# Acoustic Testing of CLT Composite Floor Assemblies for TMBR© Minneapolis

D/O
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in collaboration with

SOM

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## 1.0 Introduction

Mass timber buildings (Glulam/CLT/DLT) have received notable media attention recently because they sequester carbon emissions using a rapidly renewable resource, yielding buildings that can be erected as fast or faster than those made of concrete or steel. The industry is growing in response to the demand for sustainable building materials.

Current impediments to greater growth of mass timber include: the potential economic effects of a limited number of clustered product suppliers (10 currently in the North America), unfamiliarity in the engineering and architecture communities, and limitations placed on the size and height of structures by the International Building Code.[1]

Figure 1: Mass timber manufacturers in North America (2019)

On the plus side, new mass timber suppliers such as Vaagen Timbers and DR Johnson are coming online alongside national branding campaigns for mass timber structures such as T3 and now TMBR©, which is a signal that capital investment is increasing in mass timber products and engineering. Even the codes are changing: the 2021 International Building Code now contains new sections specific to mass timber that allow larger and taller mass timber buildings. For the trend to continue, however, the mass timber movement needs to scale up and become viable for a variety of building types to expand its market.

In recent days, media attention is focused on projects pushing the boundaries of height and area for mass timber—office towers and high-rise residential. This paper explores what the inspiring images do not convey—the challenge of acoustically isolating stacked living spaces in a multi-family timber structure. Solving a number of acoustical challenges extends the reach of mass timber into new building programs.

[1] For architects and engineers working on mass timber projects, WoodWorks is a free design assistance and education resource. See woodworks.org.

## The Acoustics of Wood (simplified)

Sound is a disturbance that moves through a medium in waves. Different mediums conduct sound with different speeds and efficiencies according to their makeup. Air, for example, is a prevalent medium for sound. A sound wave in air is propagated by air molecules that are displaced a small amount by the positive and negative pressure fluctuations of the sound wave. This is like spectators in a sports stadium who are displaced when they perform “the wave” with all of the other fans. Note that no single spectator is carried by the wave—each person stands at the peak of the wave for only for a moment as the wave passes. Air molecules behave in an analogous way. Since air is a gas, the molecules float freely and are separated from each other far more than molecules in a solid form. This makes air a relatively poor conductor for sound when compared to water, or wood. To return to the stadium analogy for a moment: air has fewer spectators to conduct the wave.

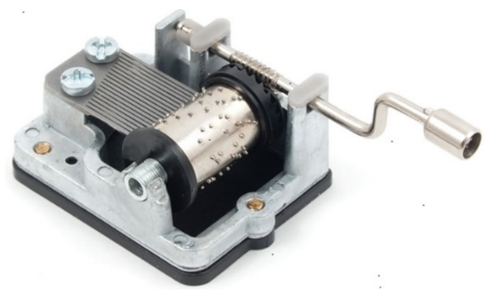


Figure 2: Music box

The poor conductivity of air is easily demonstrated by cranking a music box toy on different surfaces and comparing the sound levels.[2] The sound levels are noticeably higher when the music box rests on a table top than when it is held in hand. Wood is an excellent sound conductor for the following reason: wood is light and elastic. Not all woods are good sound conductors. Consider the limited range of wood species used for music instruments—spruce, mahogany, rosewood, or maple for example. These woods are not dense, but they are strong. The wood species used in mass timber are similar in nature—fir, spruce, and pine are all softwoods which are light, strong, and flexible.

Isolating the wood structure and the walls separating dwelling units from interior *airborne* sound is a central part of any strategy to isolate sounds within a wood structure. A complete strategy also includes measures to isolate the wood structure from *direct impact sound* created by humans in motion, which is sometimes referred to as footfall. To put a metric on airborne and direct impact sound isolation, the building industry (including building codes) has established parameters to express the ability of an assembly to limit sound transmission, STC and IIC:

a. **STC:** The capability of an assembly to reduce airborne sound transmission is the **Sound Transmission Class (STC)** (such as walls, floor, ceiling, or doors).

[2] As demonstrated to D/O Architects by Anthony Shou of Kirkegaard Associates Acoustical Engineers

b. **IIC:** The capability of an assembly to reduce impact noise is the **Impact Isolation Class (IIC)**.

There are two other key concepts worth mentioning that do not have a dedicated grade, but are very important in detailing connections between elements. Flanking sound is sound transmission around the perimeter of, or through penetrations in an assembly. Structure-borne sound is sound transmission through multiple assemblies, such as when a piece of vibrating equipment is directly attached to the structure.

### Isolation and Insulation.

As we discuss the development of strategies to isolate sound in a mass timber building, it is helpful to recognize the similar methods used in developing a thermal *insulation* strategy. Heat conduction through an assembly is analogous to sound conduction because heat and sound have wave properties that are affected by the materials that conduct them. Thermal assemblies comprised of varied materials (including air gaps) have been created to capture wave energy or trap air molecules excited by wave energy. This prevents that energy in the form of heat or cold from moving from one side of the assembly to the other. These types of multi-layered assemblies slow the inevitable passage of energy from high concentration to low concentration. Creating an acoustical strategy involves a similar process whereby an arrangement of layered materials reduces sound wave energy as it passes through a multi-layered assembly by absorbing it in various materials.

### Elements of a strategy: mass, stiffness, damping, air cavities, decoupling, air tightness.

When airborne soundwaves collide with a floor or wall surface, part of the energy is reflected back into the room, part of the energy is transmitted through the assembly, and part of the energy is absorbed by the assembly. Reflected soundwave energy, while not always desirable within a space, is an important part of a sound isolation strategy because reflected sound does not enter into the assembly. The material property that reflects sound energy best is mass. Massive materials such as concrete or stone have excellent reflective properties because the molecular movement of air molecules in a sound wave is no match for the dense concentration of molecules in a massive material. Materials that have stiffness are characteristically reflective of sound as well.

Sound energy that is *absorbed* does enter into an assembly, but is not transmitted through the assembly. Instead, the energy is trapped within the material. Absorptive materials are generally soft, pliable materials that change the sound wave motion, by conducting energy along random paths into dead ends where the wave dissipates and is converted into heat (in very small amounts.) Mineral-Wool insulation and Fiberglass insulation are common examples of sound absorptive materials. When an absorptive material is located between two more massive layers, it is generally called damping or constrained layer damping. Constrained layer damping is effective when placed between layers with different materials, densities, and stiffness.

### Designing an assembly

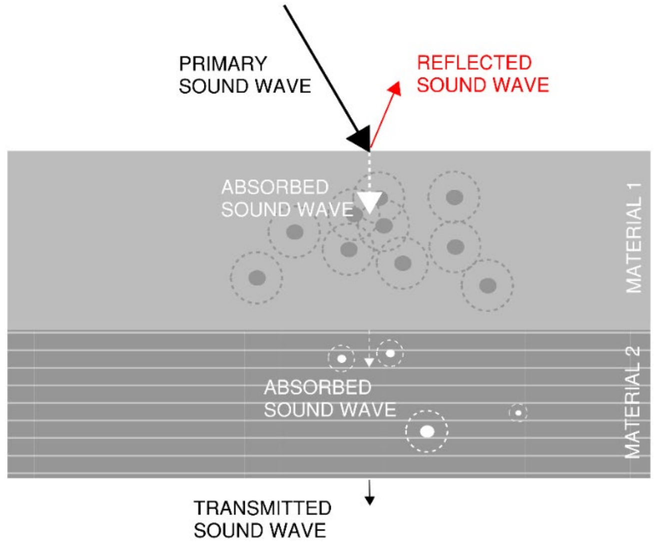



Figure 3: Wave energy passing through an assembly

**Decoupling** strategies utilize mechanical strategies like clips to separate surfaces so they can vibrate independently from one another. Wall and floor assemblies might also have an air gap layer, which reduces sound energy by exploiting the weakness of air as a sound conductor and using air as a medium for reflections within an assembly that can be dissipated by adjacent absorptive layers. It is important to note that waves reflected within a "damping" layer (especially an air layer) can be sustained as "standing waves" if the adjacent massive layers have characteristics that are too similar. For this reason, it is common to use more than one thickness of gypsum board in a wall assembly, for example. Generally utilizing different materials and thicknesses creates better sound isolation. No assembly, however, will effectively reduce sound transmission between spaces if there are holes or other paths of direct air flow between the spaces due to flanking. Overall **airtightness** is key: the connections between floor, wall and ceiling are critical to the overall performance. Air is not dense, but this fact makes it more difficult to block at the intersection of various building elements. Visually, assemblies can appear completely sealed but still allow for the passage of air which provides a path for flanking sound.[3]

[3] For conventional (non-composite) mass timber structures, an excellent resource for acoustical design is "Acoustics and Mass Timber: Room-to-Room Noise Control" by WoodWorks.

## 2.0 Case Study for Composite CLT/Concrete: TMBR© Minneapolis


TMBR is a 10-story mass timber mixed-use project located in the historic district of north Minneapolis that includes 9 stories of residential usage subdivided into 59 individual condominiums. TMBR utilizes a novel structural system— 5-ply cross laminated timber (CLT) floor deck panels with a thin layer of concrete poured over the top of the panels so that the two materials work together as a composite structural system. The composite system has several advantages appropriate for condominium construction[4]:

- Increased bending stiffness reduces both long-term creep deflections and walking induced vibrations which owners may not anticipate and find objectionable.
- Increased bending strength reduces the relative impact of CLT charring in a fire event and increases the fire endurance of the assembly.
- Rigid diaphragm behavior avoids additional lateral drift at the exterior wall due to wind and seismic forces.
- The topping slab may be thickened at the edge of the building for use of traditional high-rise cladding attachments and improved moisture resistance by holding the timber away from the exterior wall.
- Increased mass which has the potential to improve the sound isolation of the floor system.

[4] As defined by design team members from Skidmore Owings and Merrill.

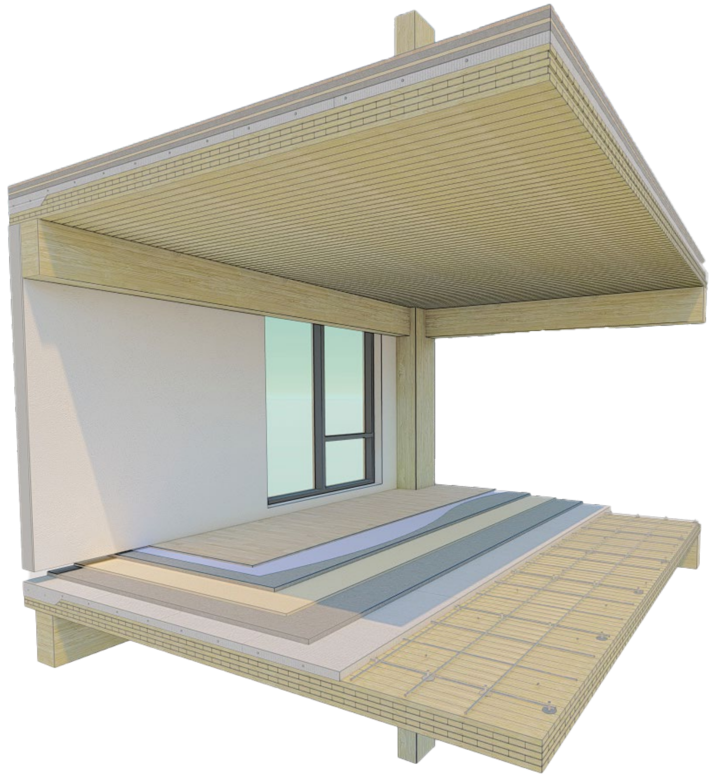


Figure 4: Section Through Typical Floor, TMBR© Minneapolis

**Setting Targets** Setting targets for the acoustical performance of a multifamily dwelling is an art balancing performance, cost, and market demand. If targets are set too low, the development team is exposed to potential litigation or negative publicity from unsatisfied buyers.[5] If set too high, the team faces the potential risk of pricing the project out of the market. For TMBR, the target value for Sound Transmission Class (STC) and Impact Isolation Class (IIC) were both set at 60, which is a level of quality competitive with other condominiums in the market and is the minimum value to achieve Grade A "Preferred Performance" based statistical survey data from human beings. The survey concluded that STC 60 is an "ideal goal that would practically eliminate the negative effects of neighbors' noises." [6]

## Tools and Solutions

For the TMBR design team, the immediate concern was finding a tested CLT floor assembly of STC and IIC of 60. To date, the most comprehensive domestic source for testing data of CLT floor assemblies is from Wood Products Council (WoodWorks).[7] From this list, there were many assemblies that combined concrete with

[5] Note that many building codes set minimum STC criteria for walls and floors.

[6] "A Guide to Airborne, Impact and Structure Borne Noise-Control in Multifamily Dwellings", U.S. Department of Housing and Urban Development

[7] Acoustically Tested Mass-Timber Assemblies, WoodWorks; https://www.woodworks.org/wp-content/uploads/Acoustically-Tested-Mass-Timber-Assemblies-WoodWorks.pdf

CLT, but in each case the assemblies employ an intermediate constrained damping layer between the wood and concrete (as might be expected from the discussion of wave dissipation). For TMBR, the proposed CLT and concrete composite requires direct contact between the two materials to function structurally. Acoustical software packages can calculate STC and IIC values for theoretical assemblies by computational interpolation of empirical acoustical test data of various materials, but the current software is limited to a maximum of 2 massive layers, damped or decoupled from one another. Using this method, a number of assemblies were developed but all them were too massive to be an adequate match for a timber structure. The thinnest overall assembly was 14" thick; the thickest was 18" thick with no ceiling assembly elements included. This led to a team decision to develop some complex assemblies to be professionally tested, financed with a grant from the Softwood Lumber Board. The goal was to develop a lean but efficient assembly that would hit the target STC/IIC, allow for the visual appeal of the CLT deck to be exposed on the underside, and be reasonably paired with the bearing capabilities of wood.

## Adapting acoustic strategies from Type IV-B code requirements:

Before reviewing testing results of individual assemblies, it is important to consider coordination of acoustical strategies with code-mandated fire resistance requirements. The changes to IBC 2021 that concern new Construction Types IV-A, IV-B, and IV-C contain new requirements on the fire resistance for timber: noncombustible materials must be added to some or all of the surfaces, depending on circumstances[8]. Concealed spaces must be protected. For Type IV-A, which has a limit of 18-stories of residential occupancy, the entire structure must be clad in 2 or 3 layers of 5/8" gypsum board depending on the element. The non-combustible requirements for Type IV-C, which allows up to 8 residential stories, are minimal. Type IV-B holds the middle ground on fire-resistance: 12 maximum residential stories and a portion of the walls or ceilings can remain exposed. TMBR can serve as an example for how the Type IV-B rules are applied.

For TMBR, which had no CLT walls, the natural choice was to expose the ceilings and columns of the Living and Dining areas at the exterior wall and cover the ceilings and columns over the remaining areas of the units. This worked nicely with a strategy of concealed HVAC ducts, electrical pathways and sprinkler piping.

Note that the mere concealment of these spaces requires gypsum protection, another of the new code requirements. A typical 8-unit residential ceiling plate for TMBR looks as follows:

[8] See WoodWorks paper "Demonstrating Fire-Resistance Ratings for Mass Timber Elements in Tall Wood Structures"

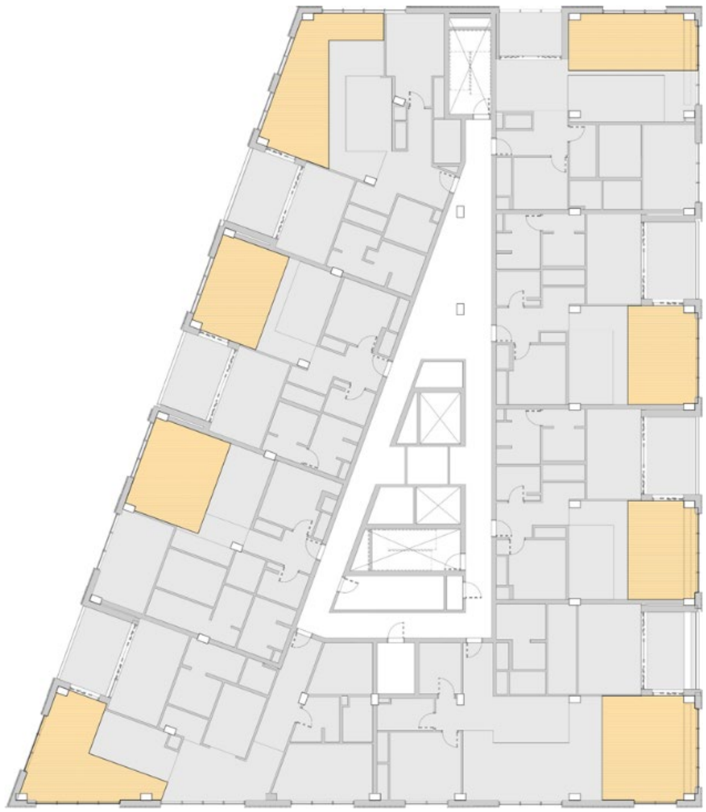


Figure 5: TMBR Reflected Ceiling Plan showing areas of exposed timber on ceilings.

To maximize the designed value (minimize cost), the team evaluated the acoustical properties of the code required assembly of mass timber covered in gypsum with a suspended ceiling to conceal utilities.

The additional layers of gypsum add mass to the floor--a benefit--but the addition of a ceiling separated by an air cavity adds a significant damping layer which boosts the overall sound transmission and impact isolation. The increase is significant enough to consider a **hybrid strategy** comprised of a less expensive floor assembly over the soffit areas that is butt-jointed to the standard exposed timber assembly in order to reduce costs.

The design team developed simple, decoupled mass solutions comprised of geofoam rigid insulation topped by gypsum concrete with finish layers that would match the above-the-slab thickness of a tested "lean" floor assembly with exposed CLT (no ceiling):

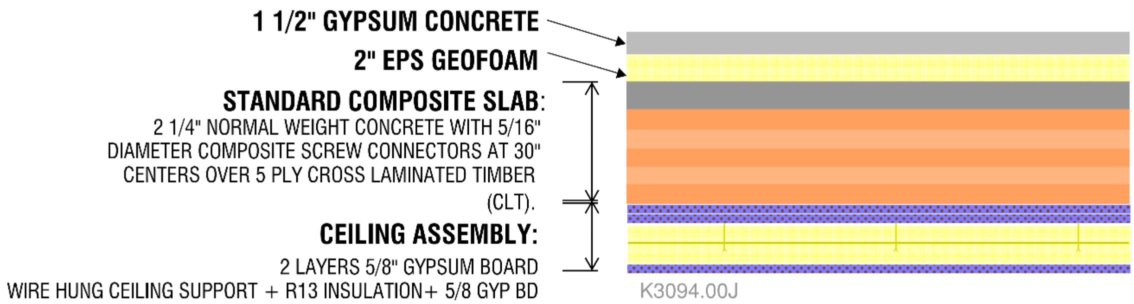



Figure 6: Elements of a Composite CLT/Concrete Slab

See Assemblies J and L in the appendix for more information.

With the two different assemblies to be butt-jointed, the team considered the best design and location for the joint to be 24" within the soffited area in order to reap the acoustic damping benefits of the air gap and ceiling. Attention was paid to match the heights of the two different acoustic build-ups so that the top layer of gypcrete was a consistent thickness and less vulnerable to cracking. The final arrangement would warrant testing, which was not in the project scope. In the end, the hybrid design approach was found to yield a sizeable savings over the initial construction estimate in material cost. However, a repetitive system in a large scale building generally reduces labor costs. Based on contractor estimates, the hybrid system was 20% higher. In the case of TMBR it did not warrant the complexity of installation. In a smaller building, it is likely the hybrid approach would be an excellent solution, but requires further testing.[9]

[9] For TMBR, the final design was a single (non-hybrid) system at a negotiated price lower than the hybrid system.

## 3.0 Floor Test Assemblies

The TMBR team developed 14 unique acoustic assembly groups. Each group is defined by four elements:

1. a composite CLT/concrete slab (standard for all assemblies)
2. a subfloor topping (multi-layer)
3. an underlayment
4. a finished floor

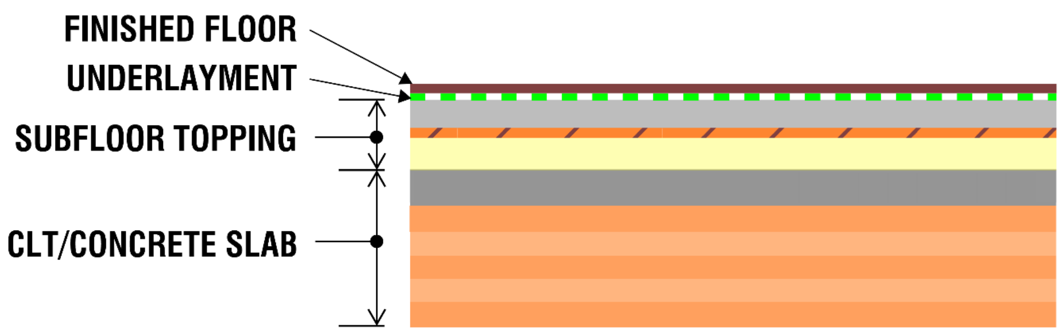



Figure 7: Elements of a Composite CLT/Concrete Slab

The **Composite CLT/Concrete Slab** is a 5-ply CLT slab this is connected to a 2 ¼" layer of normal weight concrete using angled screw connectors. The special dry mix concrete is poured over the CLT slab with the screw heads projecting diagonally so that when the concrete is fully cured the two materials act together to form a single, robust composite. The composite structural slab is the same for all groups except for Group ALT A, which utilizes a 7-ply CLT slab (intended for roof deck applications).

### Subfloor Toppings

The choice of **Subfloor Topping** defines the 14 unique assembly groups. What follows is a brief description of each:

**Group A**: a 3-layer topping that utilizes a gypsum concrete mass decoupled from the composite structural slab using a floating floor system. The "float" consists of spring and foam isolators that are separated by a layer of absorbing material. Floating Floor: CDM Float System by CDM (Belgium).

**Group A2**: a 4-layer topping that utilizes a gypsum concrete mass that is decoupled from the composite structural slab utilizing a layer of gypsum sheathing over a layer of constrained damping absorbing material. Group A2 is the only group that is built on a 7-ply structural slab.

**Group B**:  a 3-layer topping that utilizes the mass of two sheathing layers of different density over a multi-layer decoupling product made of a lightweight stiff honeycomb structure sandwiched between two absorbing damping layers.  Isolation Product:  UltraQuiet SR by Kinetics.

**Group E**:  a 5-layer topping consisting of a gypsum concrete mass layer, two layers of thin plastic sheeting, and a layer of gypsum sheathing which are isolated from the structural slab by a base constrained damping layer  of absorbing material.

**Group F**: is a sleeper floor system decoupler consisting of wood 2 x 4 boards  standing upright on the composite structural slab.  This assembly is topped by an absorptive damping layer and a layer of oriented strand board (OSB) sheathing.  The spaces between the 2 x 4 boards are not filled.  Absorptive Layer:  Acoustiboard by Soprema.

**Group F2**: is similar to Group F, except the spaces between the 2 x 4 boards are filled with absorptive material.  Absorptive Layer:  Acoustiboard by Soprema.

**Group G** is a sleeper floor decoupler system similar to Group F, except the spaces between the 2 x 4 boards are filled with an absorptive sand mass, and the topmost layer is a 1” thickness of poured gypsum concrete.  Absorptive Layer:  Acoustiboard by Soprema.

**Group H** is a sleeper decoupler system built on top of a resilient layer.  The sleeper boards are 2 x 2 lumber and the spaces between sleepers are filled with an absorptive sand mass.  The top layer is 5/8” OSB sheathing.

**Group I** is the same as Group H with the addition of two layers of polyethylene sheeting and a 1” gypsum concrete top layer.

**Group J** is developed for use in areas where mechanical piping ducts would need to be concealed behind a finished ceiling.  It consists of an economical two layer above-slab damped mass (1 1/2" gypsum concrete on extruded polystyrene) paired with a below-slab wire-hung gypsum ceiling system with voids filled absorptive material.  The underside of the CLT slab within the ceiling space is covered by two layers of 5/8” gypsum board as required by code.

**Group K** is a proprietary 3-layer damped mass system of 2” gypsum concrete on a 3/4” resilient layer.

**Group L** is similar to the Group J system, with a ceiling layer below the slab.  Group L utilizes a 1” mass layer of gypsum concrete topping over 1 3/4" of extruded polystyrene that rests on a resilient mat.  Below the slab is the same ceiling system as Group L.  The underside of the CLT slab within the ceiling space is covered by two layers of 5/8” gypsum board as required by code

**Group M** is a 2 x 2 wood sleeper system similar to Group I, but in place of the polyethylene sheeting is a resilient layer, and the sleeper system sits directly on the structural slab with no resilient layer below it.

**Group N** is a two-layer decoupled mass system consisting of 1” of gypsum concrete over a resilient layer.

**Group O** is a proprietary 3-layer damped mass system of 1 1/2” gypsum concrete on a 3/4” resilient layer.

**Underlayments:** Each subfloor topping described above is tested using 6 different **Underlayment** products or conditions:

1. Base Assembly and Subfloor Topping only, with no finished floor and no underlayment.
2. Finished floor with no underlayment
3. Underlayment: Pliteq Geniemat RS02, a flat resilient mat made of recycled rubber.
4. Underlayment: Pliteq Geniemat RS05, a flat resilient mat made of recycled rubber.
5. Underlayment: Ecore QT4002, a flat resilient mat made of recycled rubber.
6. Underlayment: Ecore QT4005, a flat resilient mat made of recycled rubber.
7. Underlayment: Maxxon Acousti-Top, a proprietary fibrous blend.

## 4.0 Conclusions and Observations

We make the following observations and conclusions of the testing data:

1. Table 1 shows a matrix of all of the assemblies, with greater detail for those assemblies that hit the target STC/IIC of 60. Six of the 14 assembly groups hit the STC/IIC 60 threshold yielding a total of **29 successful assemblies** that included finished floors. In addition, five out of 14 base assemblies hit the target threshold with no finished floor or underlayment.

2. Underlayments are not as important as the subfloor topping (see Figure 7) in determining success. For most successful Assembly Groups, nearly all of the assemblies within the group passed, even the base assembly that had no underlayment.

3. The thinnest successful assembly was B-1, a 3-layer assembly measuring 11-5/8" total thickness. It is noteworthy that this assembly did not use a mass layer of gypsum concrete.

4. All of the assemblies with ceilings were successful, including J-3, L-2, and L-5 which yielded the best STC/IIC combination at 63/62.

5. Best Low Frequency Sound Performance STC (50 Hz): Assembly A6/40.2 Assembly F2-4/40.5

## Table 1: Assembly Group Analysis

| Assembly Group See Note 1 | A | A2 | B | E | F | F2 | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Success Rate** (assemblies with finished floor meeting 60 minimum STC and IIC) | 4/6 | 0/6 | 6/6 | 0/6 | 0/6 | 1/2 | 0/6 | 0/6 | 6/6 | 6/6 | 0/6 | 6/6 | 0/6 | 0/6 | 0/6 |
| **Base Assembly meets target STC/IIC?** | YES | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES | YES | NO | NO | NO |
| **Min # of added Layers** See Note 4, 5 | 4 | | 4 | | | 6 | | | 8 | 8 | | 8 | | | |
| **Thickness (inch) Range** (assemblies with finished floor only) | 13 5/8" -- 13 7/8" | | 11 7/8" - 12-1/8" | | | 14 1/4" | | | 13 7/16" - 13 11/16" | 19" -- 19 1/4" | | 18 1/2" - 18 3/4" | | | |
| **Ceiling** See Note 2, 3 | NO | | NO | | | NO | | | NO | YES | | YES | | | |
| **Use of Sand** | NO | | NO | | | NO | | | YES | NO | | NO | | | |
| **Use of Gypcrete** See Note 6 | YES (1.5") | | NO | | | NO | | | YES (1") | YES (1.5") | | YES (1") | | | |
| **Cost (Jan 2020)** See Note 7 & 8 | $7.29 | NA | $13.23 | $7.46 | $11.09 | $7.73 | $12.35 | $11.98 | $12.54 | $12.75 | $7.55 | $7.20 | $6.11 | $4.76 | NA |
| **Highest STC/IIC Combo** | 60/66 | 58/64 | 60/64 | 58/67 | 59/62 | 60/60 | 59/63 | 59/60 | 61/66 | 63/62 | 59/65 | 63/62 | 59/59 | 53/53 | 57/62 |

1. Shaded columns indicate Assembly Groups that had one or more assemblies that meet or exceed the target STC and IIC values of 60. Advanced analysis in the lower rows is given for these assemblies only. See individual Assembly Group sheets for STC/IIC, thickness, layer information, etc. for all assemblies. The reported Success Rate does not include the base assembly, which is reported on a separate row.

2. IBC requirements for Types IV-A and B will require 2 layers of gypsum board protection installed directly to underside of clt deck for concealed spaces. Assemblies with Ceilings include the required layers. IBC Type IV-C requires 1 layer of gypsum board.

3. IBC requirements for Types IV B will require 2 layers of gypsum board protection directly attached to underside of CLT deck over a minimum of 80% of ceiling areas. For purposes of the study, unprotected slabs were tested since they posed the most challenging acoustical scenario, except where noted.

4. Minimum number of layers was calculated using assemblies with finished floors only. The intent of the data is suggest the complexity of the assembly. Layers made up of multiple elements were counted as multiple layers. For instance, wood sleepers with sand fill was indicated as two layers.

5. The standard composite slab was not considered as an added layer.

6. The standard composite slab was not considered as "use of gypcrete".

7. The standard composite slab was not included in the cost

8. The per square foot cost breakdowns are based on pricing for the TMBR project in 2019 by PCL Construction.

## 5.0 Acknowledgments

This paper originates with a project—TMBR© Minneapolis—but it is made possible by a contribution from the Softwood Lumber Board, an industry-funded initiative established to promote the benefits and uses of softwood lumber products.

D/O Architects would like to thank the following firms and organizations who helped make this paper possible:

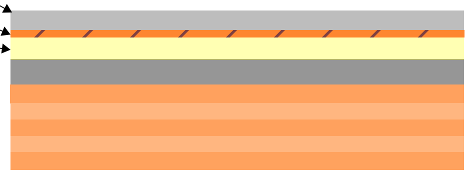
The Softwood Lumber Board
TMBR Partners, JV
Ador Homes
PCL Construction
Skidmore Owings and Merrill
Veneklasen Associates
Kirkegaard
Katerra
Maxxon

## 6.0 Assembly Data Sheets

ASSEMBLY GROUP: A

## GROUP A BASE ASSEMBLY

1 1/2" MAXXON GYPCRETE
1/2" PLYWOOD
2" CDM FLOAT SDS ISOLATION
**STANDARD COMPOSITE SLAB**: 2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).

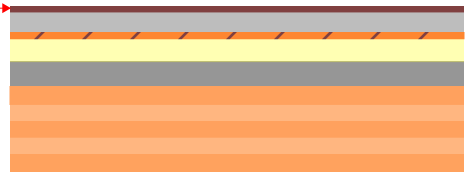


K3094.00A

1' -1 1/8"

61 STC | 62 IIC

ADD **1/2" ENGINEERED WOOD FLOORING**
(NO UNDERLAYMENT)

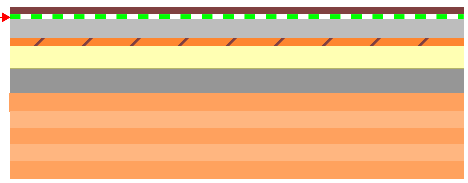


K3094.01

1' -1 5/8"

60 STC | 64 IIC

ADD **UNDERLAYMENT: PLITEQ GENIEMAT RST02 (1/8")**

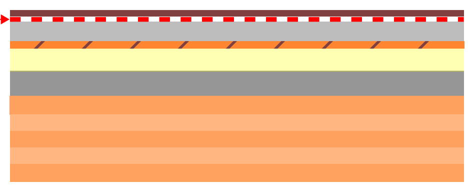


K3094.02

1' -1 3/4"

60 STC | 66 IIC

CHANGE **UNDERLAYMENT: PLITEQ GENIEMAT RST05 (1/4")**

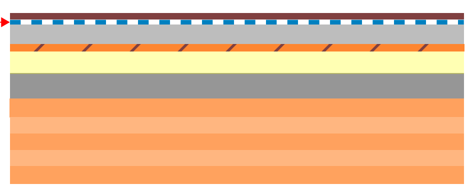


K3094.03

1' -1 7/8"

60 STC | 66 IIC

CHANGE **UNDERLAYMENT: ECORE QT4002 (0.08")**

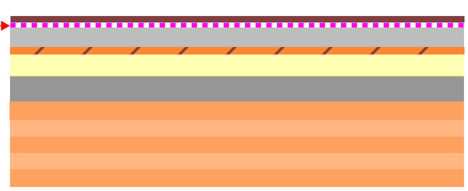


K3094.04

1' -1 11/16"

59 STC | 66 IIC

CHANGE **UNDERLAYMENT: ECORE QT4005 (0.20")**

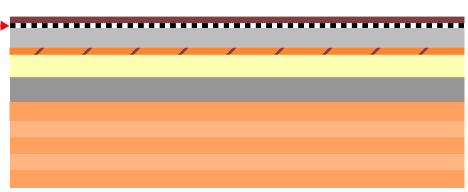


K3094.05

1' -1 13/16"

59 STC | 66 IIC

CHANGE **UNDERLAYMENT: MAXXON ACOUSTITOP (1/16")**



K3094.06

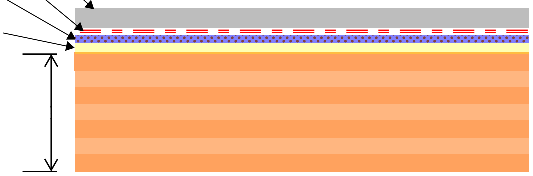
1' -1 11/16"

60 STC | 66 IIC

ASSEMBLY GROUP: **A-2**

## GROUP A-ALT BASE ASSEMBLY

1 1/2" MAXXON GYPCRETE
2 LAYERS 6 MIL POLYETHYLENE SHEETING
5/8" DENSDECK ROOF BOARD
1" FIBERGLASS INSULATION BOARD
**STANDARD CLT SLAB**:
7 PLY CROSS LAMINATED TIMBER

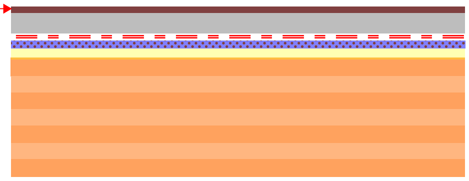


1' -0 5/8"

**57** STC **59** IIC

K3094.00AA

ADD **1/2" ENGINEERED WOOD FLOORING**
(NO UNDERLAYMENT)

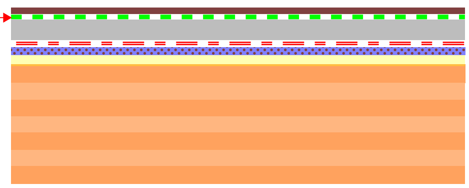


1' -1 1/8"

**57** STC **62** IIC

K3094.45

ADD **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST02 (1/8")**

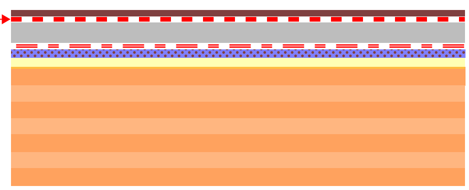


1' -1 1/4"

**57** STC **64** IIC

K3094.46

CHANGE **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST05 (1/4")**

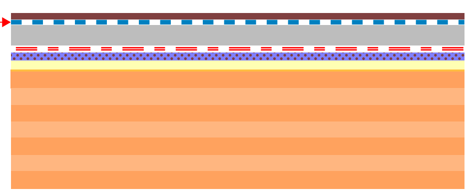


1' -1 3/8"

**57** STC **63** IIC

K3094.47

CHANGE **UNDERLAYMENT:**
**ECORE QT4002 (0.08")**

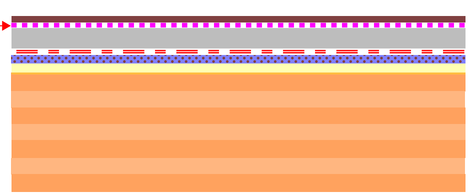


1' -1 3/16"

**58** STC **64** IIC

K3094.48

CHANGE **UNDERLAYMENT:**
**ECORE QT4005 (0.20")**

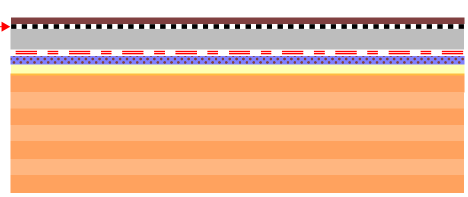


1' -1 5/16"

**57** STC **64** IIC

K3094.49

CHANGE **UNDERLAYMENT:**
**MAXXON ACOUSTITOP (1/16")**



1' -1 3/16"

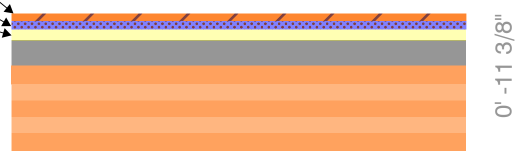
**57** STC **65** IIC

K3094.50

ASSEMBLY GROUP: B

## GROUP B BASE ASSEMBLY

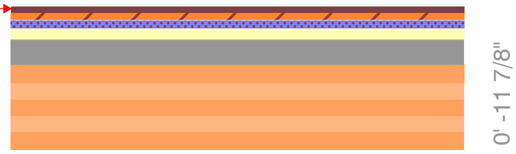
5/8" OSB SUBFLOOR
5/8" DENSDECK ROOF BOARD
1" KINETICS ULTRA QUIET SR
**STANDARD COMPOSITE SLAB**: 2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).




K3094.00B

59 STC | 57 IIC

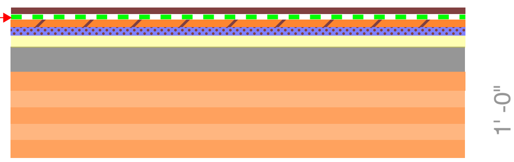
ADD **1/2" ENGINEERED WOOD FLOORING**
(NO UNDERLAYMENT)




K3094.19

60 STC | 62 IIC

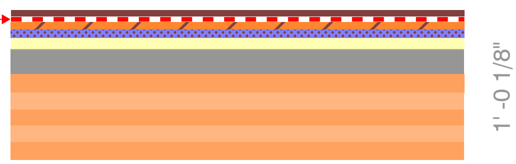
ADD **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST02 (1/8")**




K3094.20

60 STC | 64 IIC

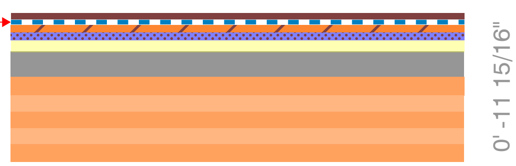
CHANGE **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST05 (1/4")**




K3094.21

60 STC | 64 IIC

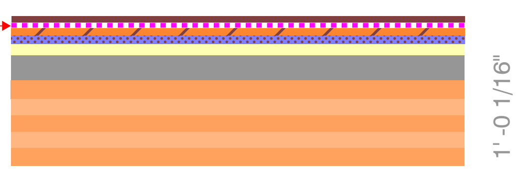
CHANGE **UNDERLAYMENT:**
**ECORE QT4002 (0.08")**




K3094.22

60 STC | 63 IIC

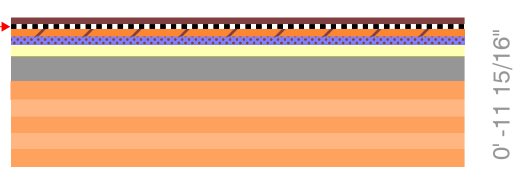
CHANGE **UNDERLAYMENT:**
**ECORE QT4005 (0.20")**




K3094.23

60 STC | 64 IIC

CHANGE **UNDERLAYMENT:**
**MAXXON ACOUSTITOP (1/16")**



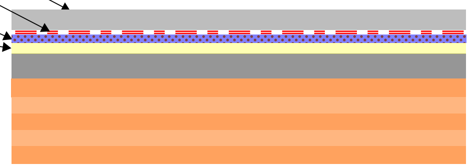

K3094.24

60 STC | 62 IIC

ASSEMBLY GROUP: E

## GROUP E BASE ASSEMBLY

1 1/2" MAXXON GYPCRETE
2 LAYERS POLYETHYLENE SHEETING
5/8" DENSDECK ROOF BOARD
1" FIBERGLASS INSULATION BOARD
**STANDARD COMPOSITE SLAB**:
2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).

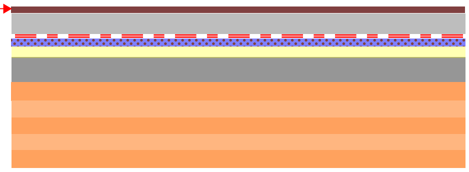


K3094.00E

1'-0 1/4"

59 STC | 66 IIC

ADD **1/2" ENGINEERED WOOD FLOORING**
(NO UNDERLAYMENT)

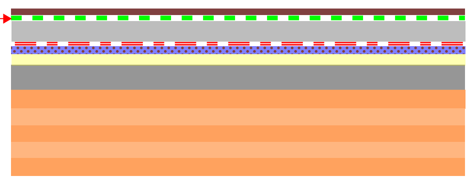


K3094.07

1'-0 3/4"

58 STC | 64 IIC

ADD **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST02 (1/8")**

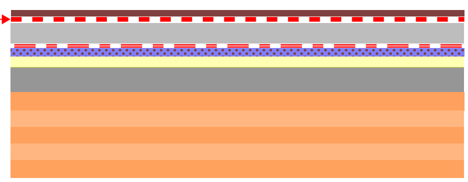


K3094.08

1'-0 7/8"

58 STC | 67 IIC

CHANGE **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST05 (1/4")**

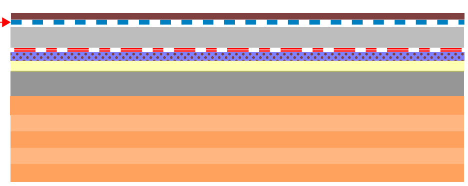


K3094.09

1'-1"

58 STC | 67 IIC

CHANGE **UNDERLAYMENT:**
**ECORE QT4002 (0.08")**

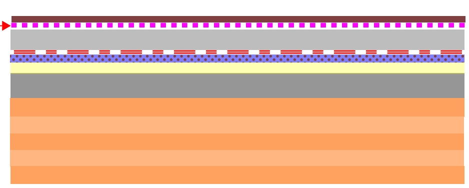


K3094.10

1'-1 13/16"

57 STC | 68 IIC

CHANGE **UNDERLAYMENT:**
**ECORE QT4005 (0.20")**

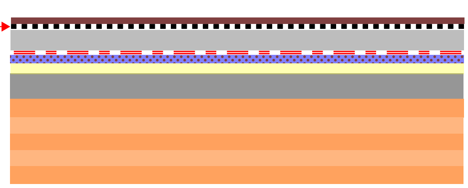


K3094.11

1'-0 15/16"

57 STC | 68 IIC

CHANGE **UNDERLAYMENT:**
**MAXXON ACOUSTITOP (1/16")**



K3094.12

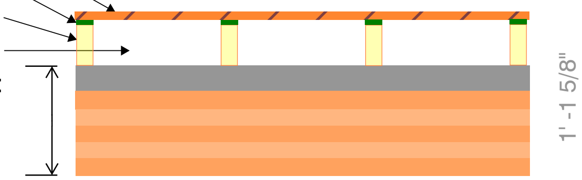
1'-0 13/16"

58 STC | 67 IIC

## GROUP F BASE ASSEMBLY

ASSEMBLY GROUP: **F**

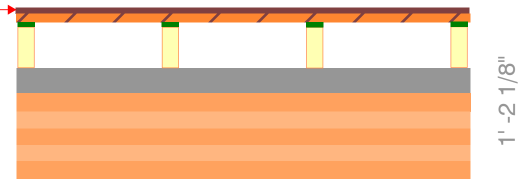
**5/8" OSB SUBFLOOR**
**SOPREMA ACOUSTIBOARD STRIPS (3/8")**
**2 X 4 WOOD SLEEPERS**
**NO FILL**
**STANDARD COMPOSITE SLAB**:
2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).




K3094.00F1

**58** STC **54** IIC

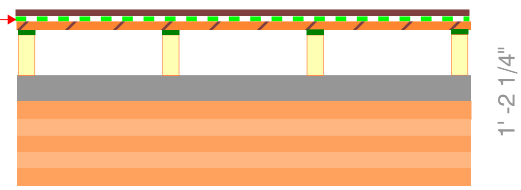
ADD **1/2" ENGINEERED WOOD FLOORING**
(NO UNDERLAYMENT)




K3094.31

**58** STC **58** IIC

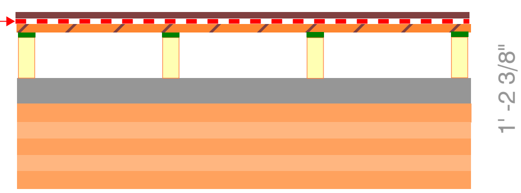
ADD **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST02 (1/8")**




K3094.32

**58** STC **61** IIC

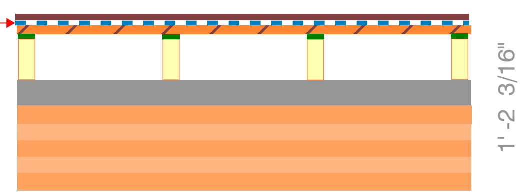
CHANGE **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST05 (1/4")**




K3094.33

**59** STC **62** IIC

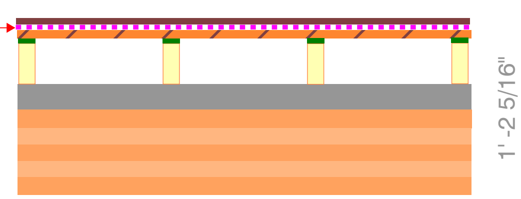
CHANGE **UNDERLAYMENT:**
**ECORE QT4002 (0.08")**




K3094.34

**58** STC **62** IIC

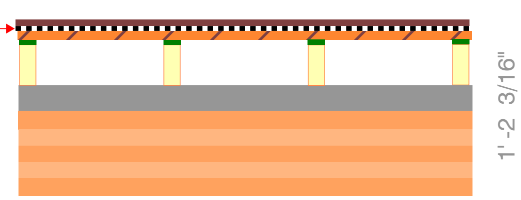
CHANGE **UNDERLAYMENT:**
**ECORE QT4005 (0.20")**




K3094.35

**58** STC **61** IIC

CHANGE **UNDERLAYMENT:**
**MAXXON ACOUSTITOP (1/16")**

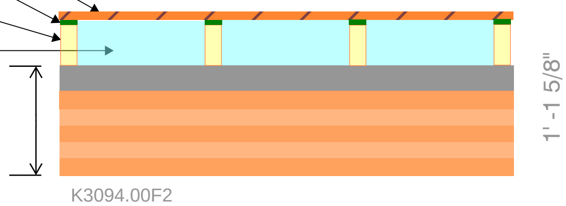



K3094.36

**59** STC **59** IIC

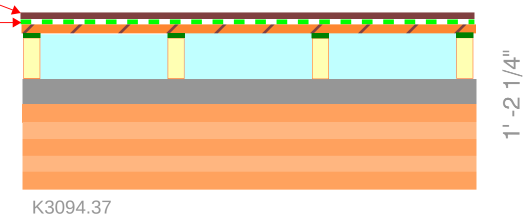
## GROUP F2 BASE ASSEMBLY

ASSEMBLY GROUP: F2




**59** STC

**56** IIC



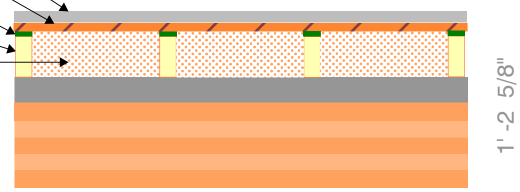

**60** STC

**60** IIC

## GROUP G BASE ASSEMBLY

ASSEMBLY GROUP: **G**

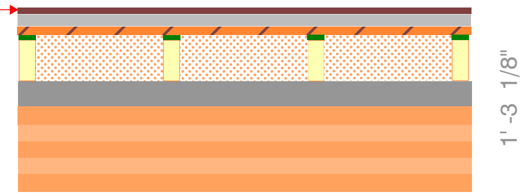
1" GYPSUM CONCRETE
5/8" OSB SUBFLOOR
SOPREMA ACOUSTIBOARD STRIPS (3/8")
2 X 4 WOOD SLEEPERS
SAND FILL
**STANDARD COMPOSITE SLAB**:
2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).




K3094.00G

60 STC 59 IIC

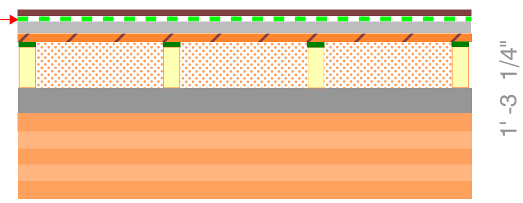
ADD **1/2" ENGINEERED WOOD FLOORING**
(NO UNDERLAYMENT)




K3094.51

59 STC 62 IIC

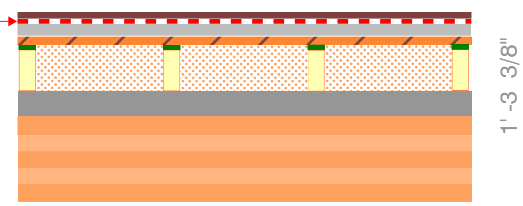
ADD **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST02 (1/8")**




K3094.52

59 STC 62 IIC

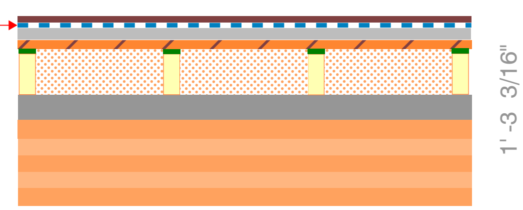
CHANGE **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST05 (1/4")**




K3094.53

59 STC 63 IIC

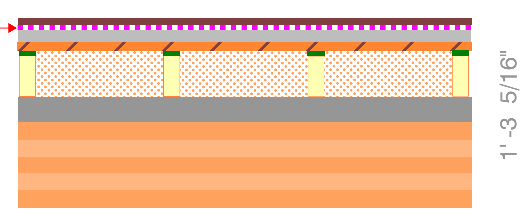
CHANGE **UNDERLAYMENT:**
**ECORE QT4002 (0.08")**




K3094.54

58 STC 63 IIC

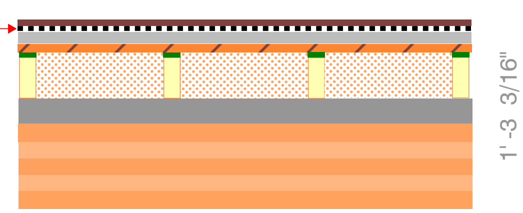
CHANGE **UNDERLAYMENT:**
**ECORE QT4005 (0.20")**




K3094.55

58 STC 63 IIC

CHANGE **UNDERLAYMENT:**
**MAXXON ACOUSTITOP (1/16")**



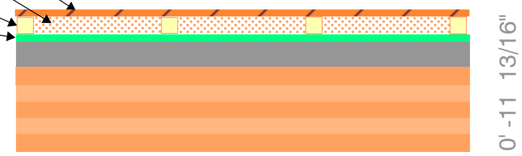

K3094.56

59 STC 62 IIC

ASSEMBLY GROUP: H

## GROUP H BASE ASSEMBLY

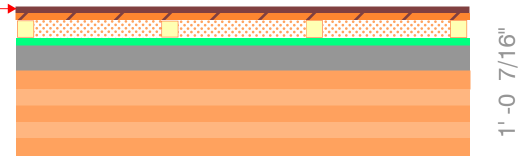
5/8" OSB SUBFLOOR
SAND FILL
2 X 2 WOOD SLEEPERS
GENIEMAT FF17 UNDERLAYMENT
**STANDARD COMPOSITE SLAB**: 2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).



K3094.00H

**56** STC **52** IIC

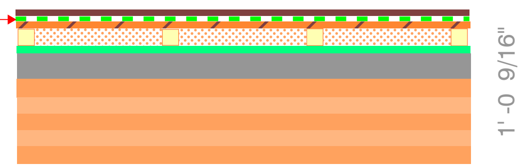
ADD **1/2" ENGINEERED WOOD FLOORING**
(NO UNDERLAYMENT)



K3094.25

**58** STC **57** IIC

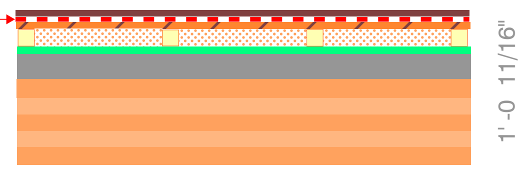
ADD **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST02 (1/8")**



K3094.26

**59** STC **58** IIC

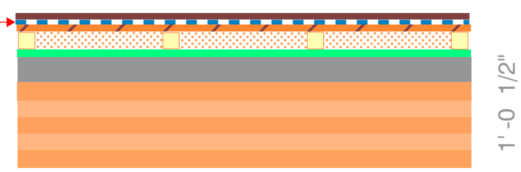
CHANGE **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST05 (1/4")**



K3094.27

**59** STC **60** IIC

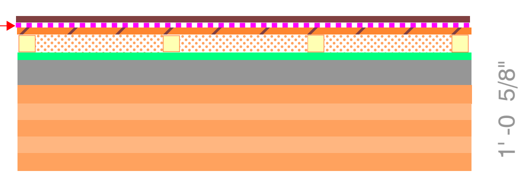
CHANGE **UNDERLAYMENT:**
**ECORE QT4002 (0.08")**



K3094.28

**59** STC **59** IIC

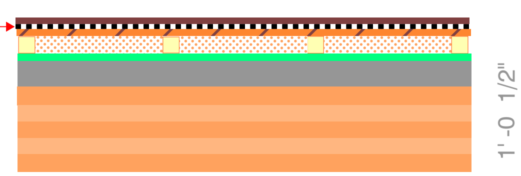
CHANGE **UNDERLAYMENT:**
**ECORE QT4005 (0.20")**



K3094.29

**58** STC **58** IIC

CHANGE **UNDERLAYMENT:**
**MAXXON ACOUSTITOP (1/16")**



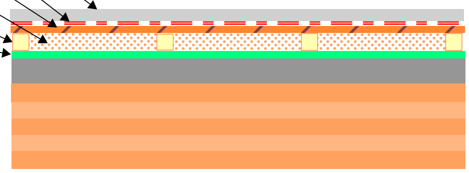
K3094.30

**57** STC **56** IIC

## ASSEMBLY GROUP: I

### GROUP I BASE ASSEMBLY

1" GYPSUM CONCRETE
2 LAYERS 6 MIL POLYETHYLENE SHEETING
5/8" OSB SUBFLOOR
SAND FILL
2 X 2 WOOD SLEEPERS
GENIEMAT FF17 UNDERLAYMENT
**STANDARD COMPOSITE SLAB**: 2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).



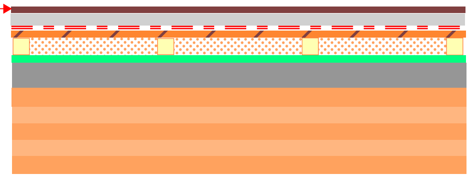
K3094.00I

1'-0 15/16"

**60** STC **62** IIC

ADD **1/2" ENGINEERED WOOD FLOORING**

(NO UNDERLAYMENT)

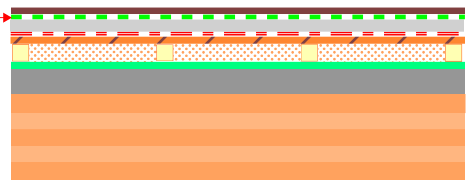


K3094.51

1'-1 7/16"

**61** STC **64** IIC

ADD **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST02 (1/8")**

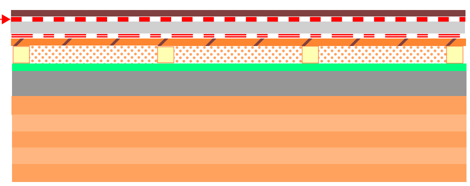


K3094.52

1'-1 9/16"

**60** STC **65** IIC

CHANGE **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST05 (1/4")**

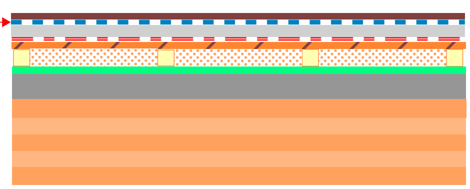


K3094.53

1'-1 11/16"

**60** STC **65** IIC

CHANGE **UNDERLAYMENT:**
**ECORE QT4002 (0.08")**

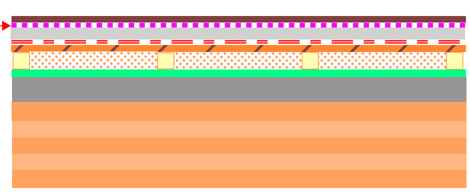


K3094.54

1'-1 1/2"

**60** STC **65** IIC

CHANGE **UNDERLAYMENT:**
**ECORE QT4005 (0.20")**

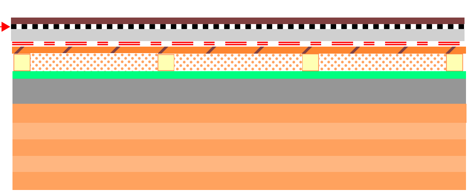


K3094.55

1'-1 5/8"

**61** STC **66** IIC

CHANGE **UNDERLAYMENT:**
**MAXXON ACOUSTITOP (1/16")**



K3094.56

1'-1 1/2"

**60** STC **64** IIC

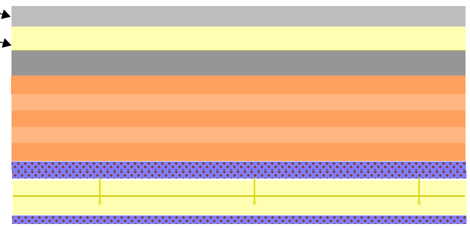
## GROUP J BASE ASSEMBLY

**1 1/2" GYPSUM CONCRETE**

**2" EPS GEOFOAM**

**STANDARD COMPOSITE SLAB:**
2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).

**CEILING ASSEMBLY:**
2 LAYERS 5/8" GYPSUM BOARD
WIRE HUNG CEILING SUPPORT + R13 INSULATION+ 5/8 GYP BD



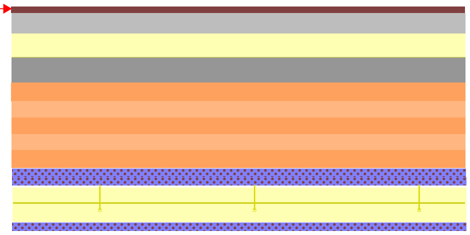
1'-6 1/2"

62 STC | 60 IIC

K3094.00J

ADD **1/2" ENGINEERED WOOD FLOORING**

(NO UNDERLAYMENT)

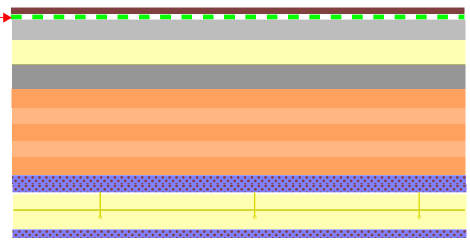


1'-7"

63 STC | 60 IIC

K3094.57

ADD **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST02 (1/8")**

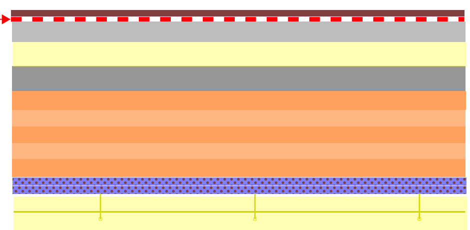


1'-7 1/8"

63 STC | 61 IIC

K3094.58

CHANGE **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST05 (1/4")**

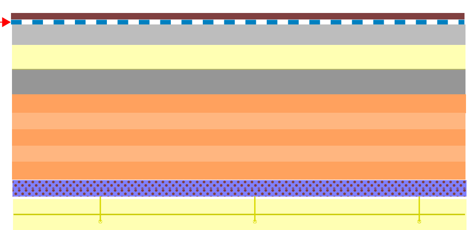


1'-7 1/4"

63 STC | 62 IIC

K3094.59

CHANGE **UNDERLAYMENT:**
**ECORE QT4002 (0.08")**

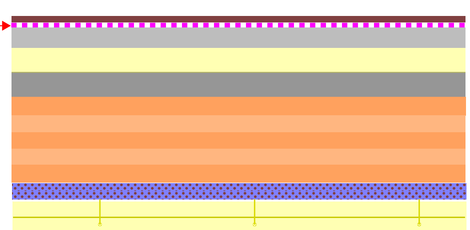


1'-7 1/16"

63 STC | 61 IIC

K3094.60

CHANGE **UNDERLAYMENT:**
**ECORE QT4005 (0.20")**

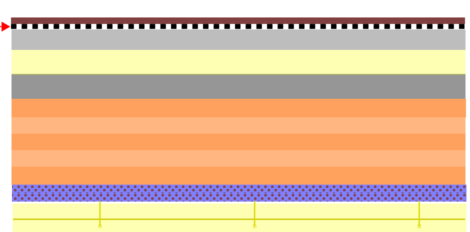


1'-7 3/16"

62 STC | 62 IIC

K3094.61

CHANGE **UNDERLAYMENT:**
**MAXXON ACOUSTITOP (1/16")**



1'-7 1/16"

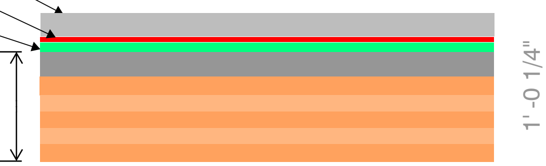
62 STC | 59 IIC

K3094.62

ASSEMBLY GROUP: K

## GROUP K BASE ASSEMBLY

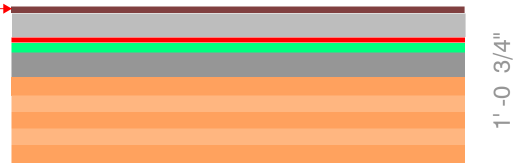
2" MAXXON GYPCRETE
MAXXON SBR+MAXXON PRIMER/REINFORCEMENT
ACOUSTI-MAT 3/4P
**STANDARD COMPOSITE SLAB**: 2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).




K3094.00K

60 STC 61 IIC

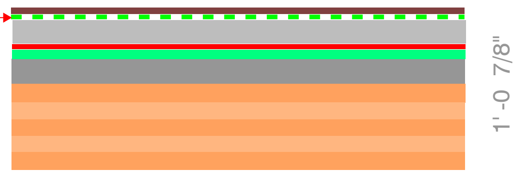
ADD **1/2" ENGINEERED WOOD FLOORING**
(NO UNDERLAYMENT)




K3094.13

58 STC 63 IIC

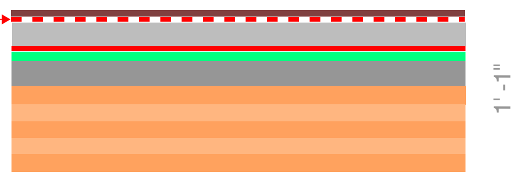
ADD **UNDERLAYMENT: PLITEQ GENIEMAT RST02 (1/8")**




K3094.14

58 STC 65 IIC

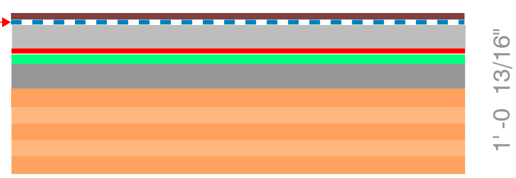
CHANGE **UNDERLAYMENT: PLITEQ GENIEMAT RST05 (1/4")**




K3094.15

59 STC 65 IIC

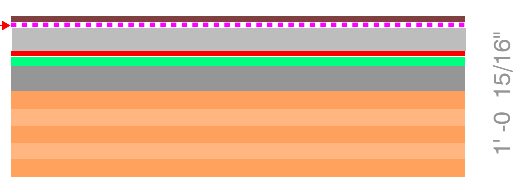
CHANGE **UNDERLAYMENT: ECORE QT4002 (0.08")**




K3094.16

59 STC 65 IIC

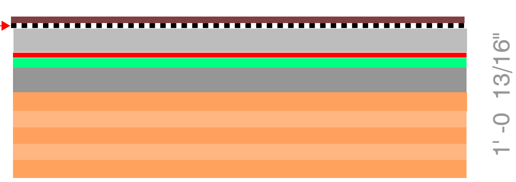
CHANGE **UNDERLAYMENT: ECORE QT4005 (0.20")**




K3094.17

59 STC 65 IIC

CHANGE **UNDERLAYMENT: MAXXON ACOUSTITOP (1/16")**



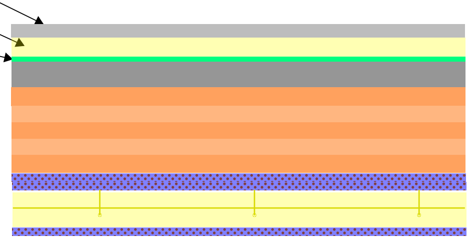

K3094.18

58 STC 64 IIC

ASSEMBLY GROUP: L

## GROUP L BASE ASSEMBLY

1" GYPSUM CONCRETE
1 3/4" EPS GEOFOAM
ACOUSTI-MAT 1/4 PREMIUM
**STANDARD COMPOSITE SLAB:**
2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).
**CEILING ASSEMBLY:**
2 LAYERS 5/8" GYPSUM BOARD
WIRE HUNG CEILING SUPPORT + R13 INSULATION+ 5/8 GYP BD

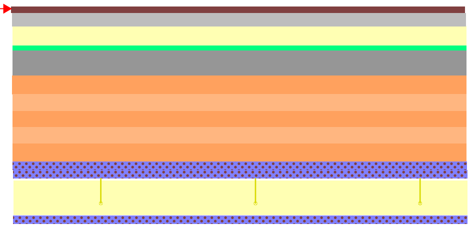


1'-6"

K3094.00L1

61 STC 61 IIC

ADD 1/2" **ENGINEERED WOOD FLOORING**
(NO UNDERLAYMENT)

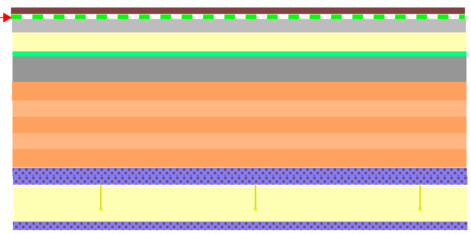


1'-6 1/2"

K3094.57

63 STC 61 IIC

ADD **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST02 (1/8")**

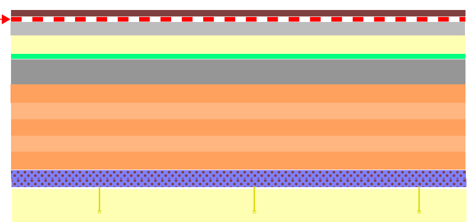


1'-6 5/8"

K3094.58

63 STC 62 IIC

CHANGE **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST05 (1/4")**

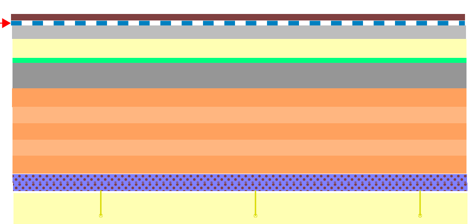


1'-6 3/4"

K3094.59

63 STC 61 IIC

CHANGE **UNDERLAYMENT:**
**ECORE QT4002 (0.08")**

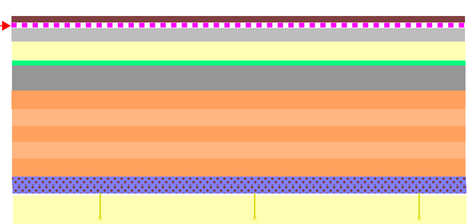


1'-6 9/16"

K3094.60

62 STC 62 IIC

CHANGE **UNDERLAYMENT:**
**ECORE QT4005 (0.20")**

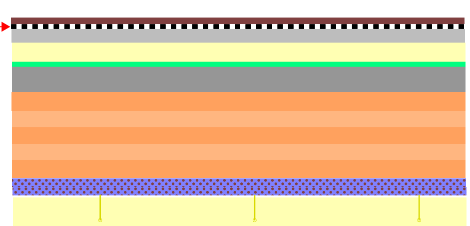


1'-6 11/16"

K3094.61

63 STC 62 IIC

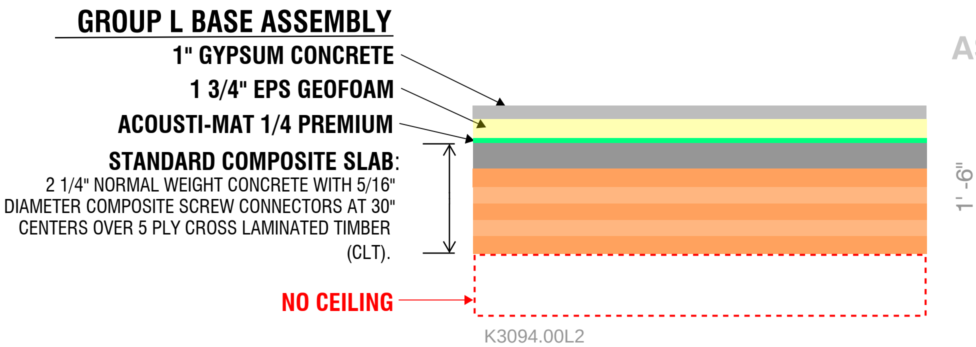
CHANGE **UNDERLAYMENT:**
**MAXXON ACOUSTITOP (1/16")**



1'-6 9/16"

K3094.62

62 STC 60 IIC




ASSEMBLY GROUP: L

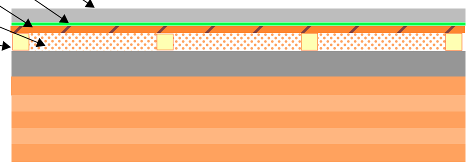
56 STC

50 IIC

ASSEMBLY GROUP: **M**

## GROUP M BASE ASSEMBLY

1" GYPSUM CONCRETE
1/4" ACOUSTI-MAT II
5/8" OSB SUBFLOOR
SAND FILL
2 X 2 WOOD SLEEPERS
**STANDARD COMPOSITE SLAB**: 2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).

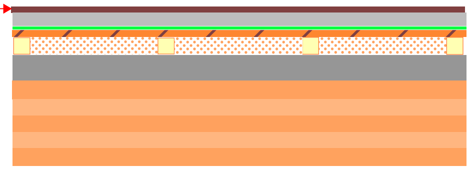


K3094.00M

1'-0 1/2"

59 STC
54 IIC

ADD **1/2" ENGINEERED WOOD FLOORING**
(NO UNDERLAYMENT)

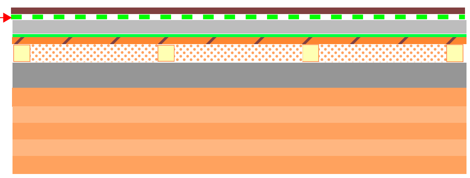


K3094.39

1'-1"

59 STC
57 IIC

ADD **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST02 (1/8")**

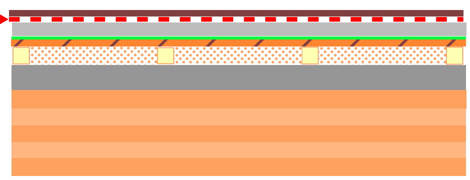


K3094.40

1'-0 9/16"

59 STC
59 IIC

CHANGE **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST05 (1/4")**

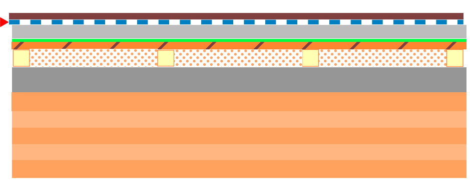


K3094.41

1'-1 1/8"

59 STC
59 IIC

CHANGE **UNDERLAYMENT:**
**ECORE QT4002 (0.08")**

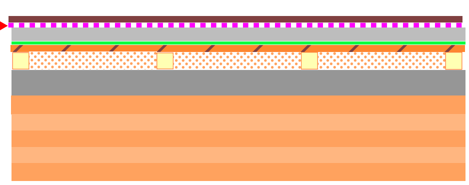


K3094.42

1'-1 1/4"

59 STC
57 IIC

CHANGE **UNDERLAYMENT:**
**ECORE QT4005 (0.20")**

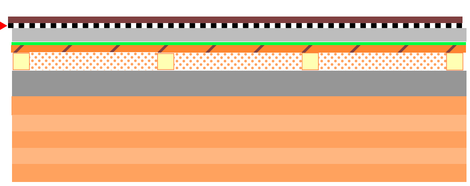


K3094.43

1'-1 3/16"

60 STC
58 IIC

CHANGE **UNDERLAYMENT:**
**MAXXON ACOUSTITOP (1/16")**



K3094.44

1'-1 1/16"

59 STC
58 IIC

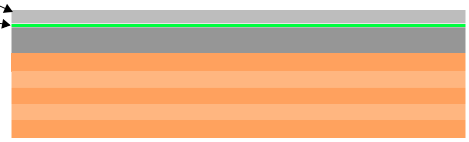
## ASSEMBLY GROUP: N

### GROUP N BASE ASSEMBLY

**1" GYPSUM CONCRETE**

**ACOUSTI-MAT 3/8**

**STANDARD COMPOSITE SLAB**: 2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).



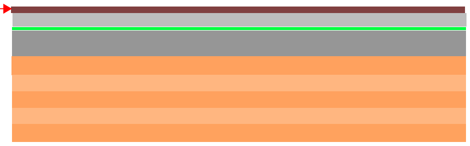
K3094.00N

0' -10 1/4"

52 STC 50 IIC

ADD **1/2" ENGINEERED WOOD FLOORING**

(NO UNDERLAYMENT)

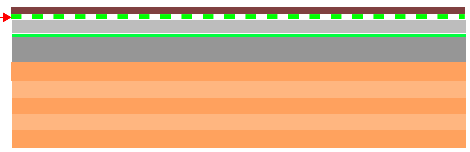


K3094.63

0' -11"

53 STC 52 IIC

ADD **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST02 (1/8")**

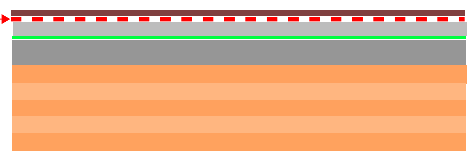


K3094.64

0' -11 1/8"

53 STC 53 IIC

CHANGE **UNDERLAYMENT:**
**PLITEQ GENIEMAT RST05 (1/4")**

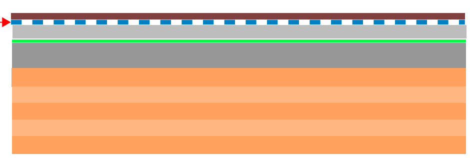


K3094.65

0' -11 1/4"

53 STC 53 IIC

CHANGE **UNDERLAYMENT:**
**ECORE QT4002 (0.08")**

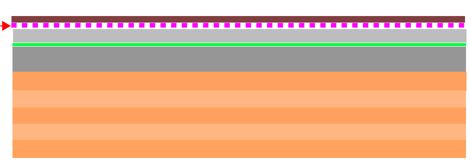


K3094.66

0' -11 1/16"

53 STC 53 IIC

CHANGE **UNDERLAYMENT:**
**ECORE QT4005 (0.20")**

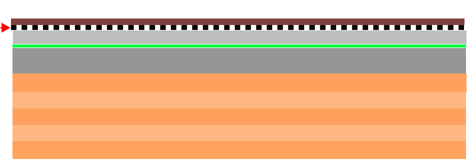


K3094.67

1' -0 3/8"

53 STC 52 IIC

CHANGE **UNDERLAYMENT:**
**MAXXON ACOUSTITOP (1/16")**



K3094.68

1' -0 5/16"

53 STC 52 IIC

ASSEMBLY GROUP: O

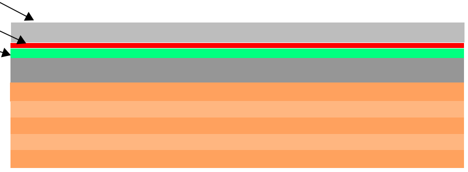
## GROUP O BASE ASSEMBLY

**1 1/2" MAXXON GYPCRETE**

**MAXXON SBR+MAXXON PRIMER/REINFORCEMENT**

**ACOUSTI-MAT 3/4P**

**STANDARD COMPOSITE SLAB**: 2 1/4" NORMAL WEIGHT CONCRETE WITH 5/16" DIAMETER COMPOSITE SCREW CONNECTORS AT 30" CENTERS OVER 5 PLY CROSS LAMINATED TIMBER (CLT).



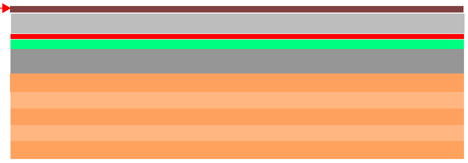
K4507.00

0'-11 3/4"

56 STC | 57 IIC

ADD **1/2" ENGINEERED WOOD FLOORING**

(NO UNDERLAYMENT)

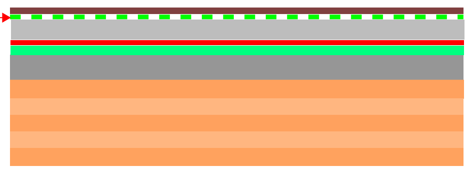


K4507.01

1'-0 1/4"

57 STC | 62 IIC

ADD **UNDERLAYMENT: PLITEQ GENIEMAT RST02 (1/8")**

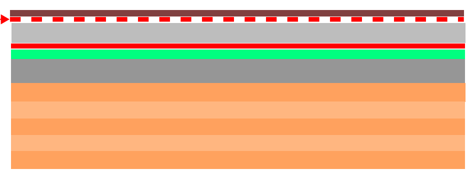


K4507.02

1'-0 3/8"

57 STC | 62 IIC

CHANGE **UNDERLAYMENT: PLITEQ GENIEMAT RST05 (1/4")**

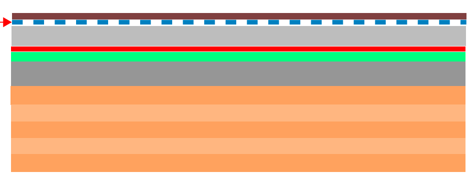


K4507.03

1'-0 1/2"

57 STC | 62 IIC

CHANGE **UNDERLAYMENT: ECORE QT4002 (0.08")**

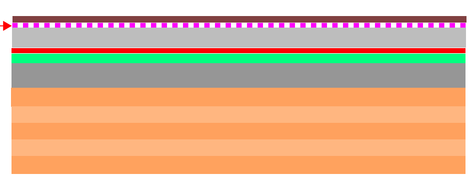


K4507.04

1'-0 5/16"

57 STC | 61 IIC

CHANGE **UNDERLAYMENT: ECORE QT4005 (0.20")**

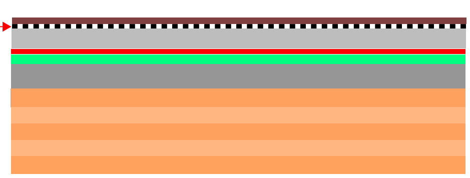


K4507.05

1'-0 7/16"

57 STC | 62 IIC

CHANGE **UNDERLAYMENT: MAXXON ACOUSTITOP (1/16")**



K4507.06

1'-0 5/16"

57 STC | 61 IIC