)	(untested)
impact isolation class (IIC code minimum 52)	64
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	AcoustiTECH Acoustical Guide PDF



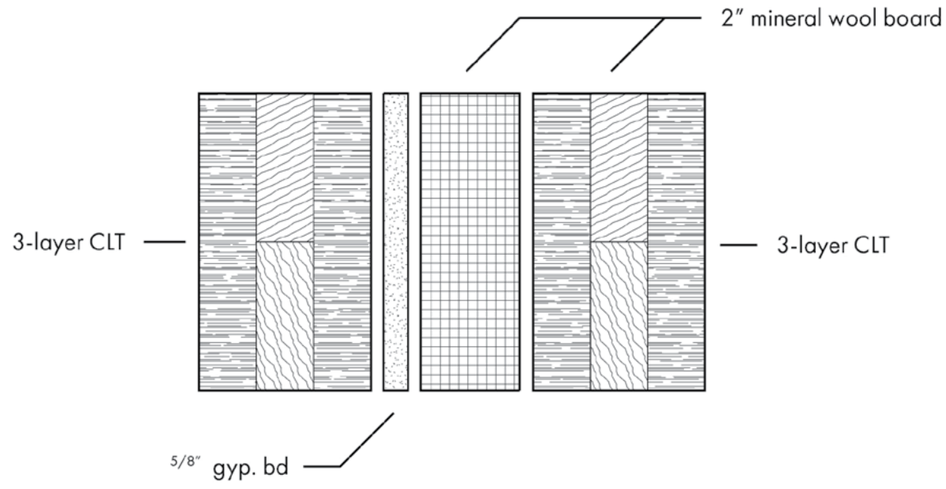
base assembly | floor assembly | **wall assembly** | suggest an assembly

assembly description (top layer - base layer)	3-layer CLT, 2″ mineral wool board, 3-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	10.3
sound transmission class rating (STC code minimum 52)	50
impact isolation class (IIC code minimum 52)	(n/a)
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	CLT Handbook FPInnovations PDF, WoodWorks: The Case for Cross Laminated Timber



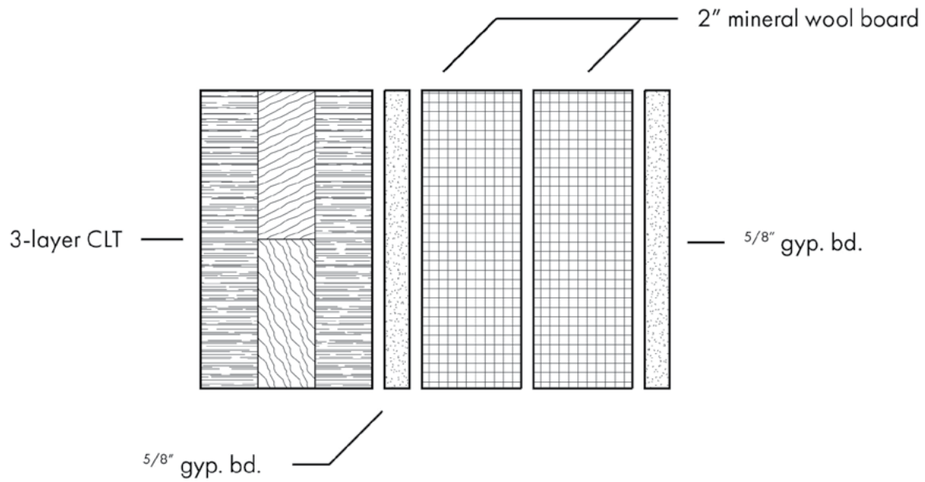
base assembly floor assembly **wall assembly** suggest an assembly

assembly description (top layer - base layer)	3-layer CLT, 1/2" air gap, 2" x 3" wood studs @ 24" o.c., 3 1/2" mineral wool batt, 5/8" gyp. bd.
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	9.8
sound transmission class rating (STC code minimum 52)	47
impact isolation class (IIC code minimum 52)	(n/a)
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	CLT Handbook FPInnovations PDF



base assembly | floor assembly | **wall assembly** | suggest an assembly

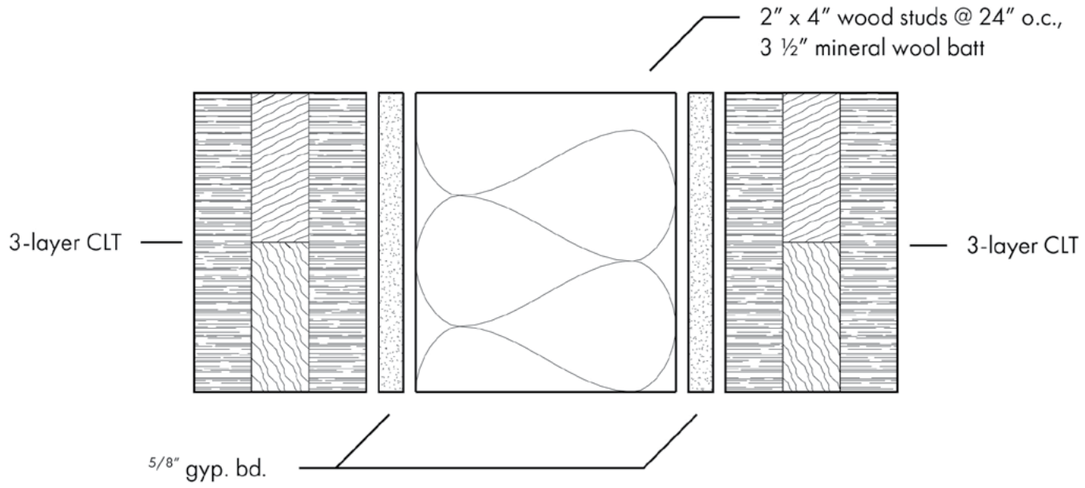
assembly description (top layer - base layer)	3-layer CLT, 5/8" gyp. bd., mineral wool board, 3-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	12.1
sound transmission class rating (STC code minimum 52)	60
impact isolation class (IIC code minimum 52)	(n/a)
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	CLT Handbook FPInnovations PDF



assembly description (top layer - base layer)	3-layer CLT, 5/8″ gyp. bd., (x2) mineral wool board, 5/8″ gyp. bd.
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	8.9
sound transmission class rating (STC code minimum 52)	49
impact isolation class (IIC code minimum 52)	(n/a)
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**

comments
(please feel free to share
comments, thoughts, questions,
reccomendations, etc.)

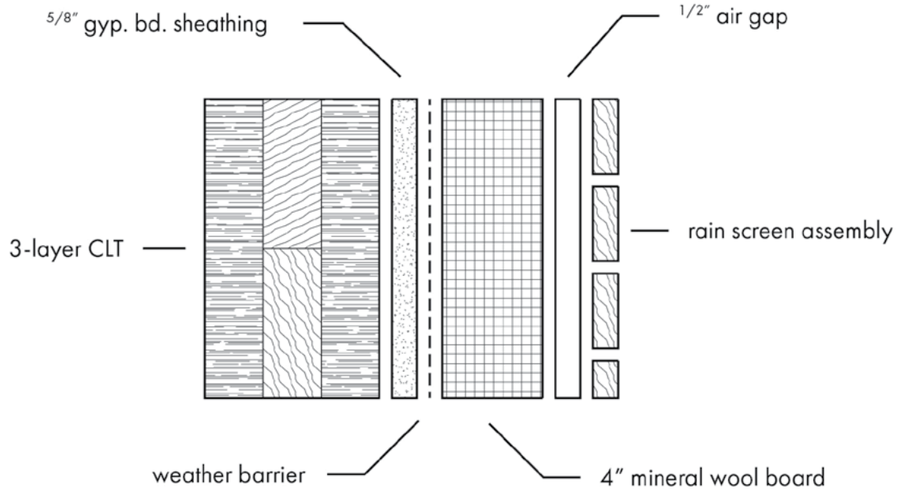
sources



assembly description (top layer - base layer)	3-layer CLT, 5/8" gyp. bd., 2 x 4" typ. stud wall @ 24" o.c., 3 1/2" mineral wool batt between studs, 5/8" gyp. bd., 3-layer CLT
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	11.8
sound transmission class rating (STC code minimum 52)	(untested)
impact isolation class (IIC code minimum 52)	(n/a)
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**

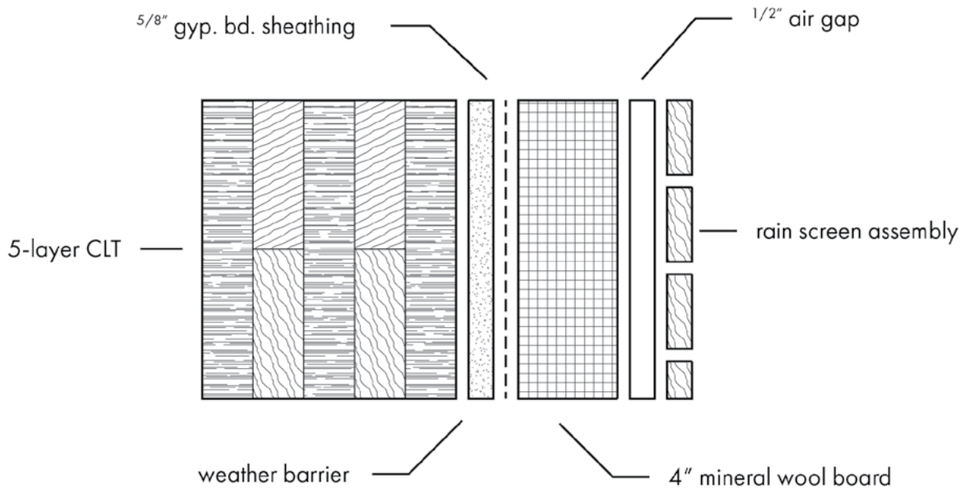
comments
(please feel free to share
comments, thoughts, questions,
reccomendations, etc.)

sources



base assembly | floor assembly | **wall assembly** | suggest an assembly

assembly description (top layer - base layer)	3-layer CLT, 5/8" gyp. bd. sheathing, weather barrier, 4" mineral wool board, air gap, exterior rain screen assembly
cost (material, labor, installed , time)	**$** **$$** **$$$**
constructability (1 - 3) easy - complex	**1** **2** **3**
aesthetic (! - !!!)	**!** **!!** **!!!**
thickness (inches)	13.3
sound transmission class rating (STC code minimum 52)	(untested)
impact isolation class (IIC code minimum 52)	(n/a)
availible in the U.S. (y / n)	**Y** **N**
would you reccomend this assembly? (y / n)	**Y** **N**
comments (please feel free to share comments, thoughts, questions, reccomendations, etc.)	
sources	



base assembly floor assembly **wall assembly** suggest an assembly

assembly description (top layer - base layer)	5-layer CLT, 5/8" gyp. bd., weather barrier, 4" mineral wool board, air gap, rain screen assembly
cost (material, labor, installed , time)	**$ $$ $$$**
constructability (1 - 3) easy - complex	**1 2 3**
aesthetic (! - !!!)	**! !! !!!**
thickness (inches)	14.7
sound transmission class rating (STC code minimum 52)	(untested)
impact isolation class (IIC code minimum 52)	(n/a)
availible in the U.S. (y / n)	**Y N**
would you reccomend this assembly? (y / n)	**Y N**

comments
(please feel free to share
comments, thoughts, questions,
reccomendations, etc.)

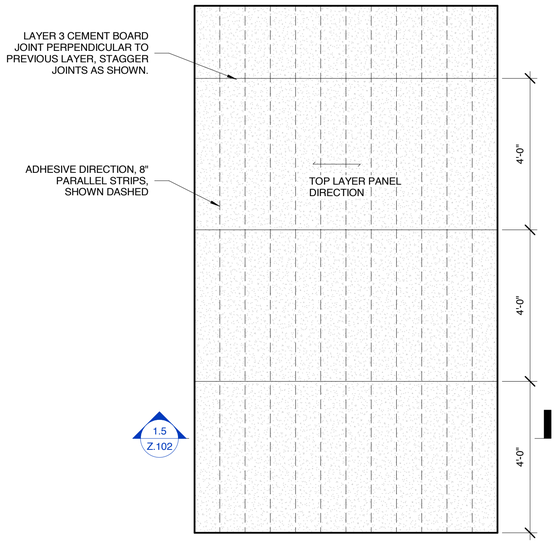
sources

base assembly floor assembly wall assembly **suggest an assembly**

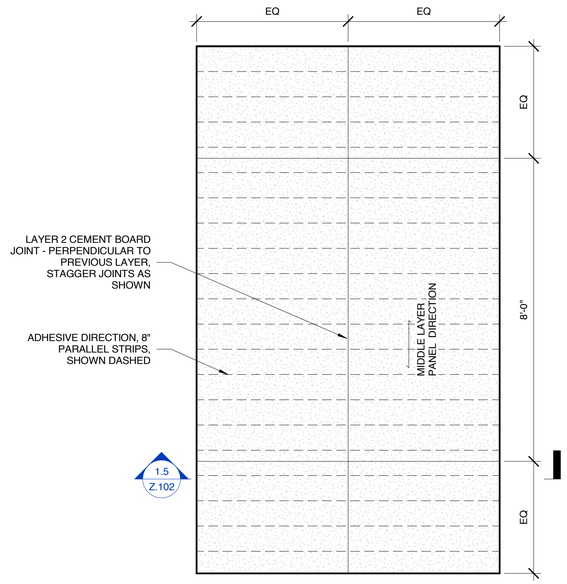
assembly description (top layer - base layer)			
cost (material, labor, installed , time)	**$**	**$$**	**$$$**
constructability (1 - 3) easy - complex	**1**	**2**	**3**
aesthetic (! - !!!)	**!**	**!!**	**!!!**
thickness (inches)			
sound transmission class rating (STC code minimum 52)			
impact isolation class (IIC code minimum 52)			
availible in the U.S. (y / n)	**Y**	**N**	

comments
(please feel free to share
comments, thoughts, questions,
reccomendations, etc.)

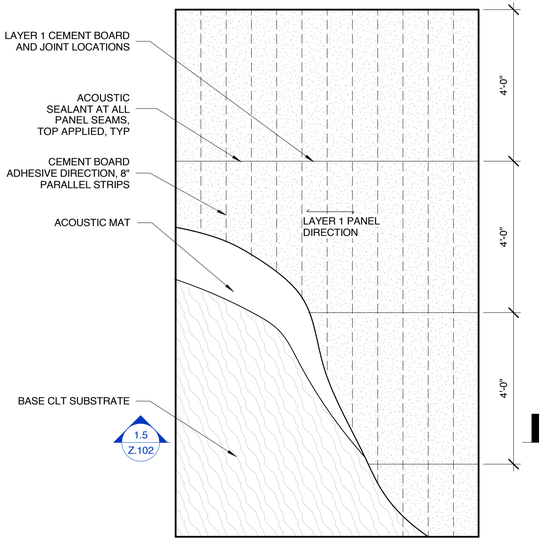
thank you!



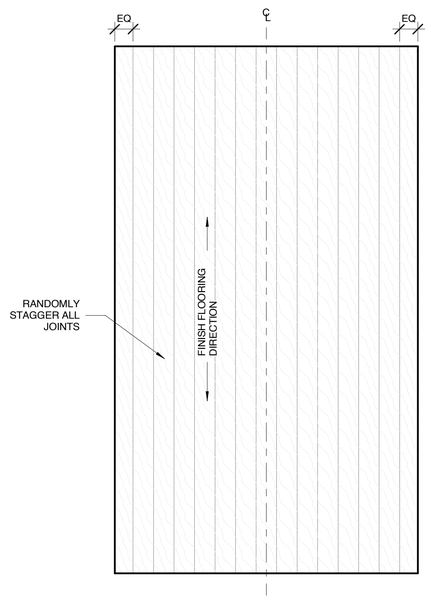
1.13 CEMENT BOARD LAYOUT - LAYER 3
1/2" = 1'-0"



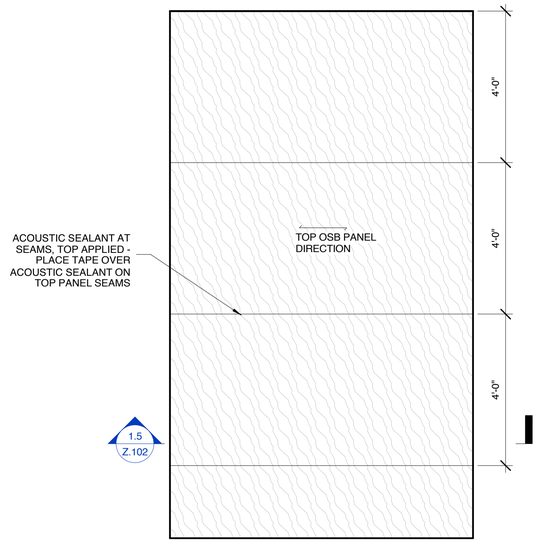
1.12 CEMENT BOARD LAYOUT - LAYER 2
1/2" = 1'-0"



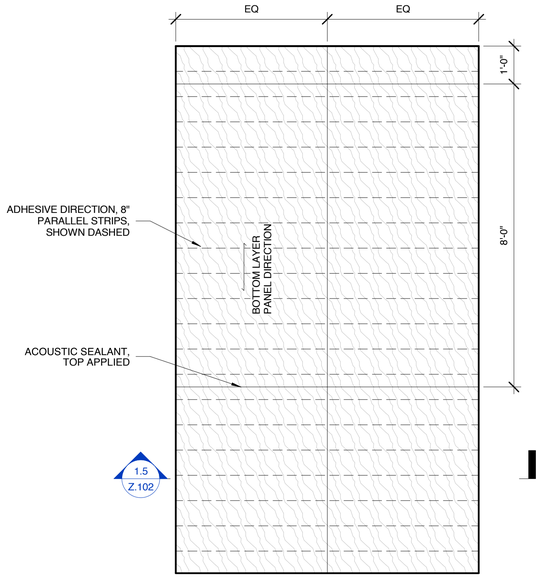
1.11 CEMENT BOARD LAYOUT - LAYER 1
1/2" = 1'-0"



1.2 FLOATING FLOOR LAYOUT PLAN
1/2" = 1'-0"



1.15 OSB LAYOUT - LAYER 2
1/2" = 1'-0"



1.14 OSB LAYOUT - LAYER 1
1/2" = 1'-0"

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UNIVERSITY OF OREGON

ENERGY STUDIES IN BUILDINGS LAB

103 Pacific Hall
University of Oregon
Eugene, Oregon
541 346 5647

Primary Contact: Dale Northcutt
p: 541/ 346-0896

105A White Stag Building
University of Oregon
Portland, Oregon, 97209

Contact: Jason Stenson
p: 503/ 412-3656

Acoustic Lab Testing of Typical Multi-Family Residential CLT Wall and Floor Assemblies

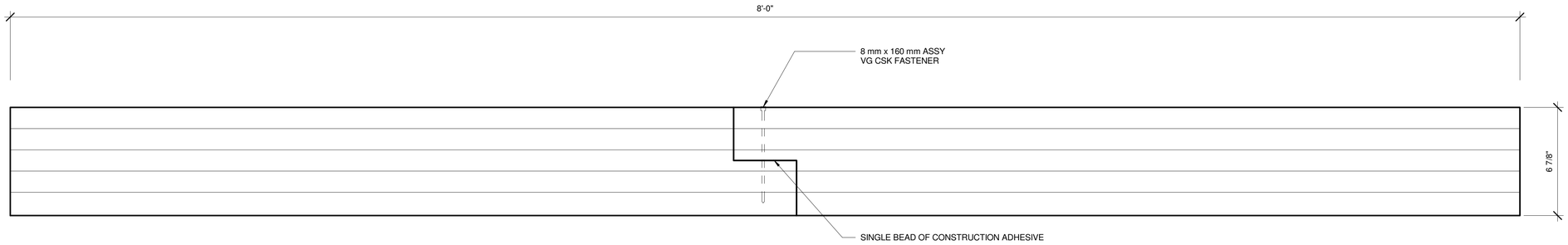
FLOATING FLOOR, CEMENT BOARD PLANS

Z.101

SCALE I 1/2" = 1'-0"

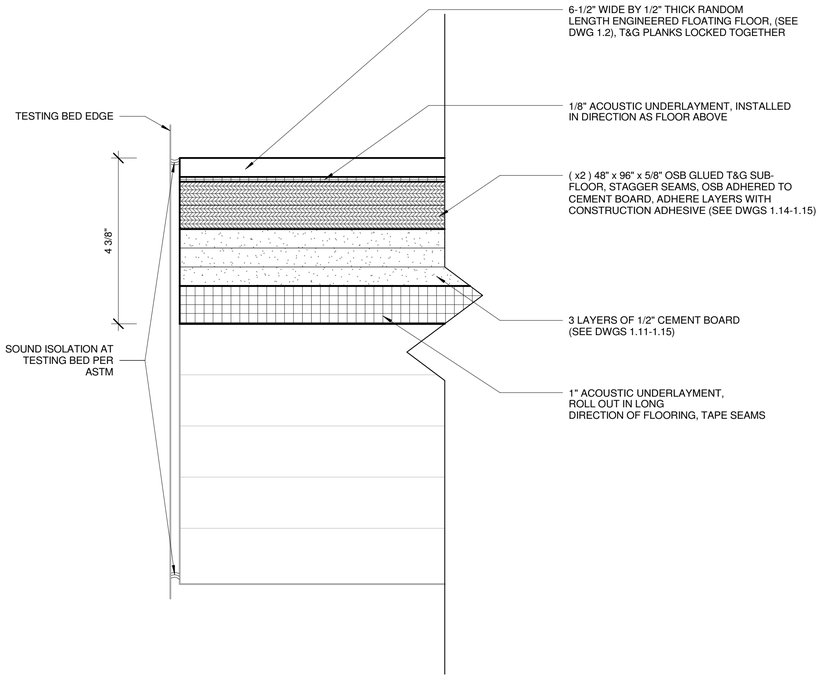
ISSUE DATE I 03.25.2019

AS-BUILT DRAWINGS



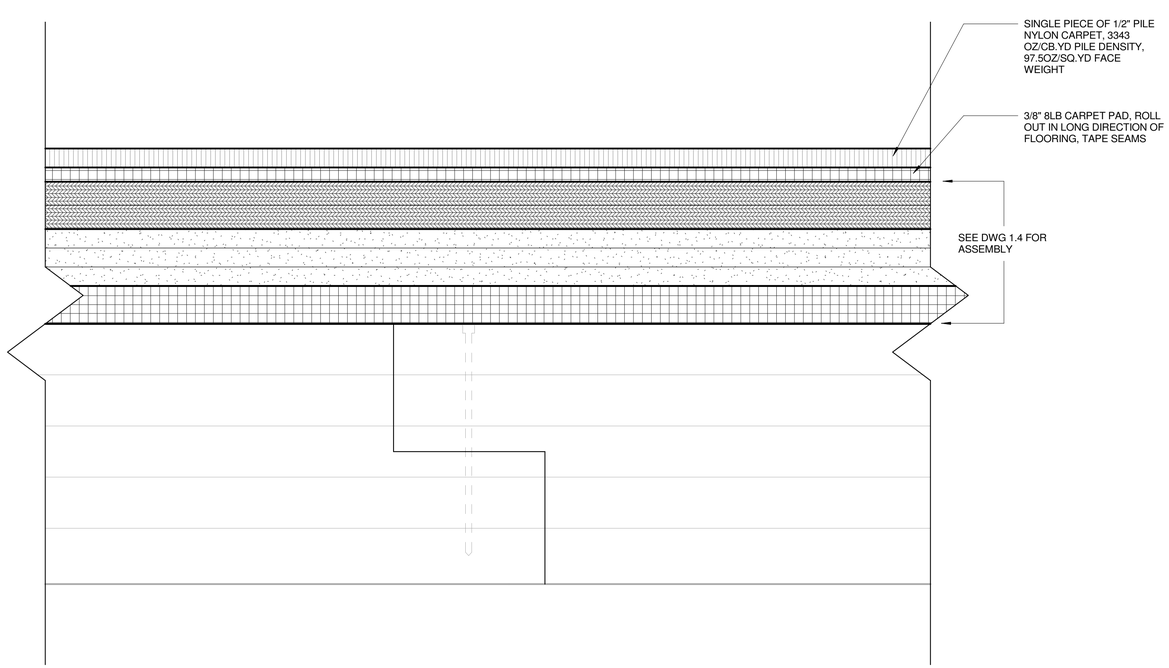
1.3 F04 - 5-LAM BASE CASE CLT SECTION

3" = 1'-0"



1.4 F05 - CEMENT BOARD SECTION

6" = 1'-0"



1.5 F06 - ALTERNATE CARPET ASSEMBLY SECTION

6" = 1'-0"

3/25/2019 8:43:45 AM

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ENERGY STUDIES IN BUILDINGS LAB

103 Pacific Hall
University of Oregon
Eugene, Oregon
541 346 5647

Primary Contact: Dale Northcutt
p: 541/ 346-0896

105A White Stag Building
University of Oregon
Portland, Oregon, 97209

Contact: Jason Stenson
p: 503/ 412-3656

Acoustic Lab Testing of Typical Multi-Family Residential CLT Wall and Floor Assemblies

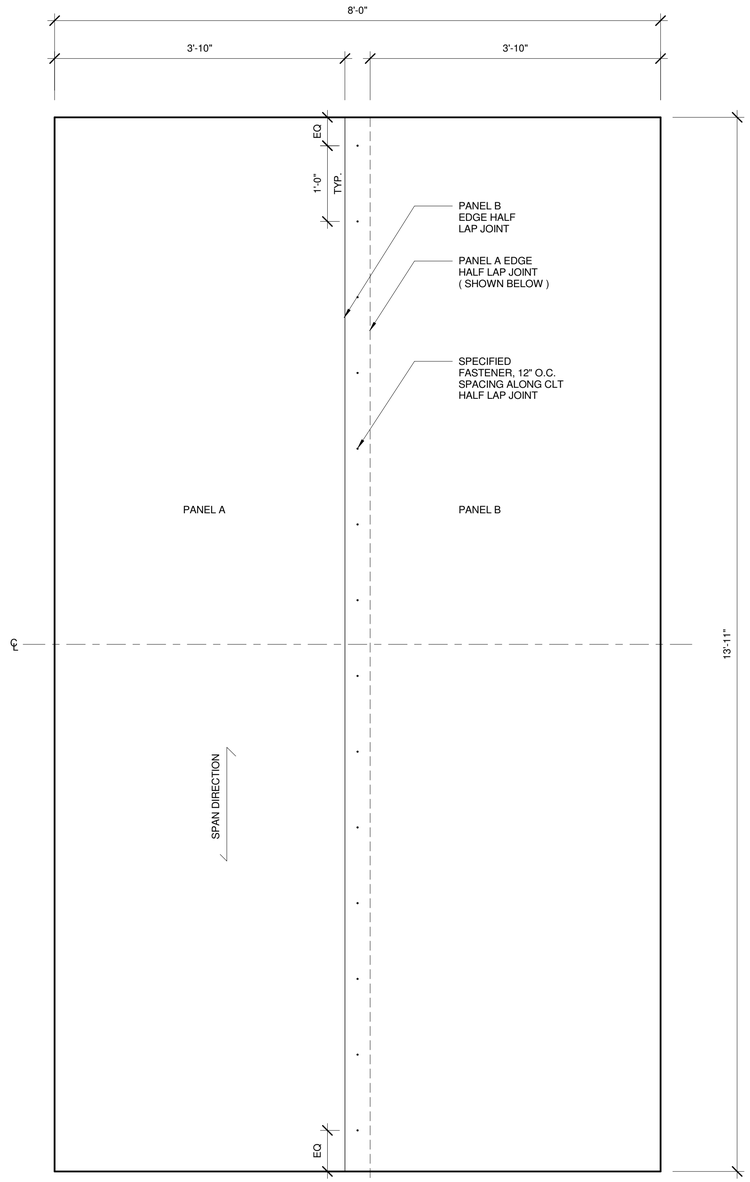
CEMENT BOARD FLOOR SECTIONS

Z.102

SCALE |As indicated

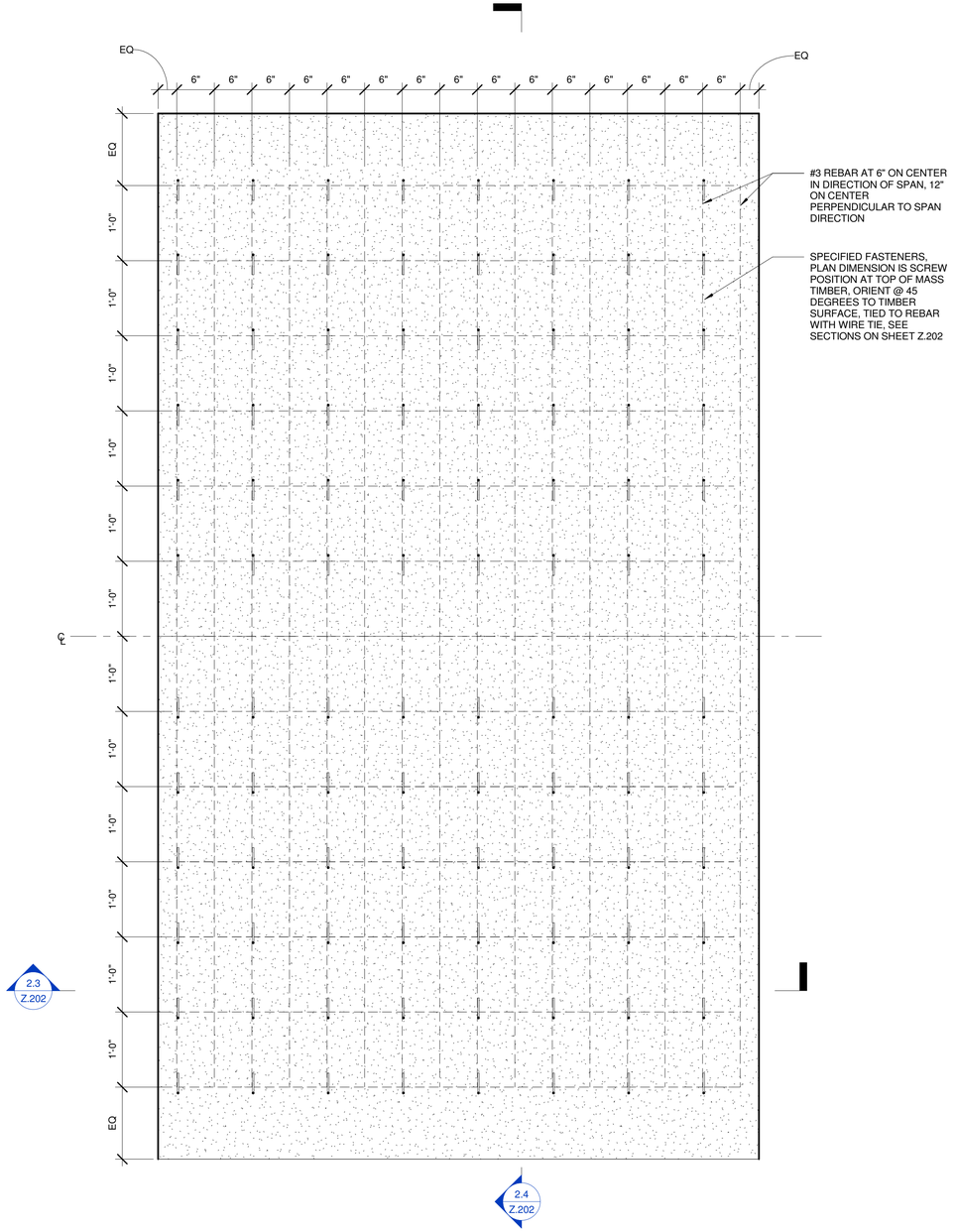
ISSUE DATE | 03.25.2019

AS-BUILT DRAWINGS



2.1 5-LAM BASE CASE CLT PLAN

1" = 1'-0"



2.2 COMPOSITE SLAB W/ STRUCTURAL REBAR REINFORCEMENT PLAN

1" = 1'-0"

3/25/2019 8:43:45 AM

Energy Studies in Buildings Laboratory

UNIVERSITY OF OREGON

ENERGY STUDIES IN BUILDINGS LAB

103 Pacific Hall
University of Oregon
Eugene, Oregon
541 346 5647

Primary Contact: Dale Northcutt
p: 541/ 346-0896

105A White Stag Building
University of Oregon
Portland, Oregon, 97209

Contact: Jason Stenson
p: 503/ 412-3656

Acoustic Lab Testing of Typical Multi-Family Residential CLT Wall and Floor Assemblies

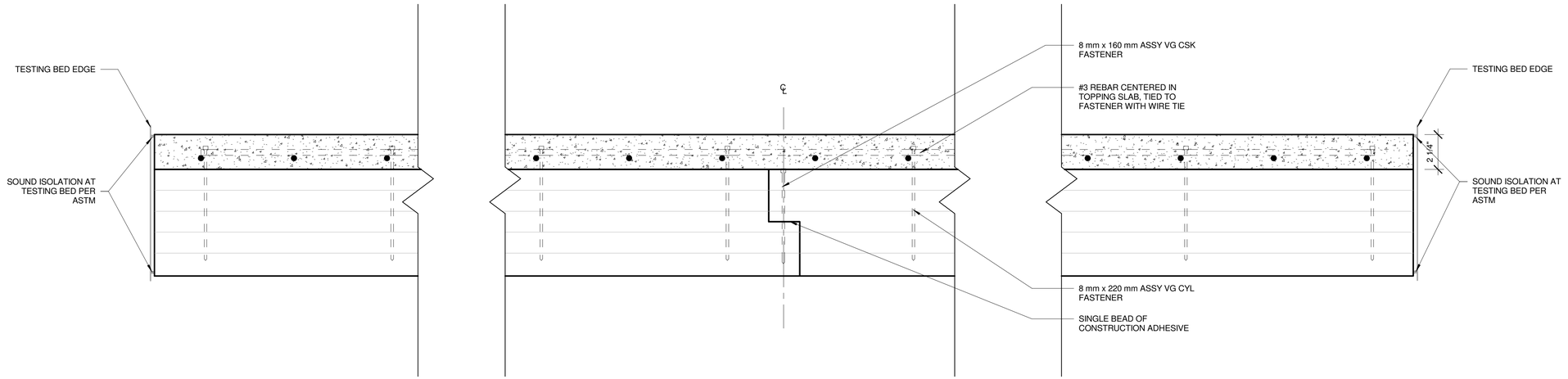
CLT BASE, COMPOSITE ASSEMBLY PLANS

Z.201

SCALE | 1" = 1'-0"

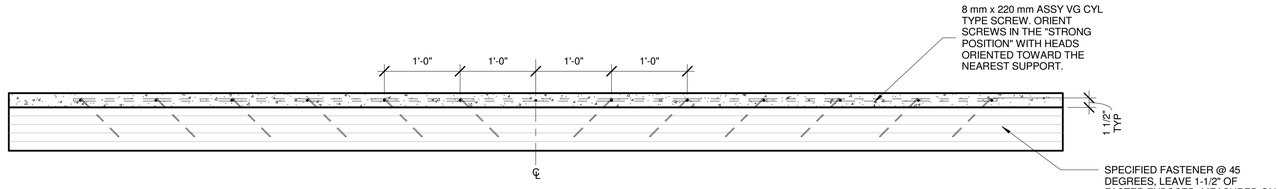
ISSUE DATE | 03.25.2019

AS-BUILT DRAWINGS



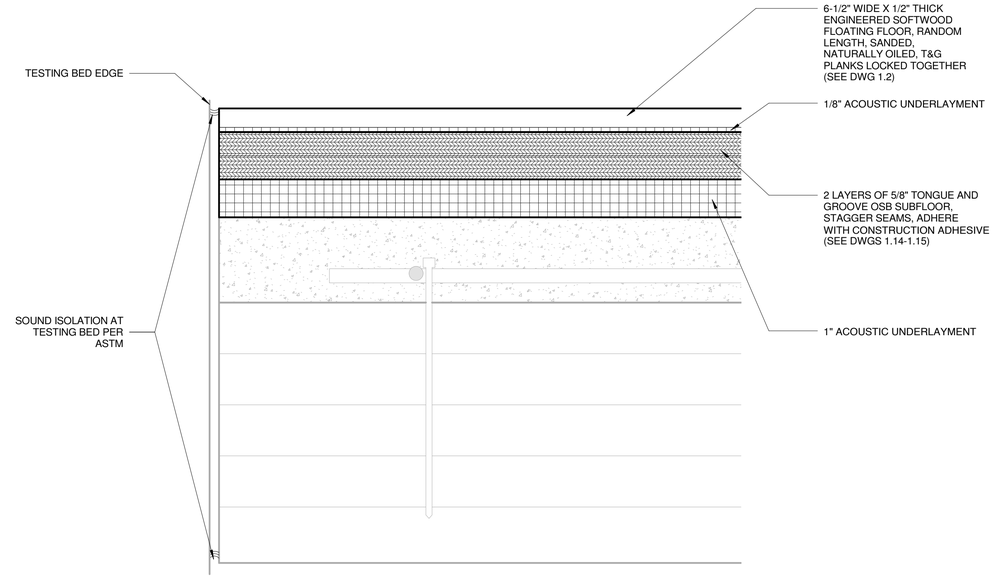
2.3 F01 - COMPOSITE SLAB, LATITUDINAL SECTION

3" = 1'-0"



2.4 F01 - COMPOSITE SLAB, LONGITUDINAL SECTION

1" = 1'-0"



2.5 F03 - ALTERNATE ENGINEERED FLOORING SECTION

6" = 1'-0"

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105A White Stag Building
University of Oregon
Portland, Oregon, 97209

Contact: Jason Stenson
p: 503/ 412-3656

Acoustic Lab Testing of Typical Multi-Family Residential CLT Wall and Floor Assemblies

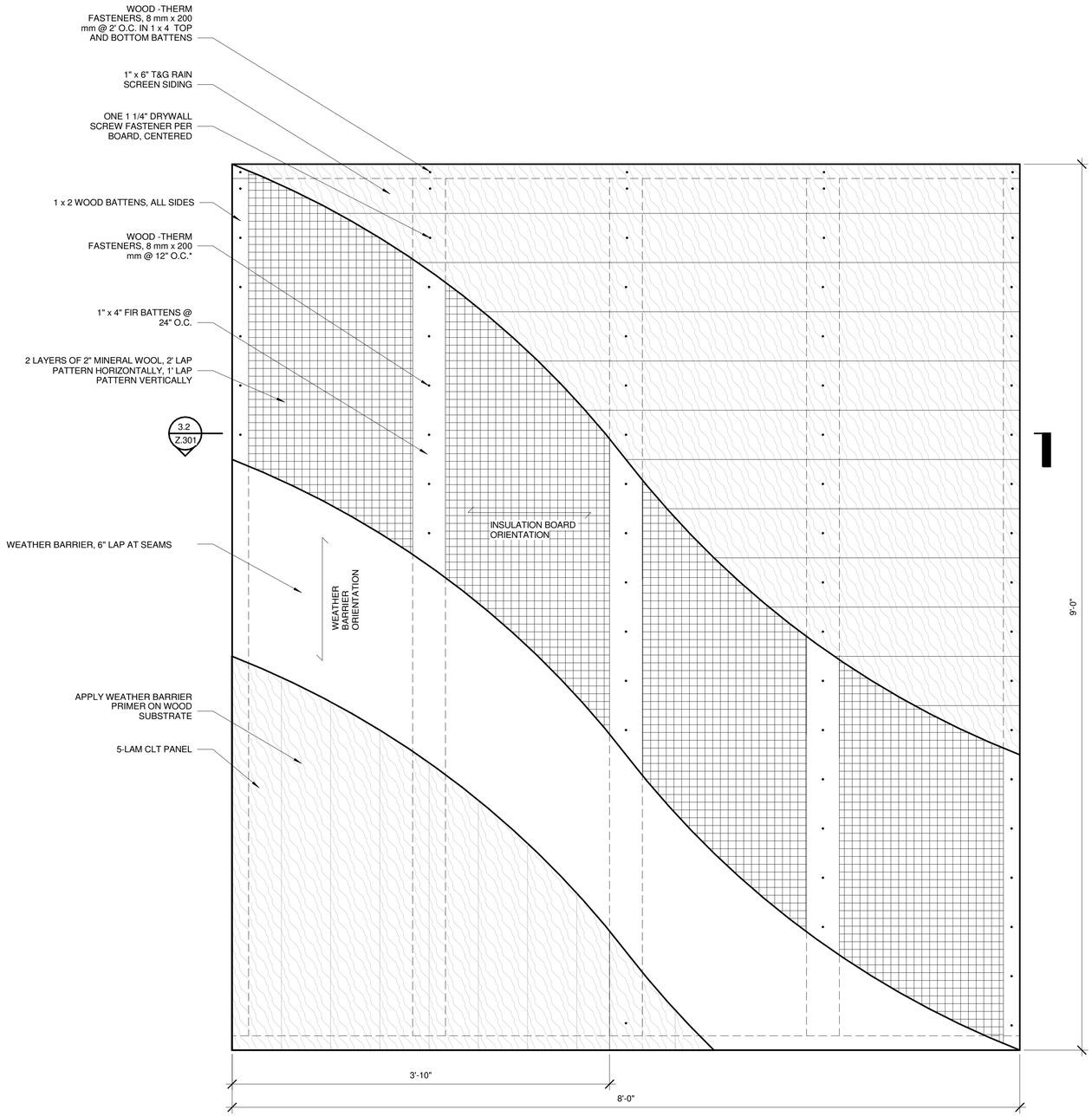
COMPOSITE SLAB FLOOR SECTIONS

Z.202

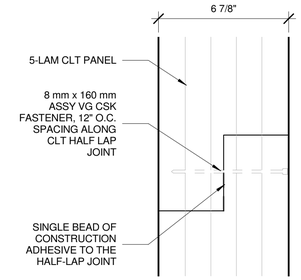
SCALE |As indicated

ISSUE DATE | 03.25.2019

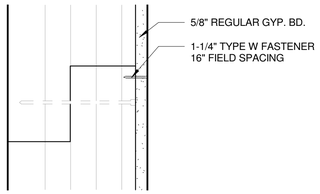
AS-BUILT DRAWINGS



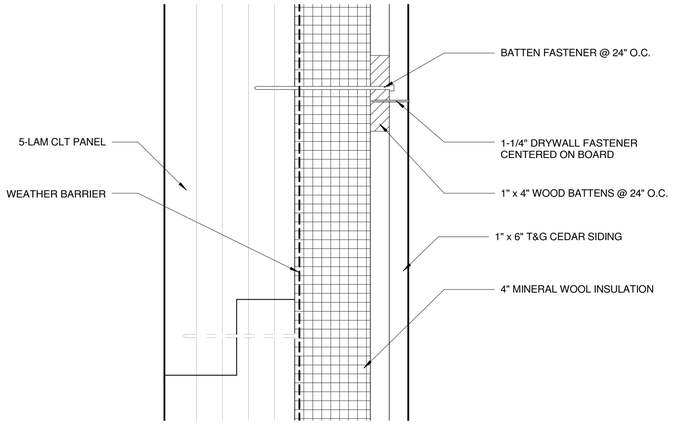
3.1 RAINSCREEN ASSEMBLY PEEL AWAY DIAGRAM
1 1/2" = 1'-0"



W01 W07 - CLT - BASE CASE
3" = 1'-0"



W02 W08 - CLT - SHAFT CASE - PLAN VIEW
3" = 1'-0"



W03 W09 - RAINSCREEN w/o GYP. BD. - PLAN VIEW
3" = 1'-0"

3/25/2019 8:43:46 AM

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University of Oregon
Portland, Oregon, 97209

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p: 503/ 412-3656

Acoustic Lab Testing of Typical Multi-Family Residential CLT Wall and Floor Assemblies

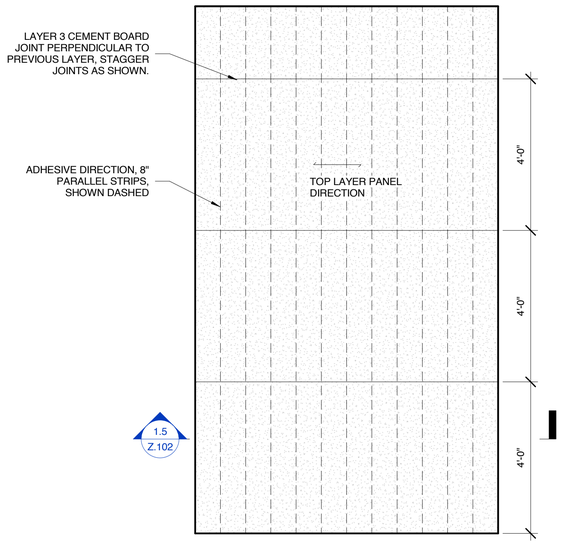
WALL ASSEMBLY, SECTION

Z.301

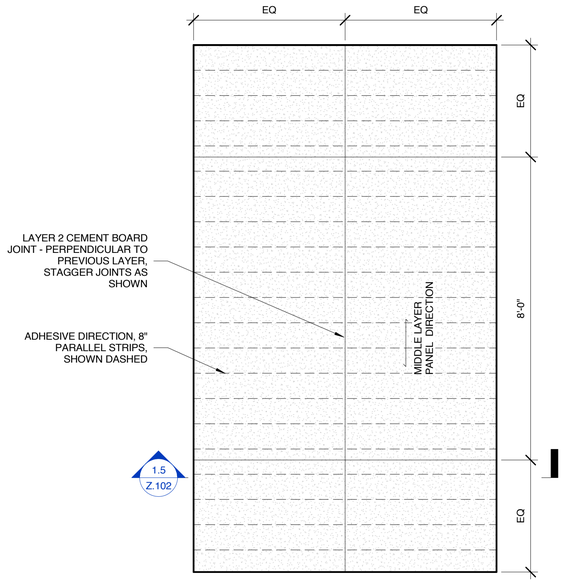
SCALE |As indicated

ISSUE DATE | 03.25.2019

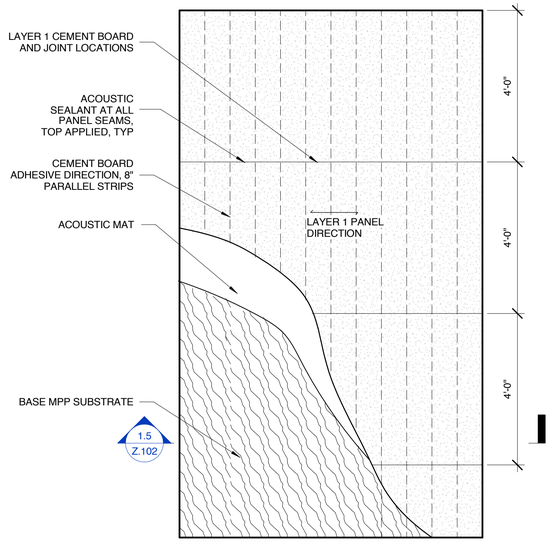
AS-BUILT DRAWINGS



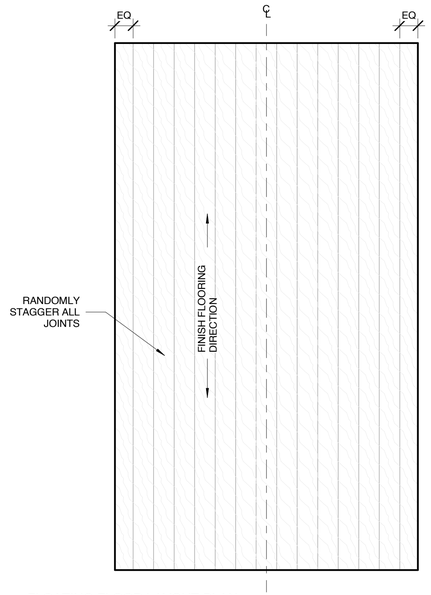
1.13 CEMENT BOARD LAYOUT - LAYER 3
1/2" = 1'-0"



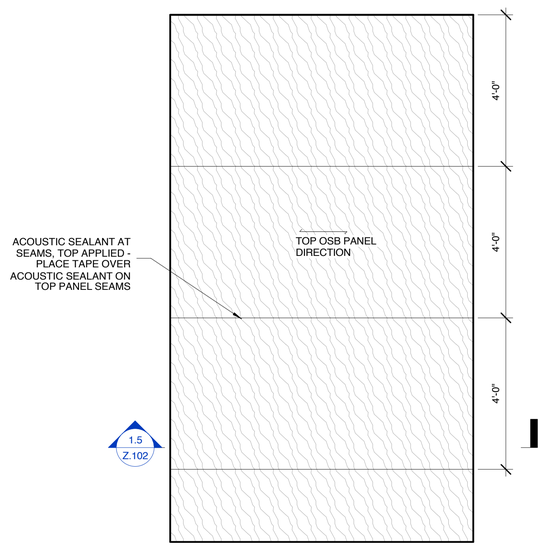
1.12 CEMENT BOARD LAYOUT - LAYER 2
1/2" = 1'-0"



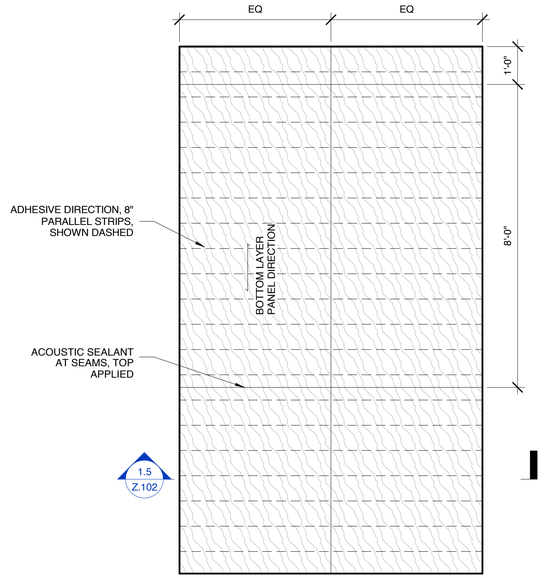
1.11 CEMENT BOARD LAYOUT - LAYER 1
1/2" = 1'-0"



1.2 FLOATING FLOOR LAYOUT PLAN
1/2" = 1'-0"



1.15 OSB LAYOUT - LAYER 2
1/2" = 1'-0"



1.14 OSB LAYOUT - LAYER 1
1/2" = 1'-0"

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University of Oregon
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p: 503/ 412-3656

Acoustic Lab Testing of Typical Multi-Family Residential MPP Wall and Floor Assemblies

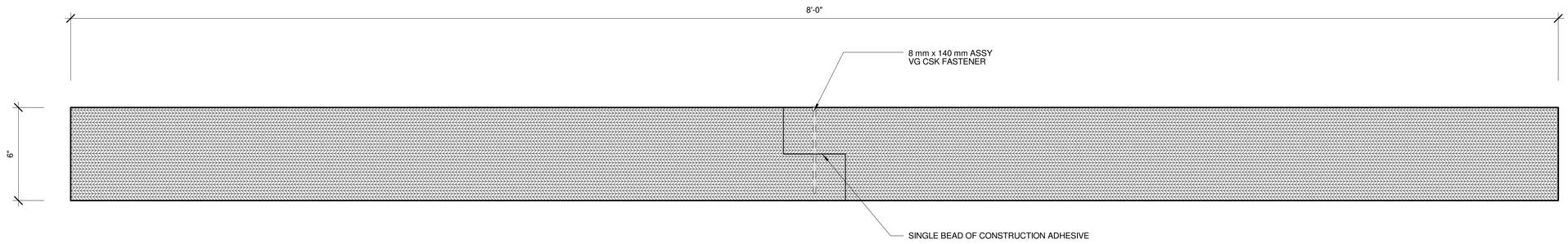
FLOATING FLOOR, CEMENT BOARD PLANS

Z.101

SCALE I 1/2" = 1'-0"

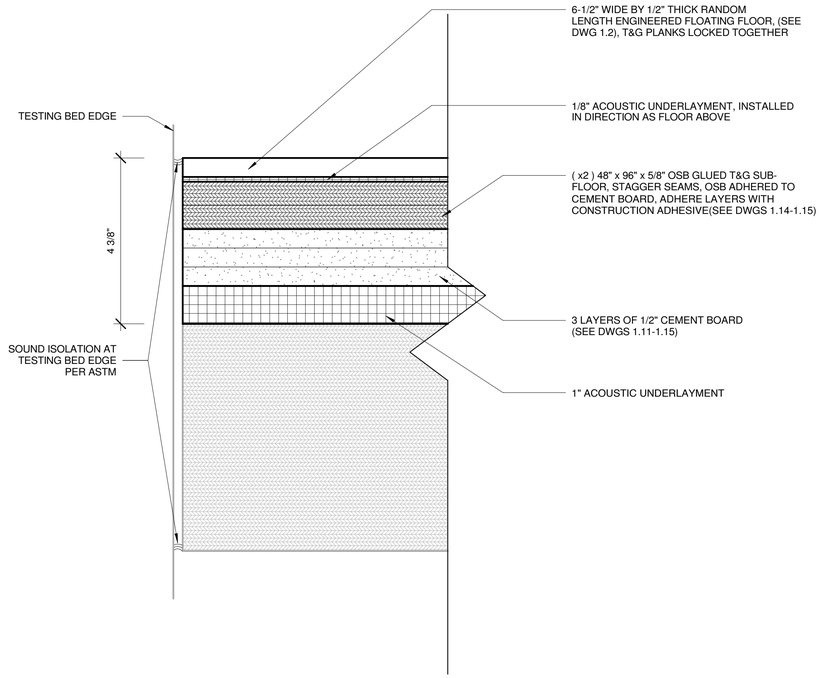
ISSUE DATE I 03.25.2018

AS-BUILT DRAWINGS



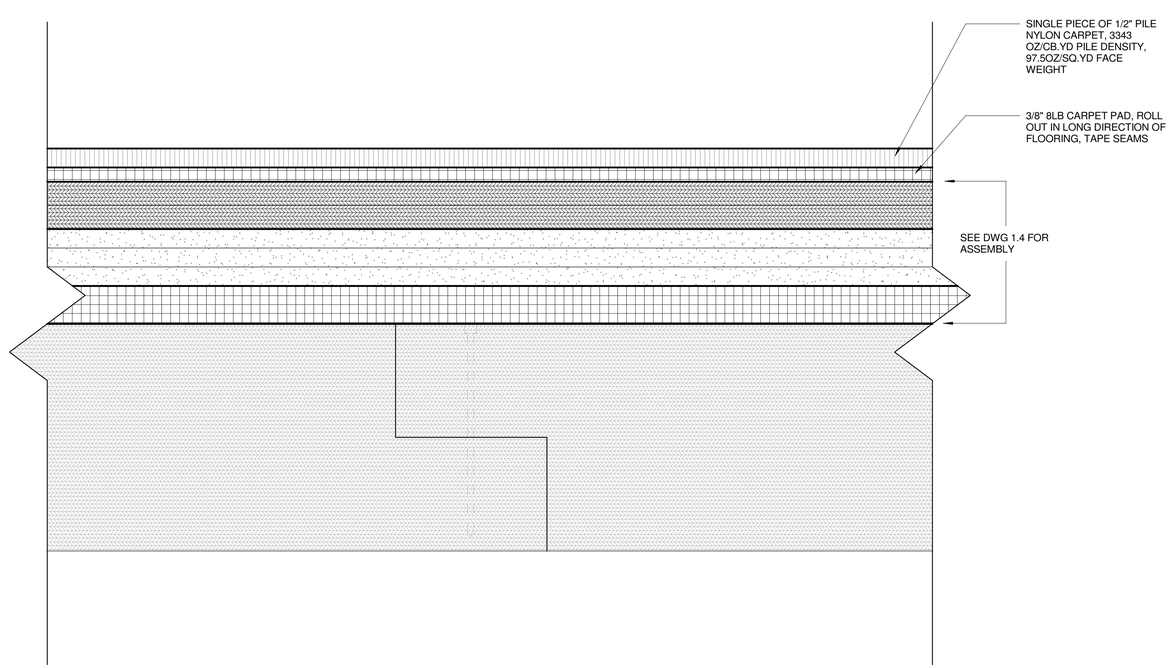
1.3 F04 - 6" MPP BASE CASE SECTION

3" = 1'-0"



1.4 F05 - CEMENT BOARD SECTION

6" = 1'-0"



1.5 F06 - ALTERNATE CARPET ASSEMBLY SECTION

6" = 1'-0"

3/25/2019 8:40:49 AM

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105A White Stag Building
University of Oregon
Portland, Oregon, 97209

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p: 503/ 412-3656

Acoustic Lab Testing of Typical Multi-Family Residential MPP Wall and Floor Assemblies

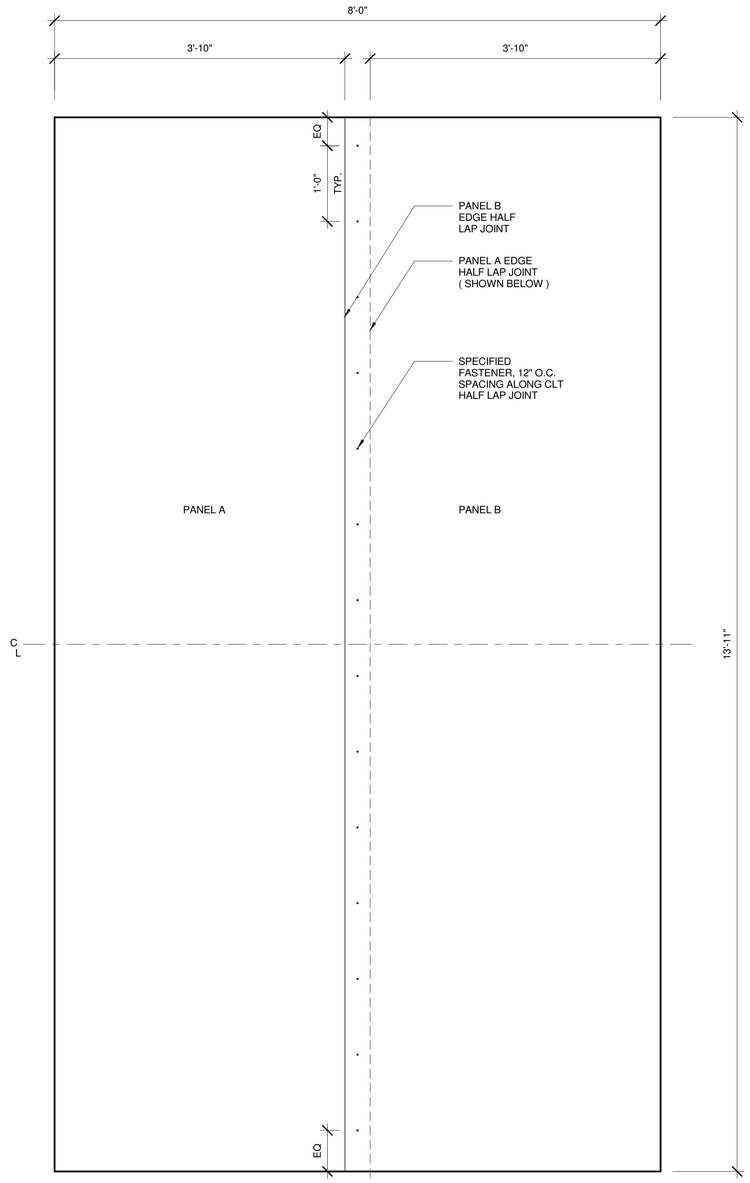
CEMENT BOARD FLOOR SECTIONS

Z.102

SCALE |As indicated

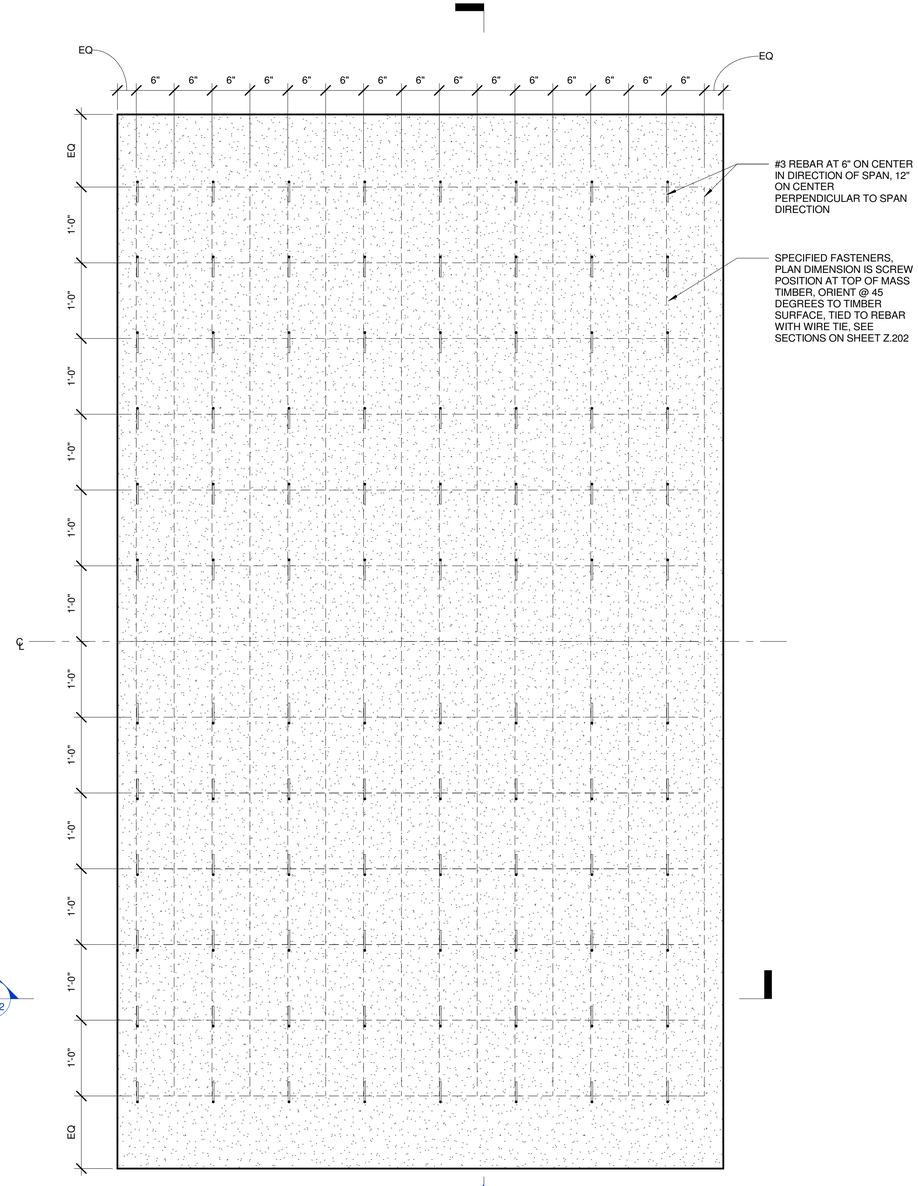
ISSUE DATE | 03.25.2018

AS-BUILT DRAWINGS



2.1 6" MPP BASE CASE PLAN

1" = 1'-0"



2.2 COMPOSITE SLAB W/ STRUCTURAL REBAR REINFORCEMENT PLAN

1" = 1'-0"

3/25/2019 8:40:50 AM

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p: 541/ 346-0896

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University of Oregon
Portland, Oregon, 97209

Contact: Jason Stenson
p: 503/ 412-3656

Acoustic Lab Testing of Typical Multi-Family Residential MPP Wall and Floor Assemblies

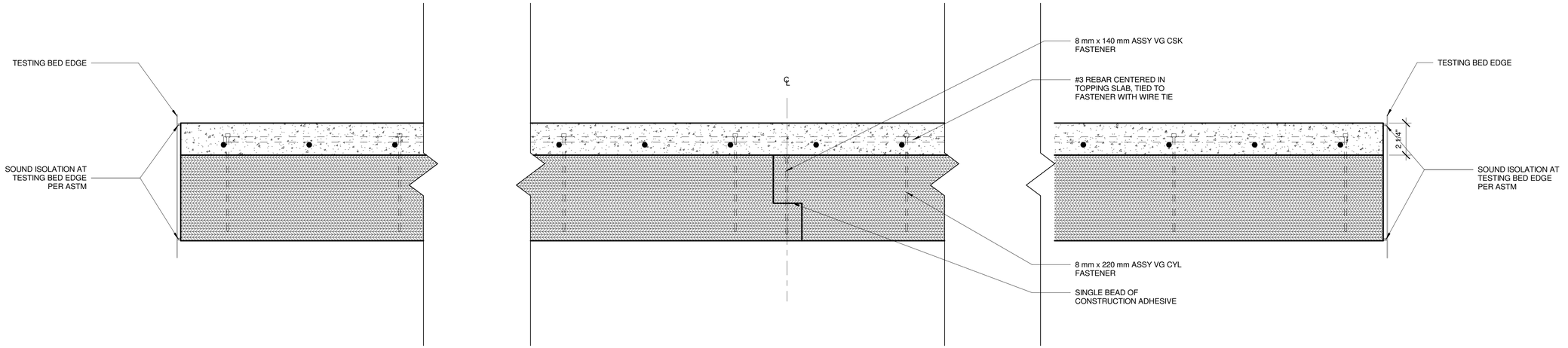
MPP BASE, COMPOSITE ASSEMBLY PLANS

Z.201

SCALE | 1" = 1'-0"

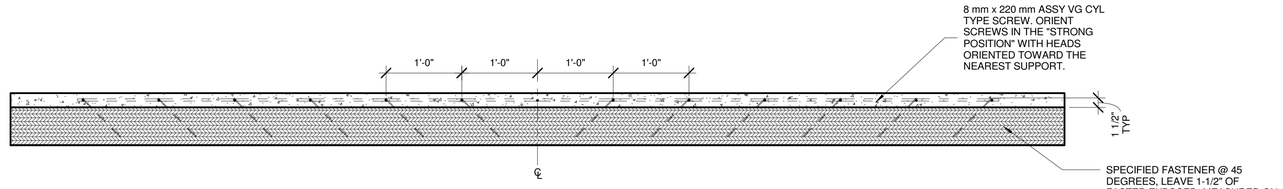
ISSUE DATE | 03.25.2018

AS-BUILT DRAWINGS



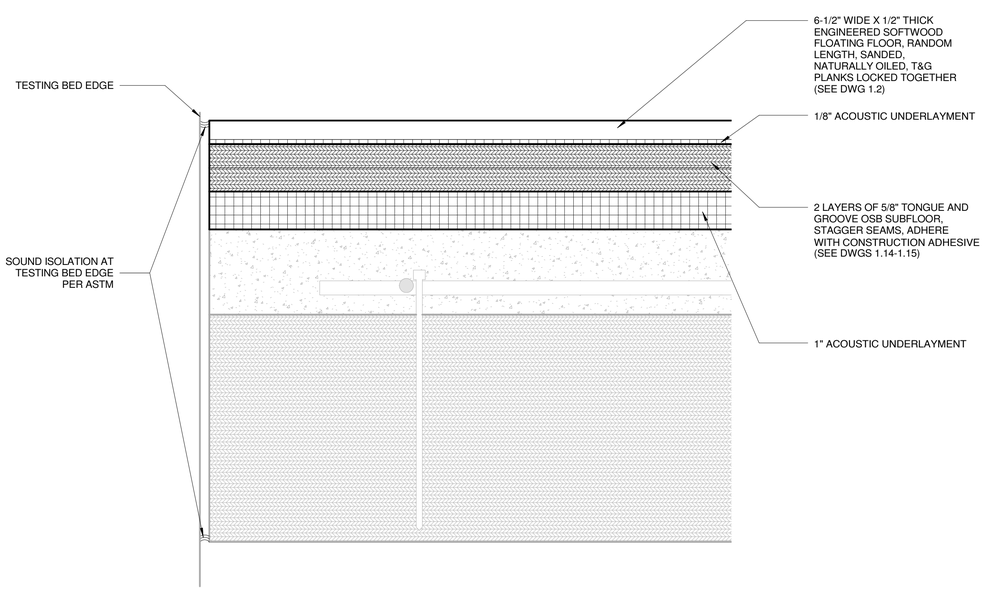
2.3 F01 - COMPOSITE SLAB, LATITUDINAL SECTION

3" = 1'-0"



2.4 F01 - COMPOSITE SLAB, LONGITUDINAL SECTION

1" = 1'-0"



2.5 F03 - ALTERNATE ENGINEERED FLOORING SECTION

6" = 1'-0"

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Acoustic Lab Testing of Typical Multi-Family Residential MPP Wall and Floor Assemblies

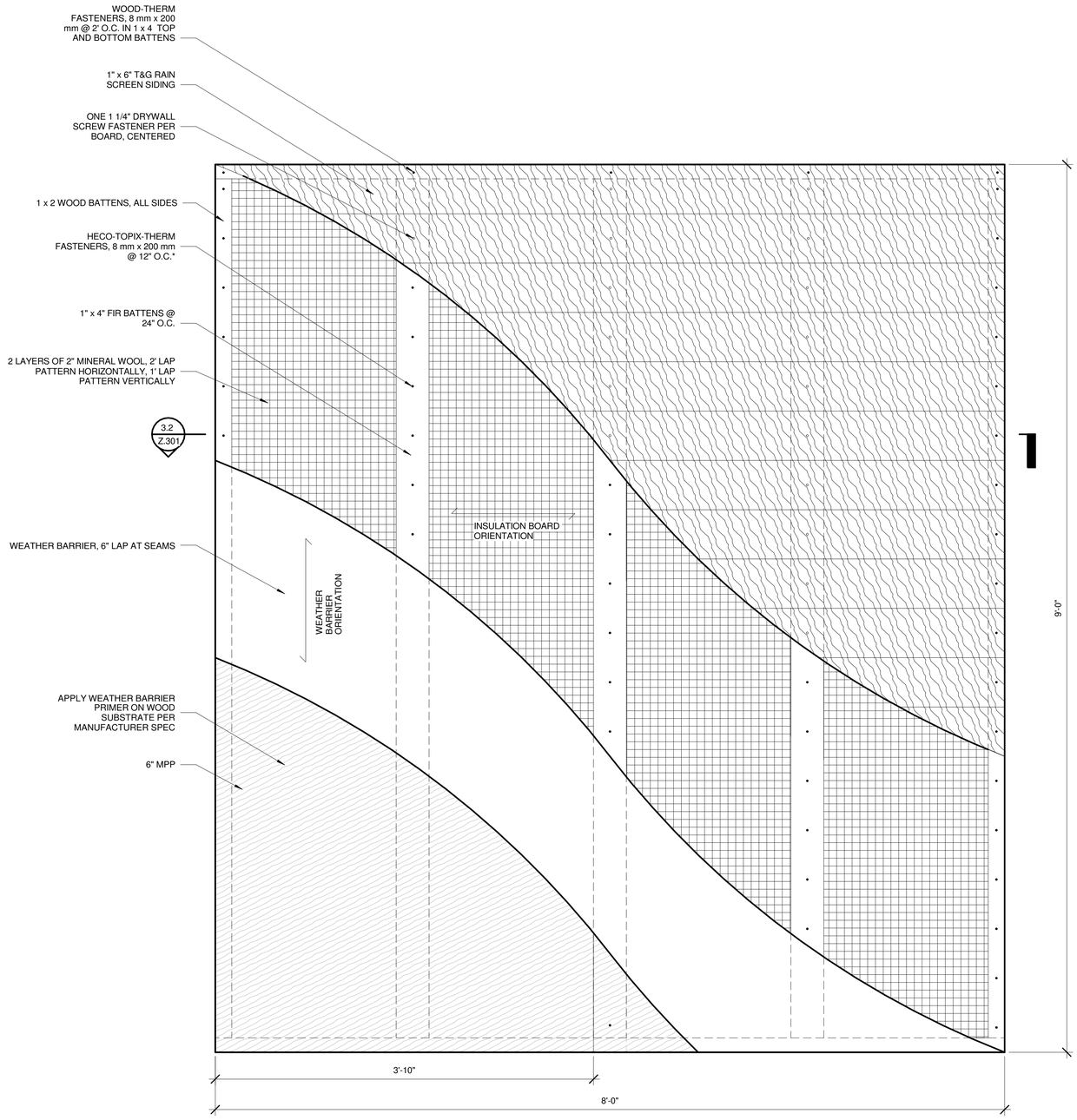
COMPOSITE SLAB FLOOR SECTIONS

Z.202

SCALE |As indicated

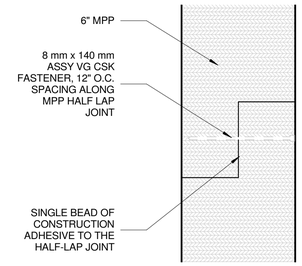
ISSUE DATE | 03.25.2018

AS-BUILT DRAWINGS



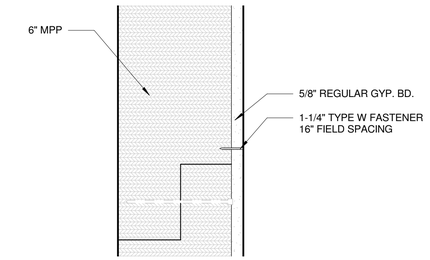
3.1 RAINSCREEN ASSEMBLY PEEL AWAY DIAGRAM

1 1/2" = 1'-0"



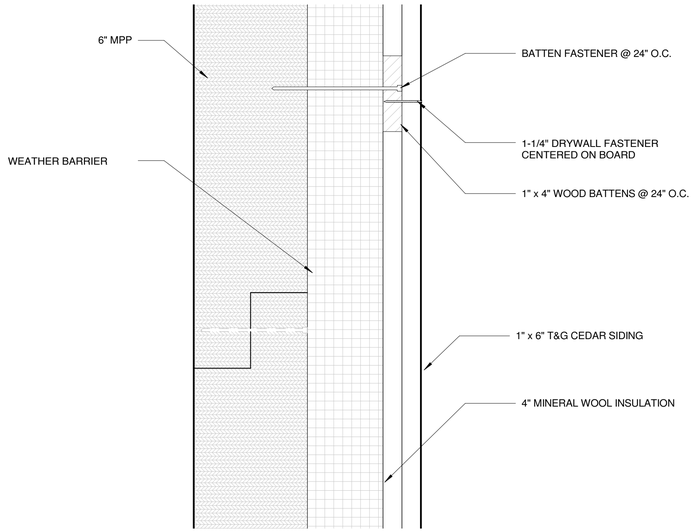
3.2 W07 - MPP BASE CASE - PLAN VIEW

3" = 1'-0"



3.3 W08 - MPP SHAFT CASE - PLAN VIEW

3" = 1'-0"



3.4 W09 - RAINSCREEN w/o GYP. BD. - PLAN VIEW

3" = 1'-0"

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Acoustic Lab Testing of Typical Multi-Family Residential MPP Wall and Floor Assemblies

WALL ASSEMBLY, SECTION

Z.301

SCALE |As indicated

ISSUE DATE | 03.25.2018

AS-BUILT DRAWINGS