Movement in Wood Buildings

Understanding, Designing and Building with Wood

Marty Houston
Walsh Construction Co.

WALSH Seminar
June 2016

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

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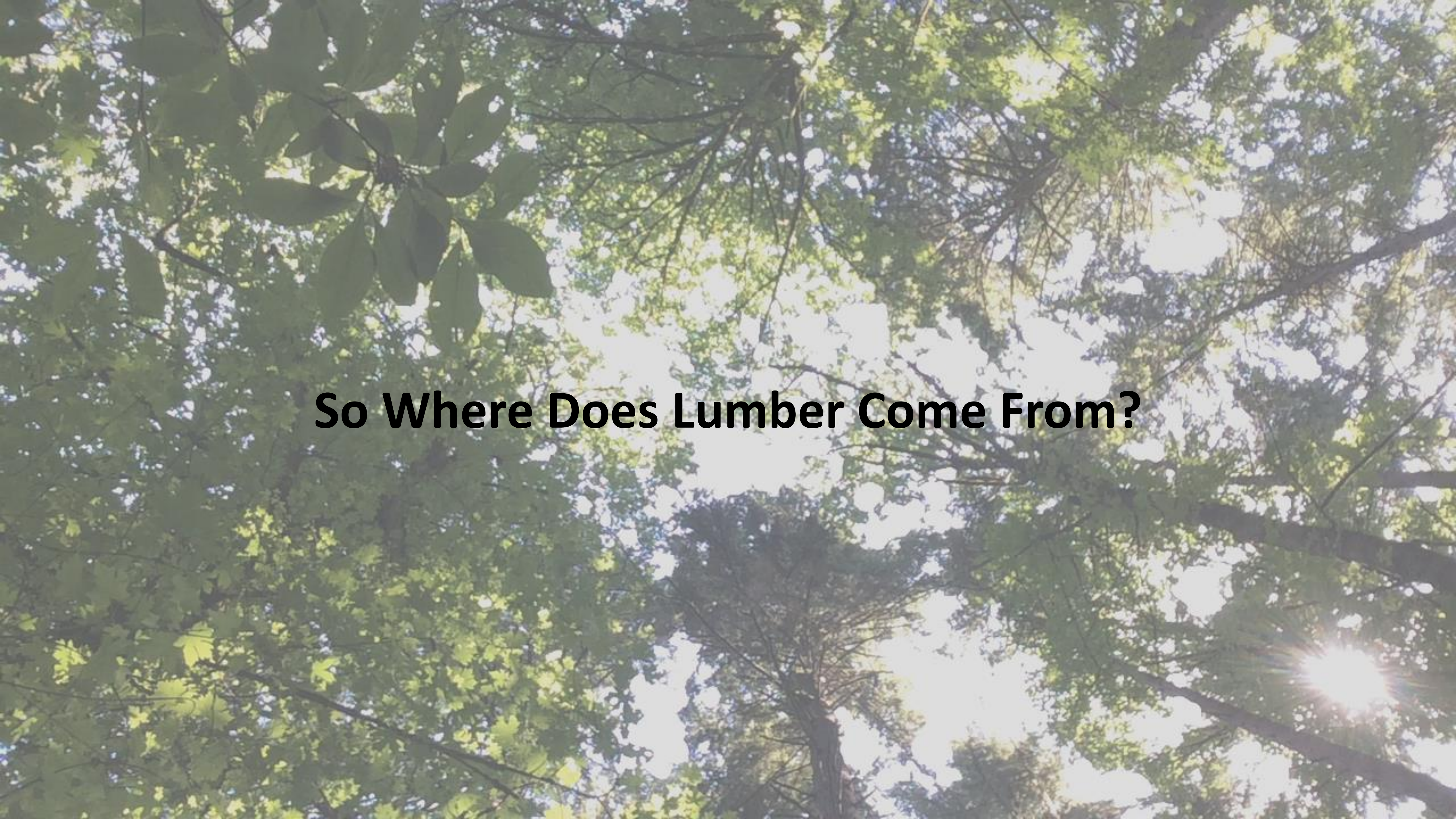
Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Learning Objectives

At the end of the this course, participants will be able to:

1. Understand the physical properties of wood as a structural material and the consequent issues associated with its use.
2. Understand how the issues associated with the use of wood as a structural system can be mitigated with proper material selection, design and installation.
3. Understand the impact that wood frame structural systems can have on cladding systems.
4. Understand the impact that wood frame structural systems can have on MEP systems.

- Design for Shrinkage and Settlement
- Specify and Use the Right Framing Material
- Specify and Use the Right Sheathing Material
- Moisture Content Monitoring
- Understand the Implications of Hybrid Structural Systems
- Hold Down System Design Considerations
- Shrinkage and Settlement Effects on Cladding Systems
- Shrinkage and Settlement Effects on MEP Systems



So Where Does Lumber Come From?


Lumber One
MANITOU


PARR
7STRAND
PREMIUM
16

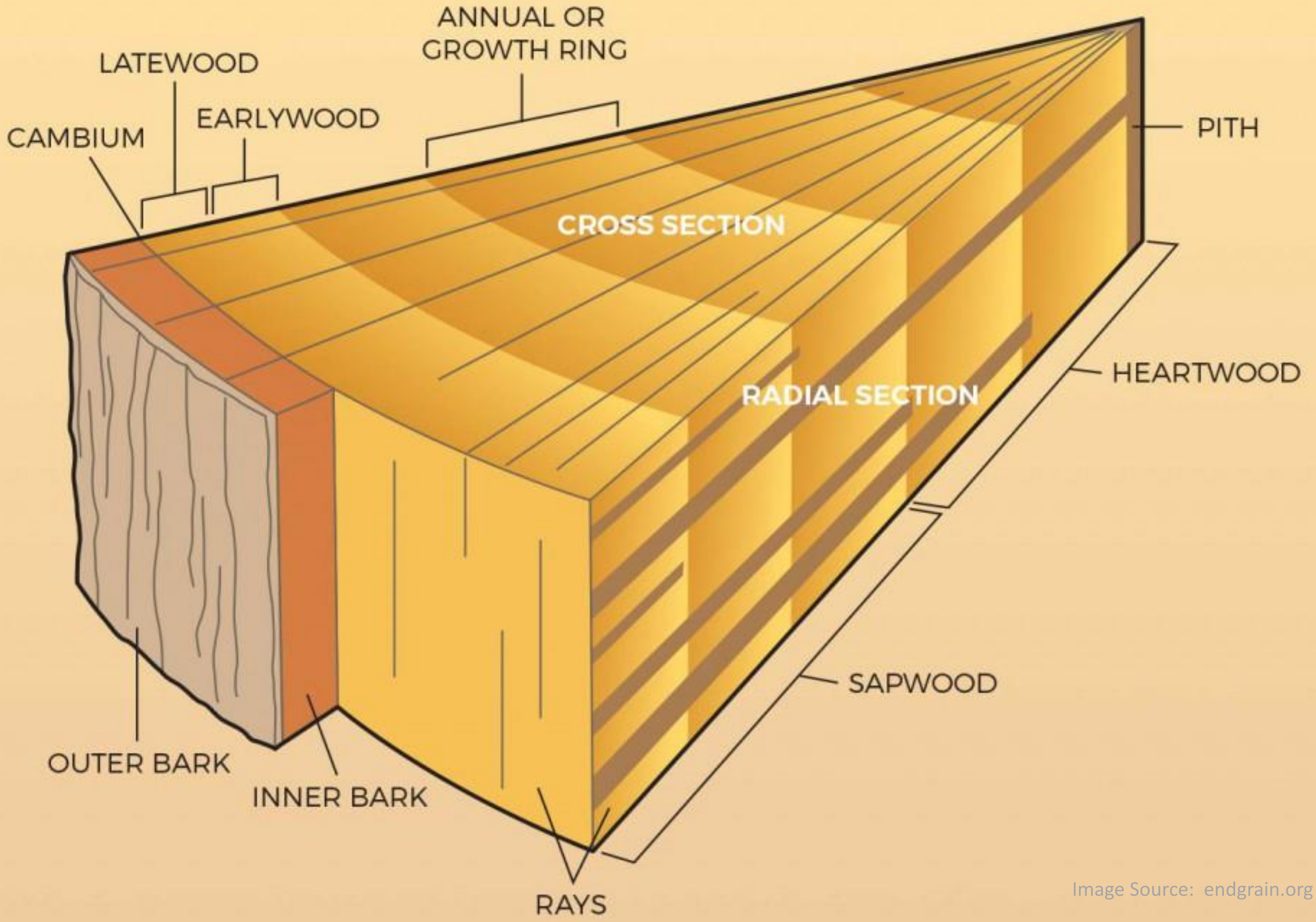


Image Source: endgrain.org

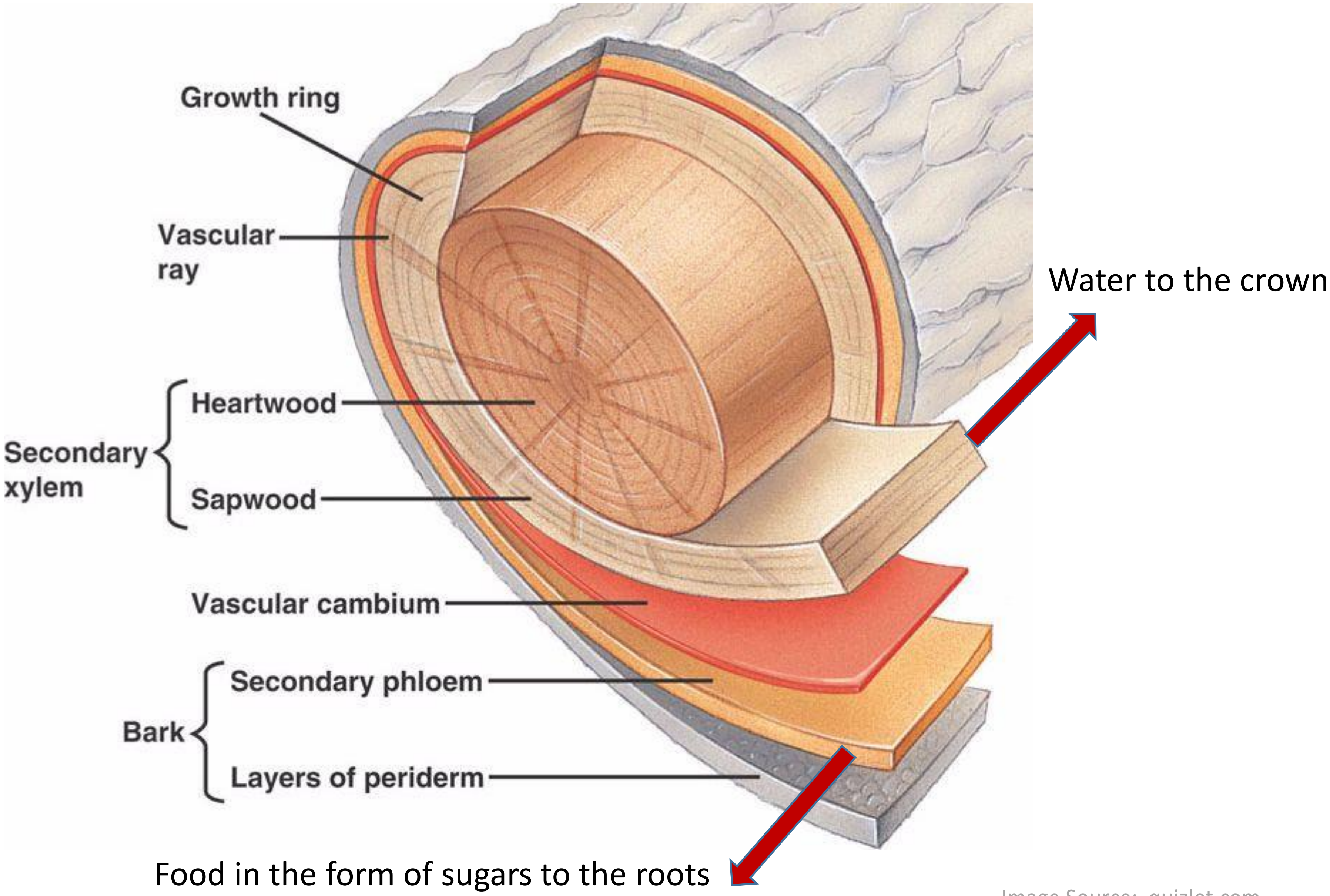
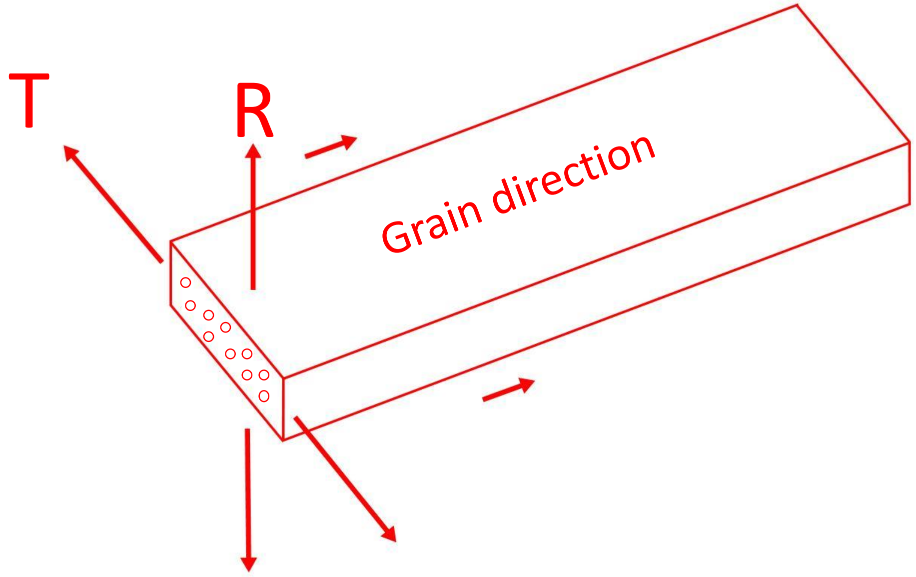
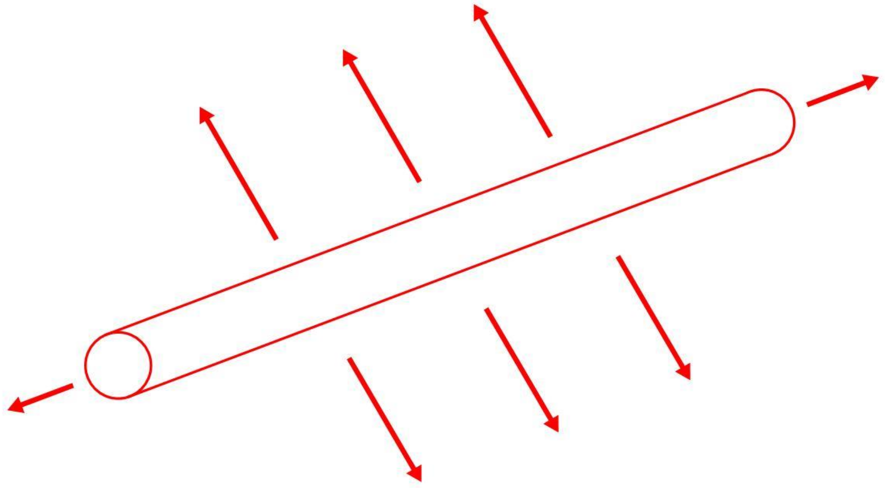


Image Source: quizlet.com



Wood Stud

Gets thicker and wider rather than longer



Wood Fiber

Gets much thicker rather than longer when they pick up moisture

Image Source: Building Science Corporation

Shrinkage Example: A four-story building framed with Douglas Fir, S-DRY, 2x10 lumber floor joists and 2x6 wall plates, with an EMC of 10% in use.

Cumulative Size and Number of Horizontal Members Used: 3 – 2x10 floor joists, 12 – 2x6 sills and wall plates shown in *Figure 3*.

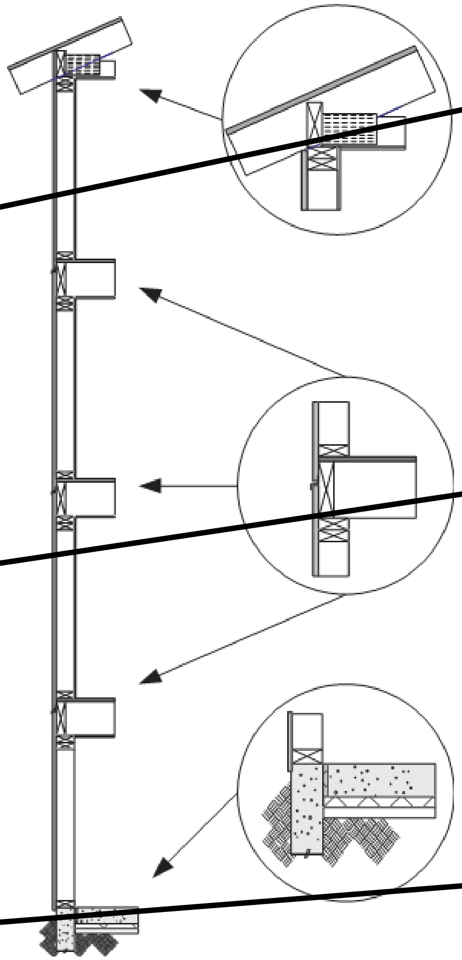
D = (3 x 9.25") + (12 x 1.5") = 45.75"
M = 19% MC (S-DRY) – 10% EMC = 9% MC
C = 0.0020
S = 0.0020 x 9 x 45.75" = 0.824" total shrinkage estimate from the first-story sill plate to the last top plate on the third-story wall.

The 19% MC (S-DRY) in the above calculation for M is conservative given the average MC for S-DRY lumber at the time of manufacture is around 15%.

If S-GRN lumber is used instead of S-DRY, the estimated shrinkage for all plates, sills and joists is 1.796 inches (0.0020 x 19 x 47.26).

Calculating longitudinal shrinkage of wall studs is generally neglected because it is relatively small. It can be calculated and added to the total shrinkage estimate above using the same procedures but using a shrinkage coefficient of 0.00005.

For the above example, assuming S-DRY, KD or KD HT lumber studs 92.25 inches in length at each story; additional shrinkage for all vertical studs (4 stories) is 0.166 inches (0.00005 x 9 x 4 x 92.25).



.824" S-DRY

1.796" S-GRN

.166" S-W

WWPA "Wood Frame Shrinkage Calculations"

"For typical conventional light-frame wood construction with **solid sawn lumber**, framing **shrinkage** due to wood drying can be on the order of .25 inch to 0.5 inch or more per floor. **Engineered wood products** are manufactured relatively dry compared to sawn lumber, and as a result **have less shrinkage** potential compared to solid sawn lumber framing"

Zeno Martin, P.E., S.E. and Eric Anderson, P.E., S.E
Multistory Wood Frame Shrinkage Effects on Exterior Drainage
Structure Magazine, April 2012

Leslie,

Total anticipated deflections due to shrinkage and settlement of framing (given at top of top plate for each level):

Penthouse: 1.31”

Roof: 1.08”

L7: 0.86”

L6: 0.65”

L5: 0.43”

L4: 0.22”

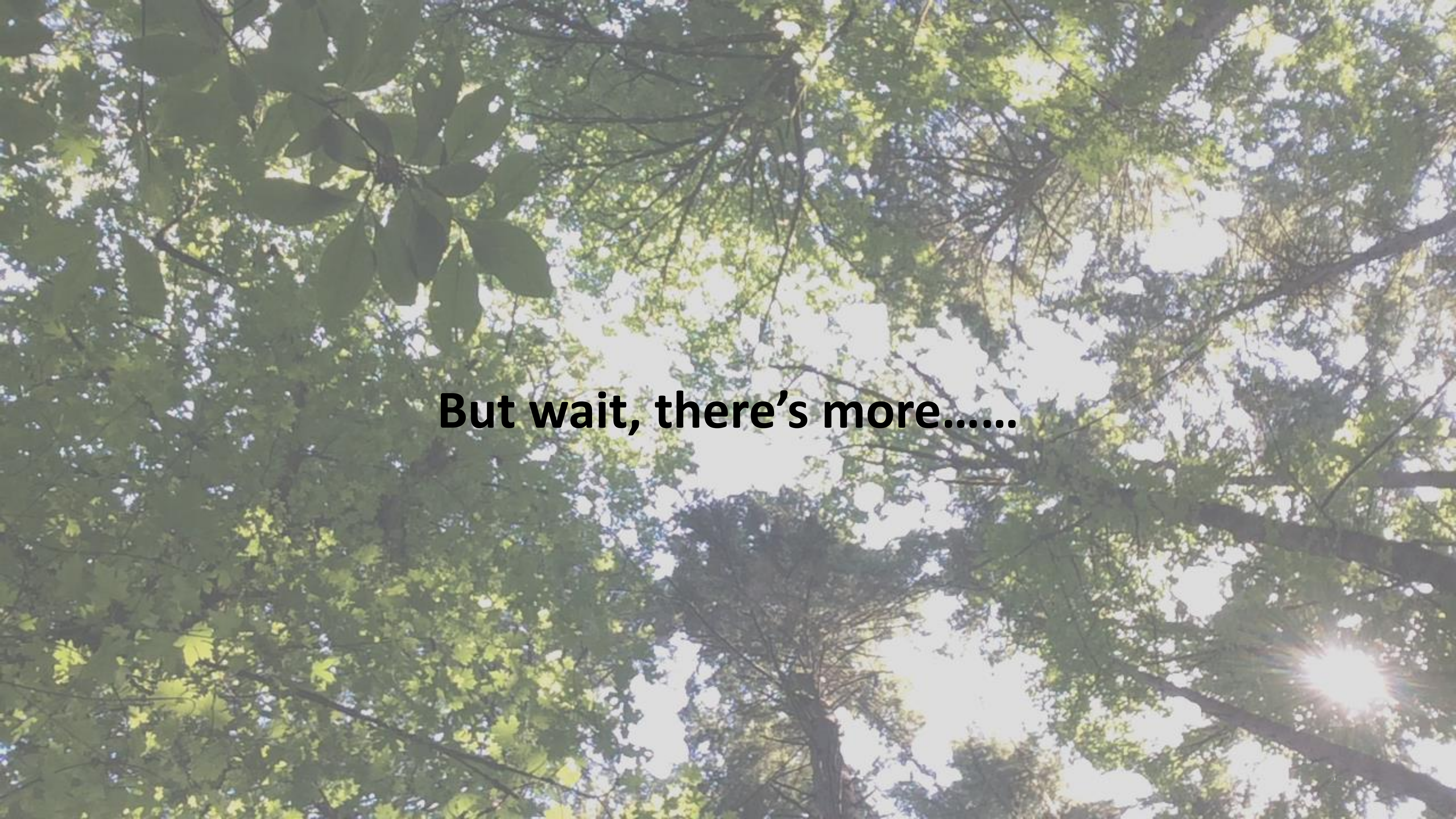
Let me know if you have any additional questions.

So there are ways to calculate shrinkage, but is it a big deal?



Sprinkler System is an Automatic Story Pole

Sprinkler System is an Automatic Story Pole


But wait, there’s more……

If someone invented wood today it would never be approved as a building material. It burns, it rots, it has different strength properties depending on its orientation, no two pieces are alike, and most cruelly of all, it expands and contracts based on relative humidity. Can it get worse? But, of course. Wood expands differently based on orientation.

Joe Lstiburek
Building Science Insight 023
“Wood is Good…But Strange”

So Why Do We Use Wood?


GP
DensGlass

So Why Do We Use Wood?

- Cost Effective
- Readily Available
- Renewable Resource
- Trade Familiarity
- Speed of Construction
- Easily Modified for Future Uses

2303.7 Shrinkage. Consideration shall be given in design to the possible effect of cross-grain dimensional changes considered vertically which may occur in lumber fabricated in a green condition.

So if you build with kiln dried lumber……
Can you say code schmode?

2304.3.3 Shrinkage. Wood walls and bearing partitions shall not support more than two floors and a roof unless an analysis satisfactory to the *building official* shows that shrinkage of the wood framing will not have adverse effects on the structure or any plumbing, electrical or mechanical systems, or other equipment installed therein due to excessive shrinkage or differential movements caused by shrinkage. The analysis shall also show that the roof drainage system and the foregoing systems or equipment will not be adversely affected or, as an alternate, such systems shall be designed to accommodate the differential shrinkage or movements.


Start with the Right Material

Trust But Verify

Shrinkage Example: A four-story building framed with Douglas Fir, S-DRY, 2x10 lumber floor joists and 2x6 wall plates, with an EMC of 10% in use.

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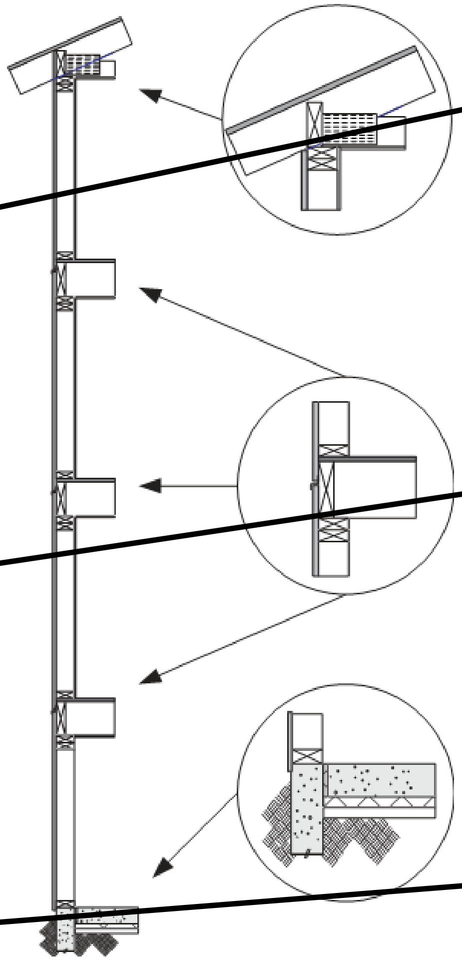

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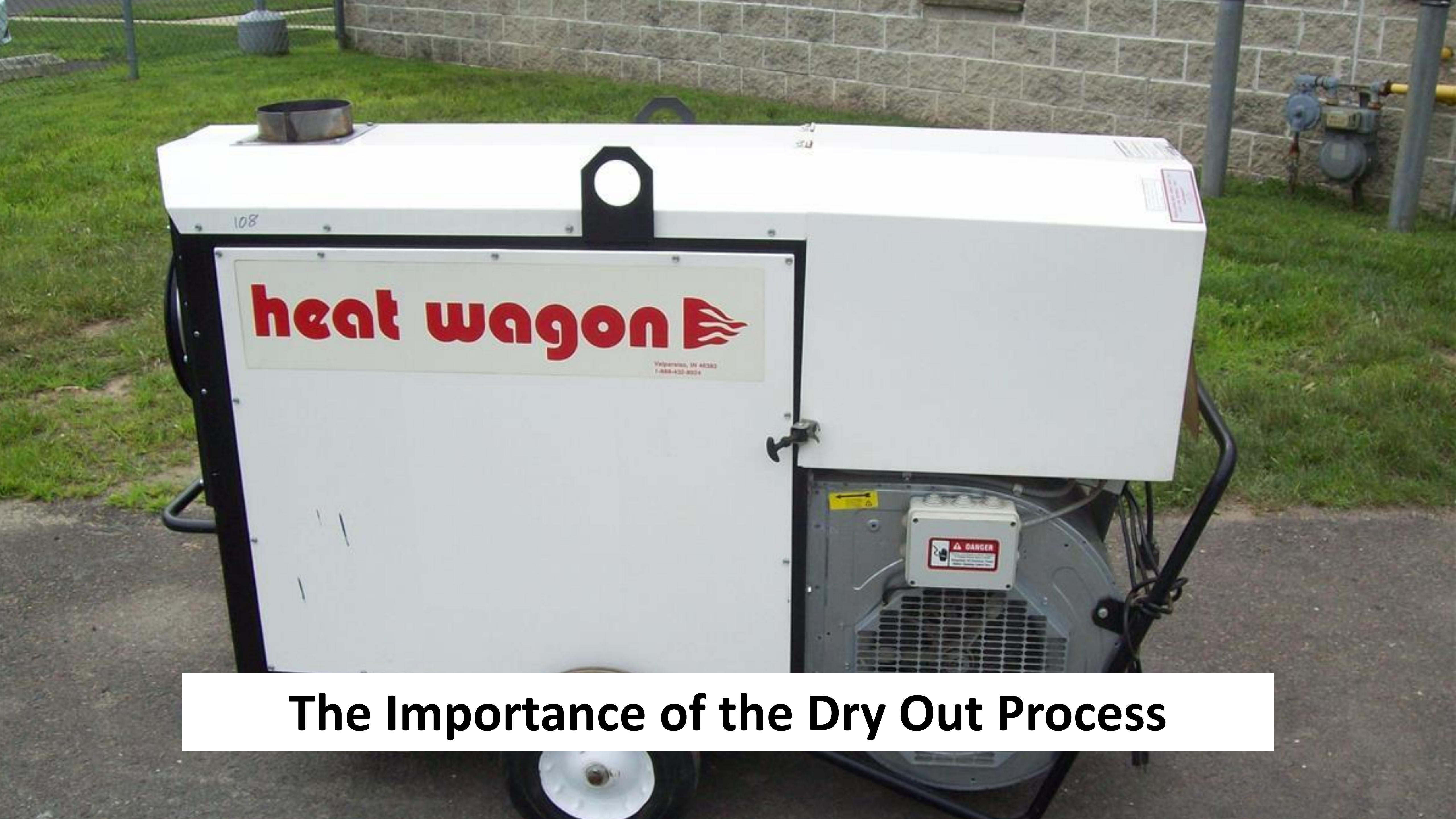
1.796" S-GRN

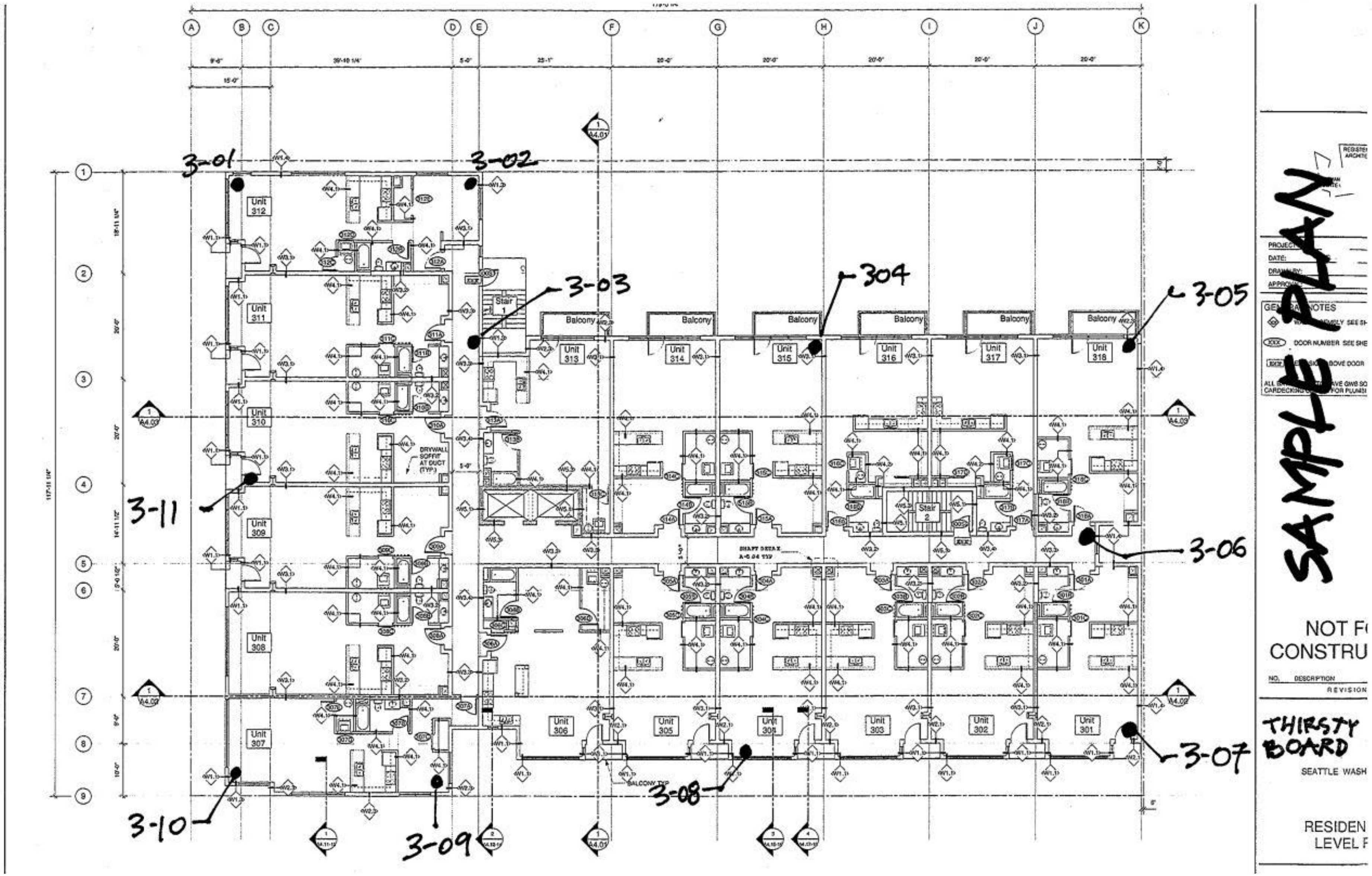
.166" S-W

WWPA "Wood Frame Shrinkage Calculations"


D'INSTALLATION



The Importance of the Dry Out Process



The Importance of the Dry Out Process

Project: Thirsty Board Apt.
Dryout system used: Munters
Moisture meter: Delmhorst BD-2100
Pin depth: 1/5 of overall depth of material
Building side: N/A

Building Level: 3
Building I.D.: C
Date started: 2/13/06
Date completed: 3/10/06

Location/unit: 3-01	2/13/2006	2/17/2006	2/21/2006	2/26/2006	3/1/2006	3/5/2006	3/10/2006
Sill plate	21	21	20	19	17	17	15
Stud	19	18	18	17	15	13	12
Rim Joist	21	21	20	18	18	17	16
Stud pack	19	19	17	17	15	15	13
Header	22	19	18	17	16	15	13

Location/unit: 3-02							
Sill plate	22	21	19	18	18	17	16
Stud	18	18	17	16	15	15	15
Rim Joist	20	19	18	18	17	17	16
Stud pack	20	20	19	18	16	15	15
Header	19	18	18	17	16	16	15

Location/unit: 3-03							
Sill plate	23	23	21	19	19	18	17
Stud	20	19	19	17	17	16	16
Rim Joist	21	20	19	19	18	18	16

Location/unit: 3-04							
Sill plate	22	22	21	21	20	20	19

SAMPLE LOG

The Importance of the Dry Out Process

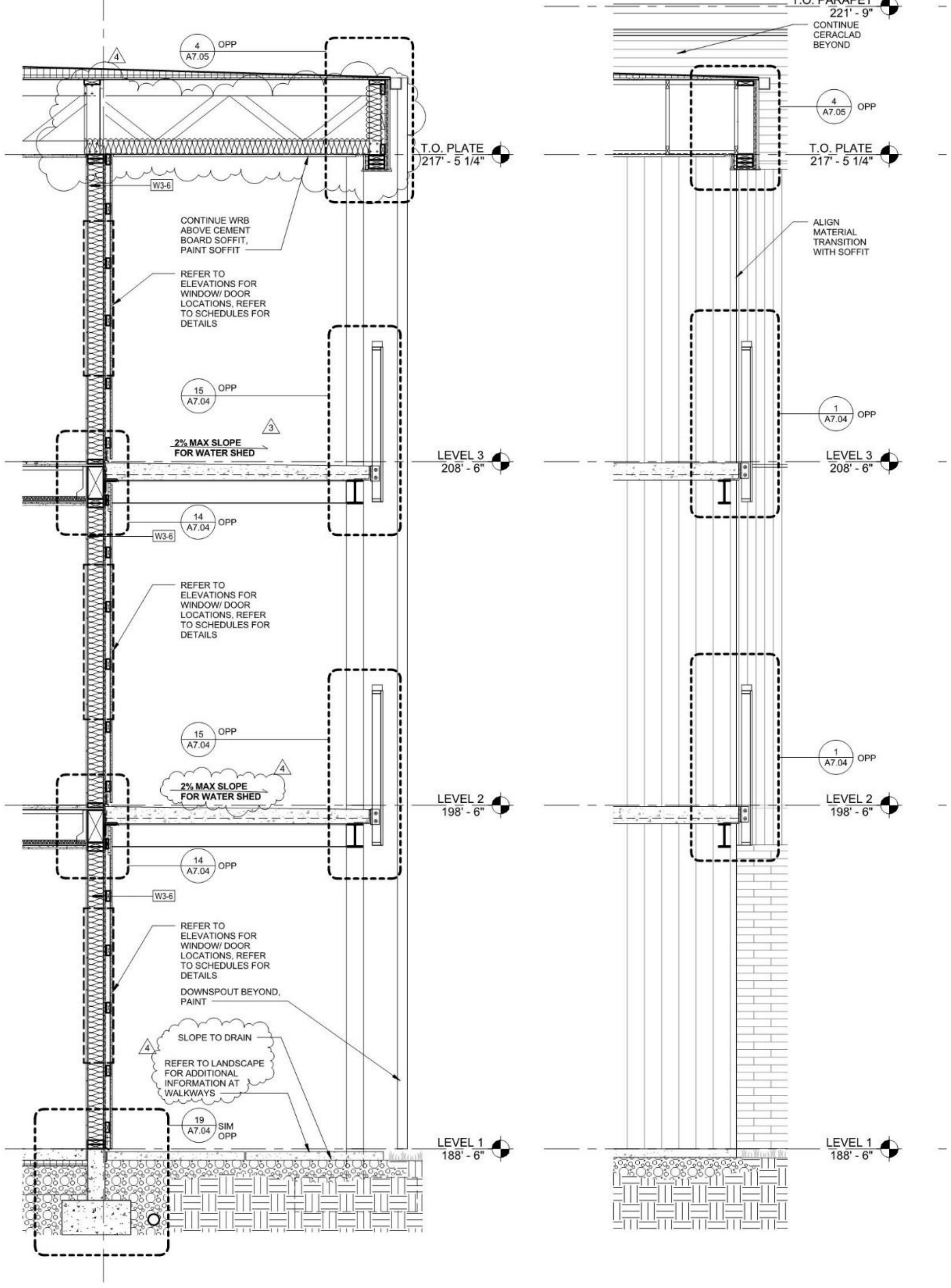
* start another sheet for locations 3-05 through 3-11

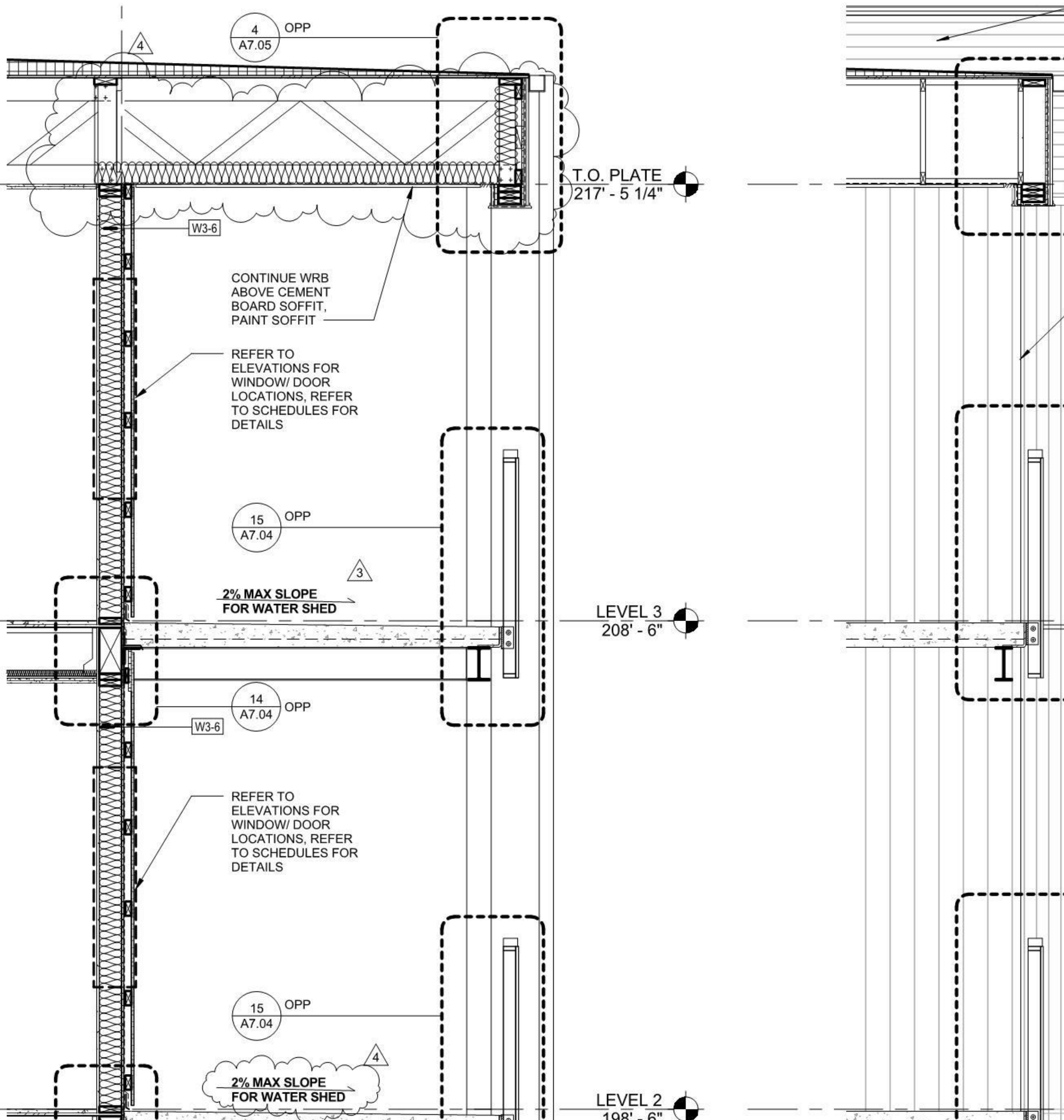

Honey Bucket

SOPREMA
SOPRAVAP R
DensDeck

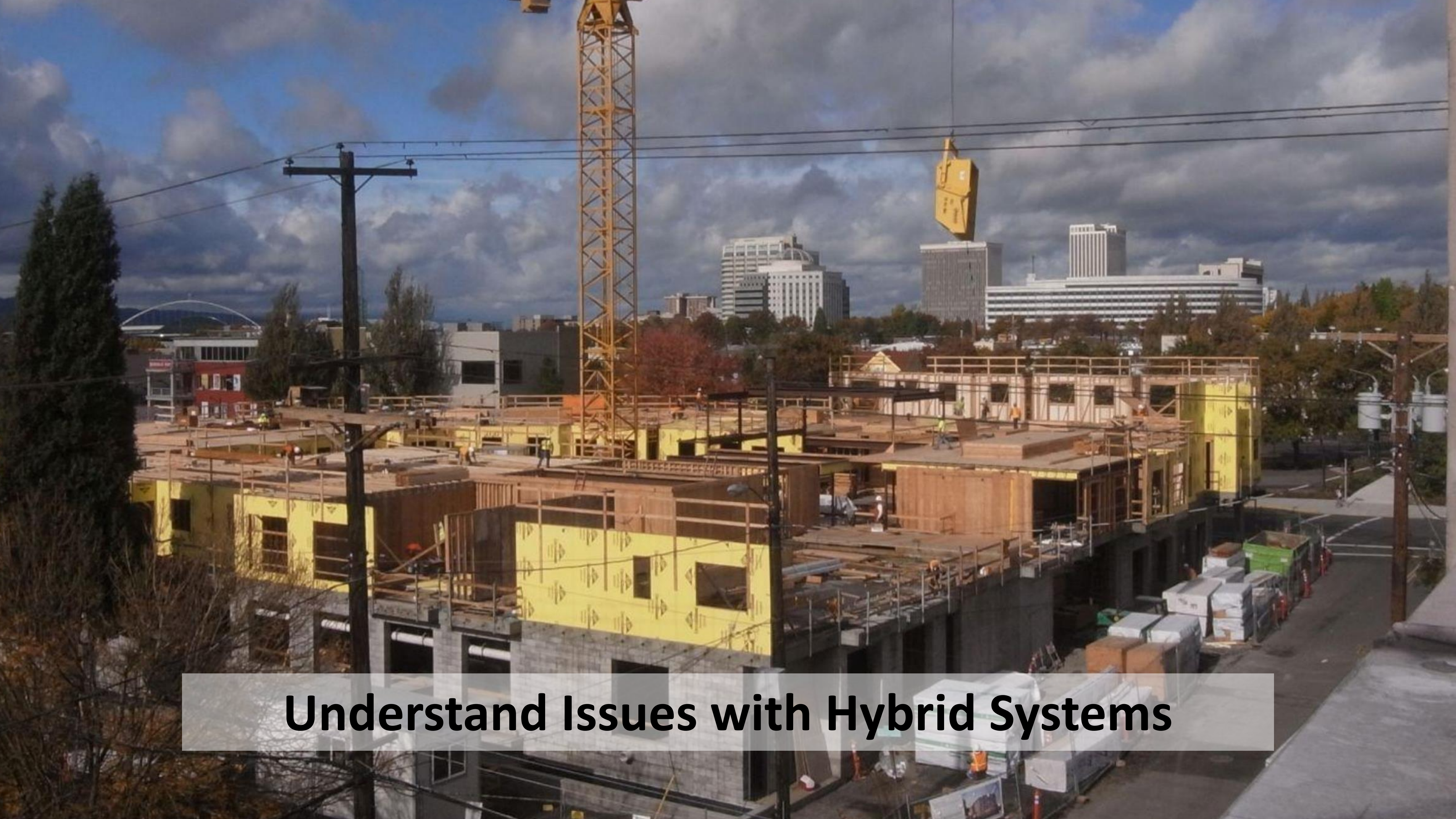

Understand Issues with Sheathing Materials

Understand Issues with Sheathing Materials


4 A7.05 OPP
4
T.O. PLATE 217' - 5 1/4"
W3-6
CONTINUE WRB ABOVE CEMENT BOARD SOFFIT, PAINT SOFFIT
REFER TO ELEVATIONS FOR WINDOW/ DOOR LOCATIONS, REFER TO SCHEDULES FOR DETAILS
15 A7.04 OPP
3
2% MAX SLOPE FOR WATER SHED
LEVEL 3 208' - 6"
14 A7.04 OPP
W3-6
REFER TO ELEVATIONS FOR WINDOW/ DOOR LOCATIONS, REFER TO SCHEDULES FOR DETAILS
15 A7.04 OPP
4
2% MAX SLOPE FOR WATER SHED
LEVEL 2 198' - 6"
14 A7.04 OPP
W3-6
REFER TO ELEVATIONS FOR WINDOW/ DOOR LOCATIONS, REFER TO SCHEDULES FOR DETAILS
DOWNSPOUT BEYOND, PAINT
SLOPE TO DRAIN
4
REFER TO LANDSCAPE FOR ADDITIONAL INFORMATION AT WALKWAYS
19 A7.04 SIM OPP
LEVEL 1 188' - 6"
T.O. PARAPET 221' - 9"
CONTINUE CERACLAD BEYOND
4 A7.05 OPP
T.O. PLATE 217' - 5 1/4"
ALIGN MATERIAL TRANSITION WITH SOFFIT
1 A7.04 OPP
LEVEL 3 208' - 6"
1 A7.04 OPP
LEVEL 2 198' - 6"
LEVEL 1 188' - 6"

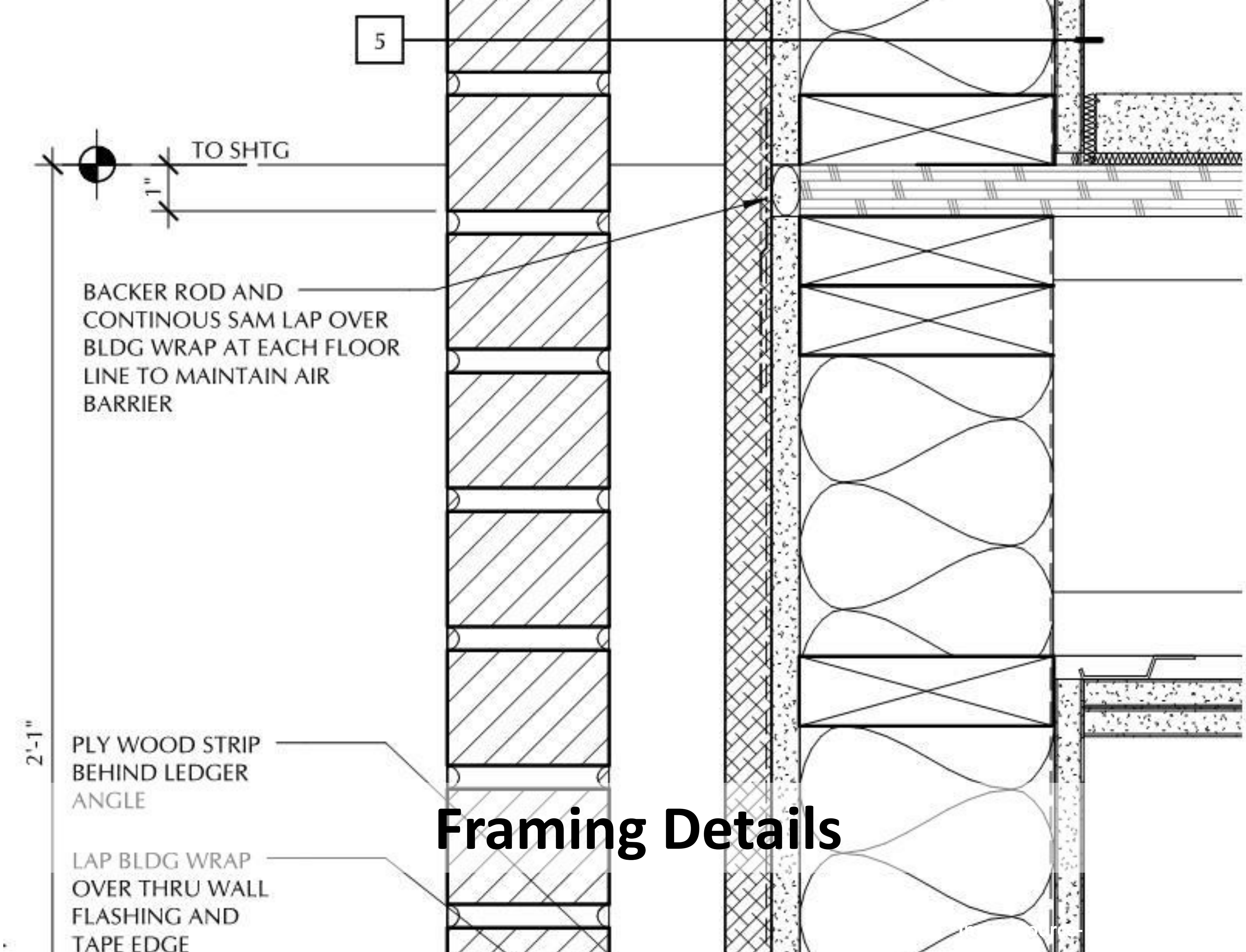

4 A7.05 OPP
4
T.O. PLATE 217' - 5 1/4"
W3-6
CONTINUE WRB ABOVE CEMENT BOARD SOFFIT, PAINT SOFFIT
REFER TO ELEVATIONS FOR WINDOW/ DOOR LOCATIONS, REFER TO SCHEDULES FOR DETAILS
15 A7.04 OPP
3
2% MAX SLOPE FOR WATER SHED
LEVEL 3 208' - 6"
14 A7.04 OPP
W3-6
REFER TO ELEVATIONS FOR WINDOW/ DOOR LOCATIONS, REFER TO SCHEDULES FOR DETAILS
15 A7.04 OPP
4
2% MAX SLOPE FOR WATER SHED
LEVEL 2 198' - 6"

Understand Issues with Hybrid Systems



Understand Issues with Hybrid Systems

Framing Details



Understand Lateral and Hold Down Systems

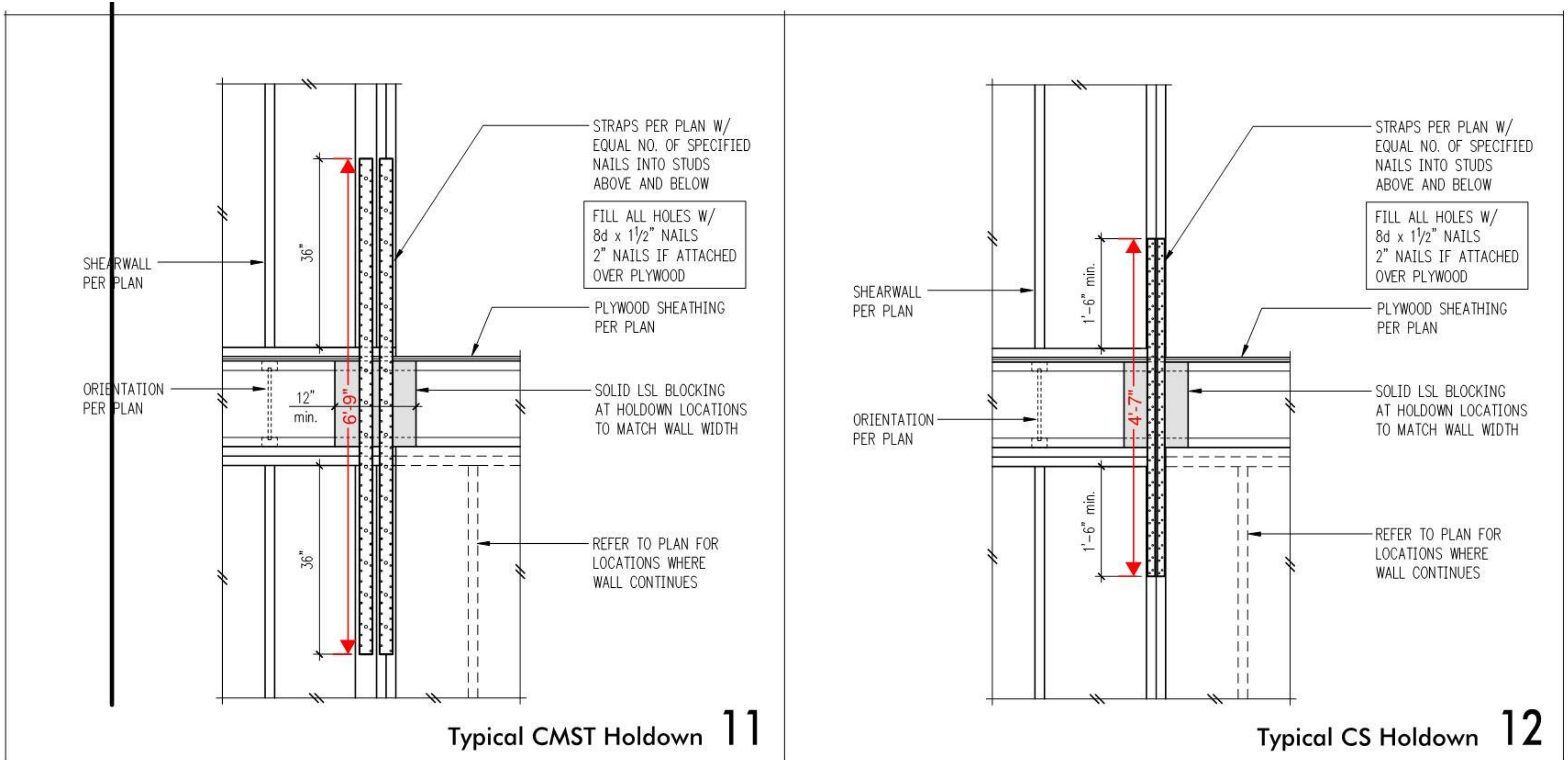
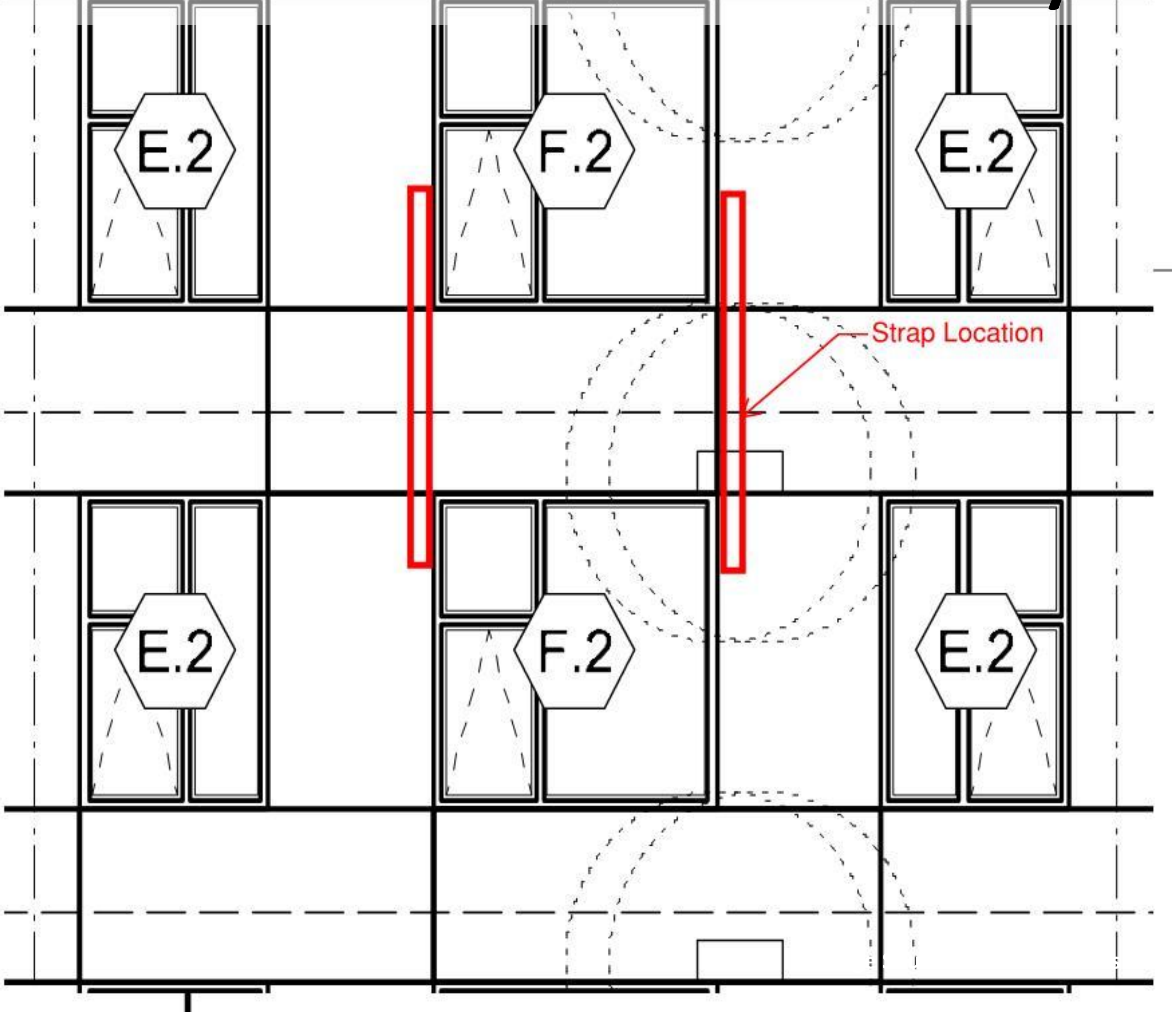
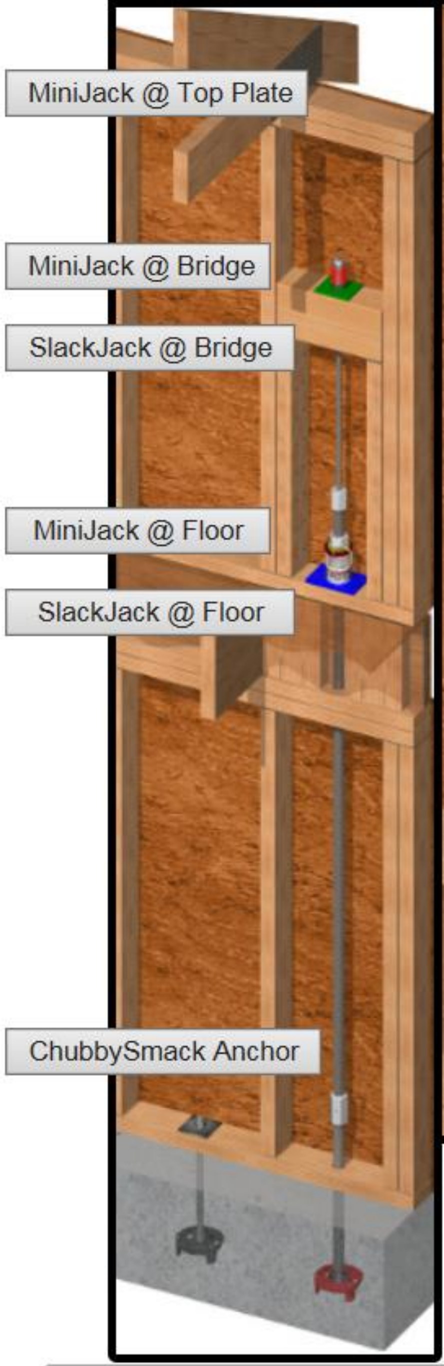


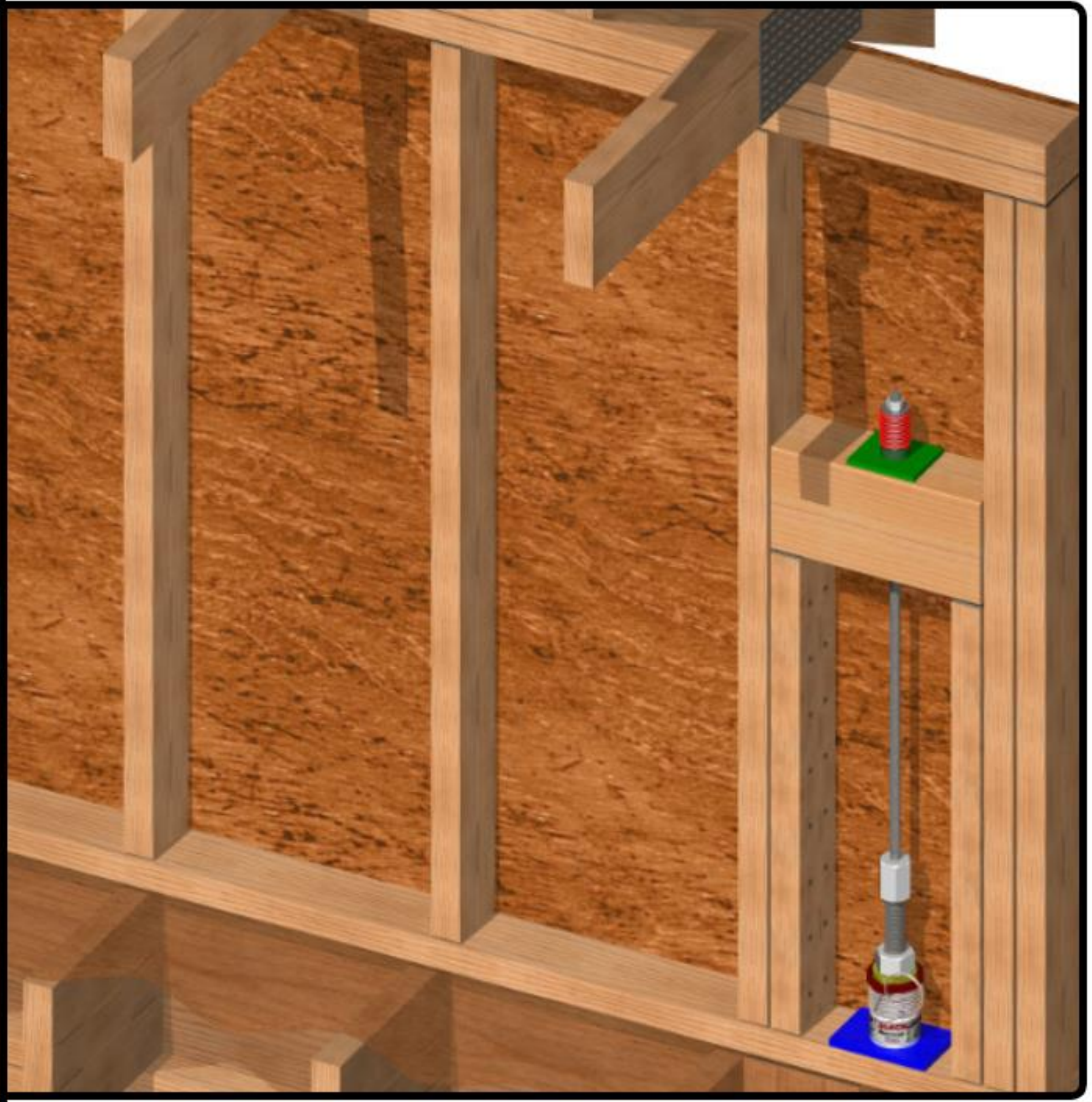
Image Source: SMR Architects

Understand Lateral and Hold Down Systems



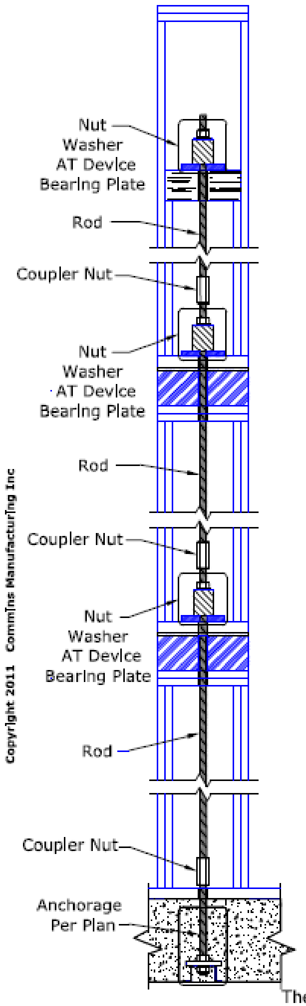
EARTHBOUND SYSTEM





Show me how it works!

AutoTight Templates help speed tie-down design. Complete systems can be designed in 30 minutes. Our designs always begin with system strength. The designer then adjusts elongation to meet jurisdiction requirements. The demonstration package provides an overview of the software and the process.



Package	Description
Demonstration Sample Package (pdf)	The **Demonstration Sample** showcases a typical design process. The example includes: **Project information** (one page). Project and code requirements. **Load justification** (one page). Enter system loads. Adjust elongation. **Run Take-Off** a run-by-run materials list. **Run Materials list.** Every item need to build the system. **Calculation Package.** Review ready calculations, every floor, every run. **AT 10 Holdown Run Details.** (selected per code) **AT 11 Holdown Run Elevations.** Shop Drawings for field assembly. **AT 12 Anchor Bolt Embedments** Details every location
Run Sorter (Excel) (1)	The **Run Sorter** provides a method of combining loads floor-by-floor to create the "Best" balance of cost vs the number of runs. Loads are entered by location (X and Y) and then by floor level 1,2 3 etc. Using the excel data sort function allows the operator to optimize the number of different runs. **Run Sorter** Instructions 10 page PDF.
AutoDesign (2a) (Excel) **AutoDesign Quick Start (2b)**	**AutoDesign** generates a strength based design. The designer then adjusts elongation by changing rod or bearing plates. **Output includes:** a Load Justification Table and a hardware list. **Estimated Design Time:** 15-45 minutes **AutoDesign Quick Start** is a fully functional sample **AutoDesign Instructions** A PDF Power Point presentation (6.7) MB.
Calculation Pack (Excel) (3)	**AutoTight Calculation Package** uses AutoDesign information to provide ready-to-review job specific calculations. The calculations are floor-by-floor one page per run. **Instructions** see worksheet tab **Estimated Time:** 20 minutes
AT 10 Drawing Details (AutoCAD) (4a – 4f)	**AT 10: Drawing Details** includes Rod, Bearing Plate and AT Auto Take-Up information, code information and common details. Select the version required per your building code, make simple changes for the project. Instructions are on layout tab "Instructions". **Output:** Complete customized details. **Estimated Time:** 15 minutes
AT 11 Run Details (AutoCAD) (5)	**AT 11: Run Details** is a ready-to-modify drawing in a pick-and-place format. Runs from one to six stories are selected from a library. Couplers, rod, TUD's and plates are added based on AutoDesign. Instructions are on layout tab "Instructions". **Output:** Multistory Run Elevation Drawings ready for review. **Estimated Time:** 30 minutes per run.
AT 12 Embedments (AutoCAD) (6)	**AT 12: Embedments** provides a ready to modify embedment template compatible with most tie downs. Instructions are on layout tab "Instructions".

The numbers in Green are keyed to the thumb drive index. These are the most used for system design. See "***#12 Delta R Compared***" for a graphic Delta R illustration.

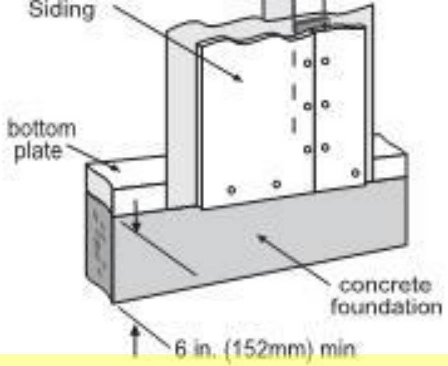
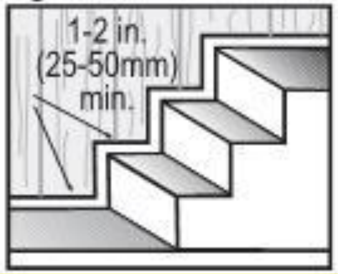
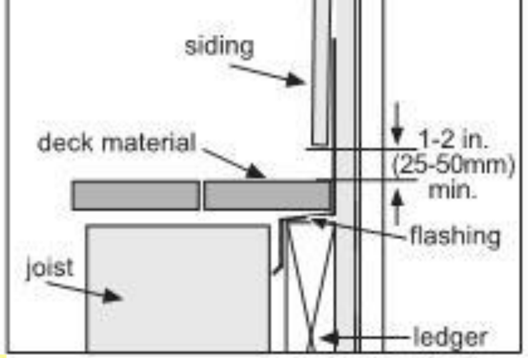


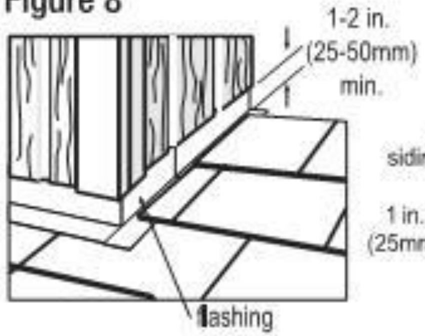
Figure 6





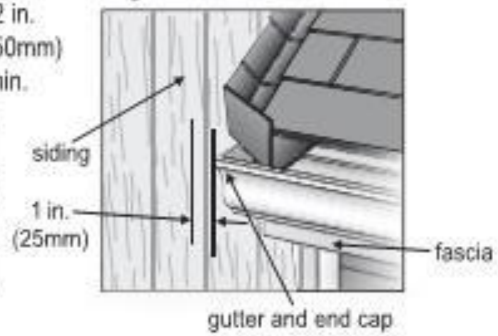
clearance between the roofing and the bottom edge of the siding and trim.

Figure 8



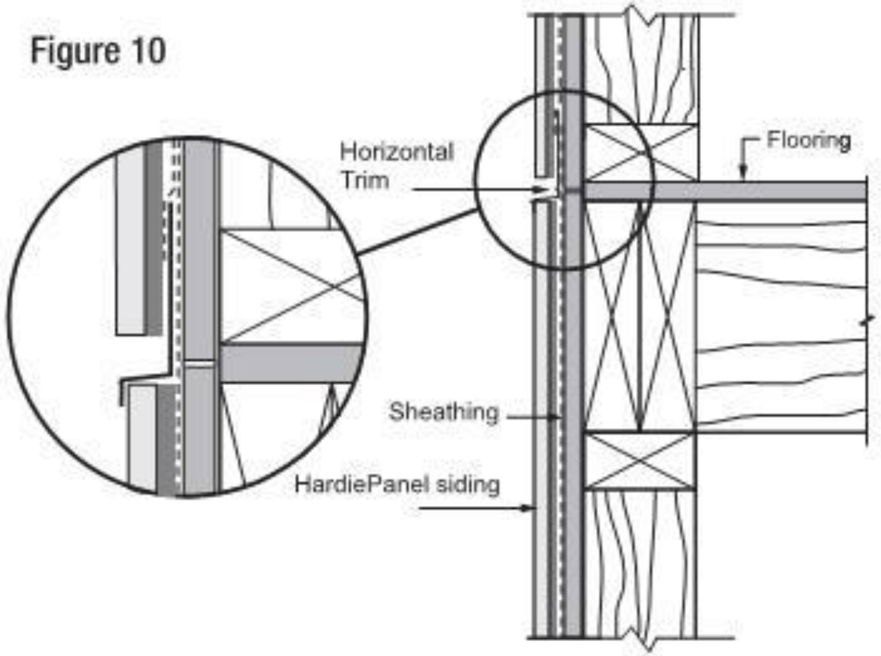
Maintain a minimum 1 in. (25mm) gap between gutter end caps and siding & trim.

Figure 9

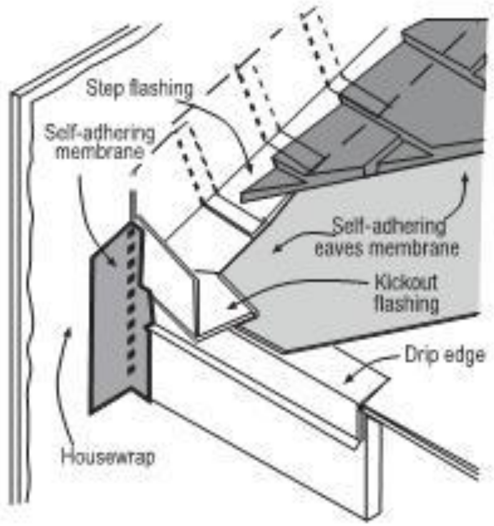


* Do not bridge floors with HardiePanel siding. Horizontal joints should always be created between floors (fig. 10).

Figure 10



Note: Furring shown is as a best practice or as prescribed per Table 1.



KICKOUT FLASHING

Because of the volume of water that can pour down a sloped roof, one of the most critical flashing details occurs where a roof intersects a sidewall. The roof must be flashed with step flashing. Where the roof terminates, install a kickout to deflect water away from the siding. It is best to install a self-adhering membrane on the wall before the subfascia and trim boards are nailed in place, and then come back to install the kickout. **Figure 11, Kickout Flashing*** To prevent water from dumping behind the siding and the end of the roof intersection, install a "kickout" as required by IRC code R905.2.8.3 : "…flashing shall be a min. of 4 in. high and 4 in. wide." James Hardie recommends the kickout be angled between 100° - 110° to maximize water deflection

GENERAL FASTENING REQUIREMENTS

Fasteners must be corrosion resistant, galvanized, or stainless steel. Electro-galvanized are acceptable but may exhibit premature corrosion. James Hardie recommends the use of quality, hot-dipped galvanized nails. James

PNEUMATIC FASTENING

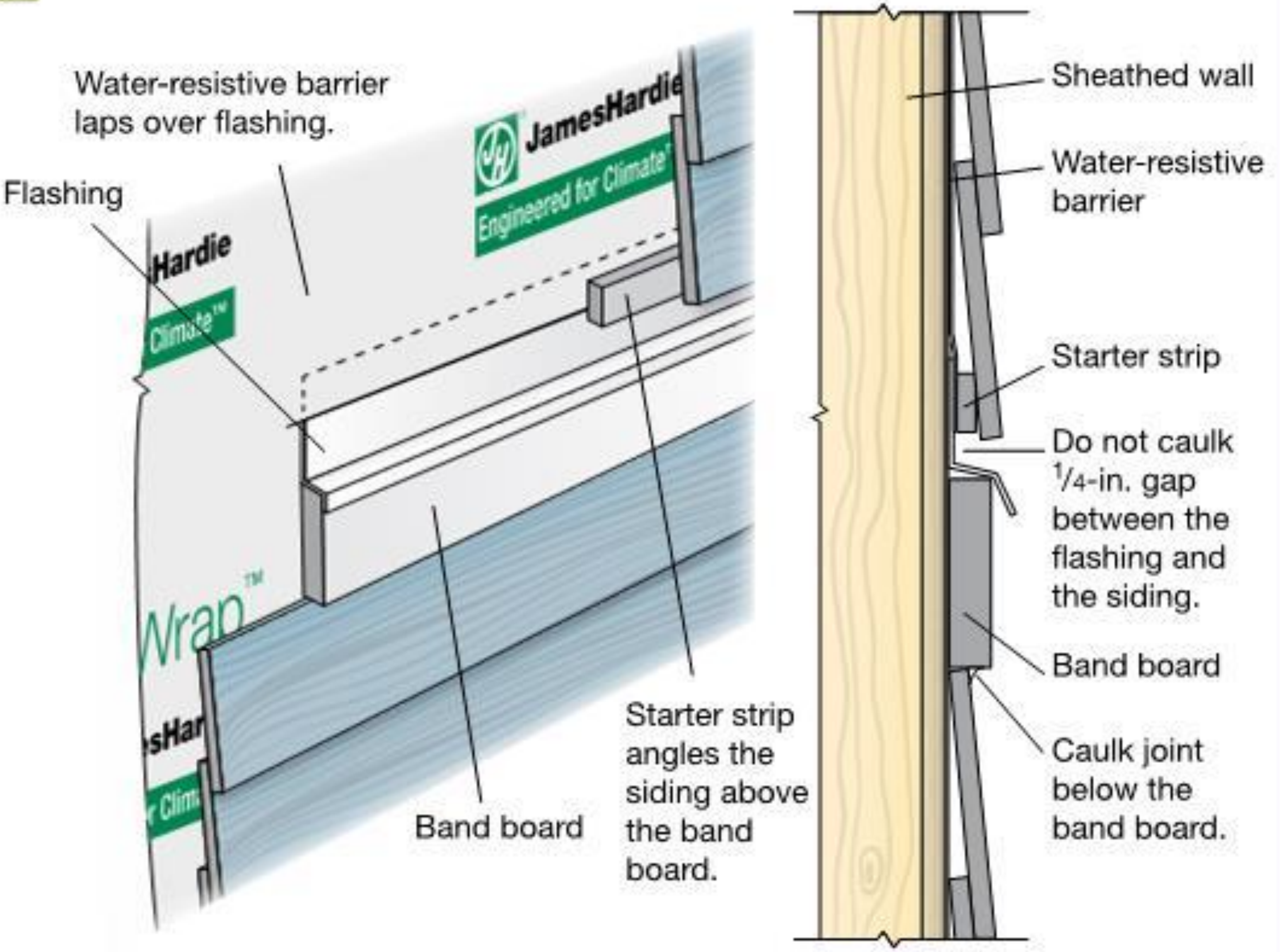
James Hardie products can be hand nailed or fastened with a pneumatic tool. Pneumatic fastening is highly recommended. Set air pressure so that the fastener is driven snug with the surface of the siding. A flush

BAND BOARD

A Band board is a decorative horizontal trim used to break up the field of siding on a building. Any width of HardieTrim® boards can be used for band board depending on the type of detail desired. If installing a band board, pay special attention to flashing details and allow for potential shrinkage of solid rim joists in the walls that the band board may be attached to.

Caulk between the underside of the band board and the siding below. Do not caulk between the flashing and siding above the band board, and maintain a 1/4-in. gap between the two. Also make sure that the water-resistive barrier laps over the flashing for a continuous drainage plane. If running lap siding or

8.19



Shrinkage and Settlement Effects on Cladding

Shrinkage and Settlement Effects on Cladding

Shrinkage and Settlement Effects on Cladding

Shrinkage and Settlement Effects on Cladding

Shrinkage and Settlement Effects on Cladding

HORIZONTAL EXPANSION JOINTS

Horizontal expansion joints are typically needed if the brick wythe is supported on a shelf angle attached to the frame or used as infill within the frame. Placing horizontal expansion joints below shelf angles provides space for vertical expansion of the brickwork below and deformation of the shelf angle and the structure to which it is attached. Structures that support the brick wythe on shelf angles, usually done for each floor, must have horizontal expansion joints under each shelf angle. Figure 8 shows a typical detail of a horizontal expansion joint beneath a shelf angle. If the shelf angle is not attached to the structure when the brick below it are laid, any temporary shims that support the angle must be removed after the shelf angle is connected. The joint is formed by a clear space or highly compressible material placed beneath the angle, and a backer rod and

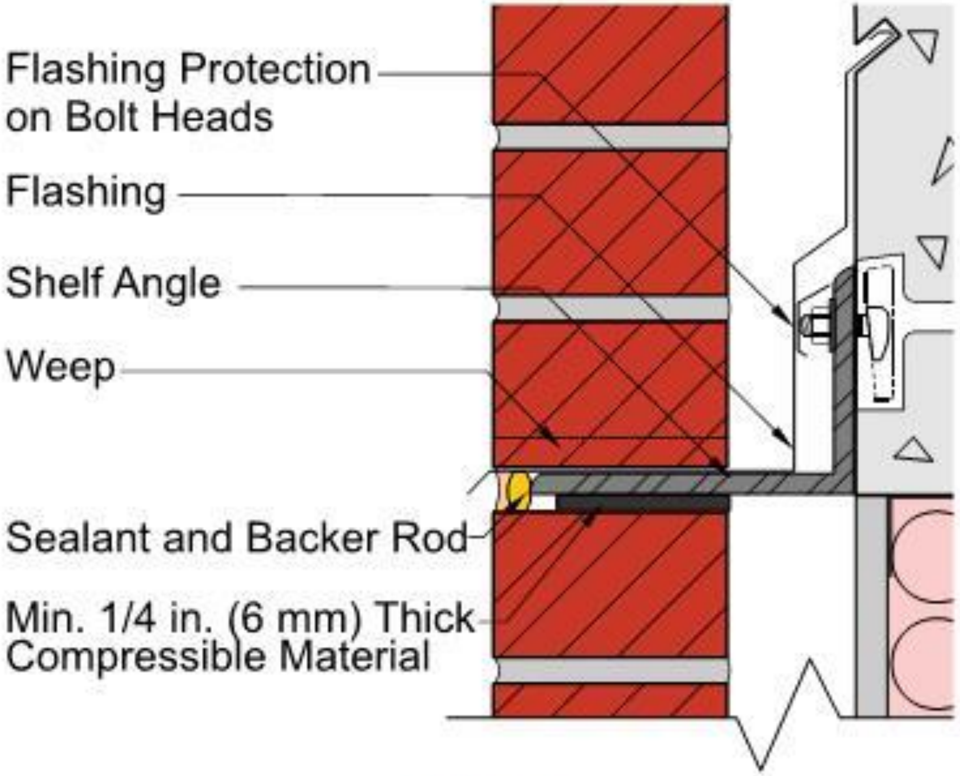
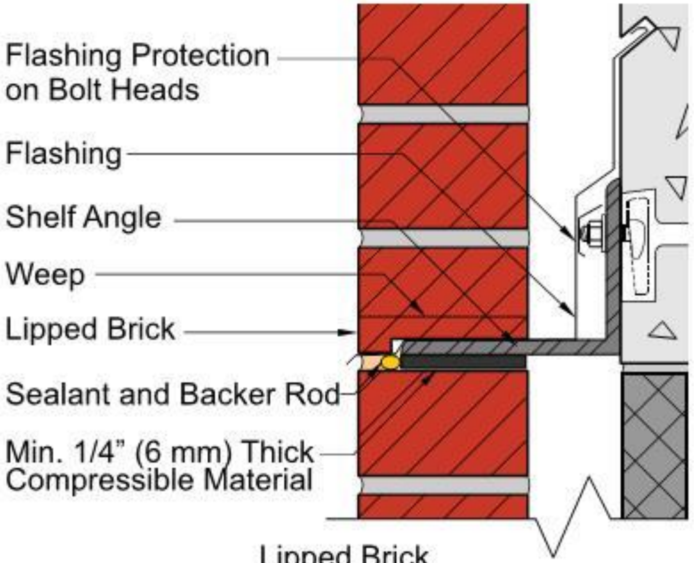


Figure 8
Expansion Joint at Shelf Angle

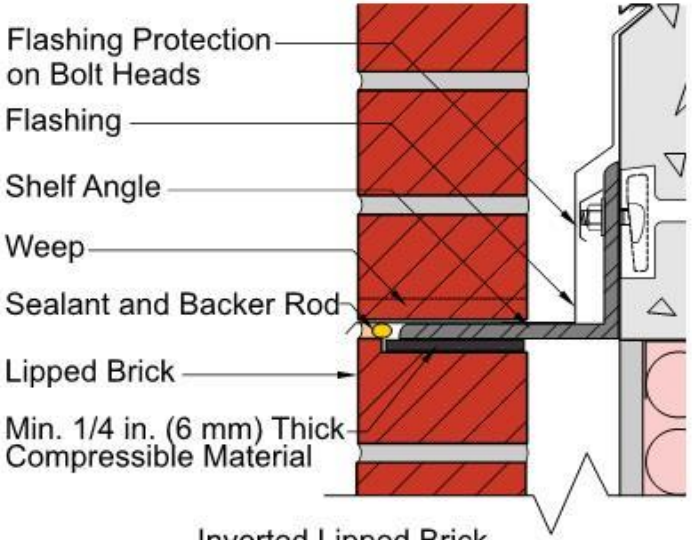
Construction using lipped brick requires careful consideration of the frame movements noted previously. Allowance for adjacent material tolerances including the building frame should also be considered. Adequate space should be provided between the lipped portion of the brick and the shelf angle to ensure no contact. Contact should not occur between the lipped brick and the brickwork below the shelf angle or between the lip of the brick and the shelf angle, not only during construction, but also throughout the life of the building.

Lipped brick may be installed as the first course above a shelf angle, as shown in Figure 9a. Flashing should be placed between the shelf angle and the lipped brick course. Proper installation of flashing is made more difficult because the flashing must conform to the shape of the lip. This shape may be achieved with stiffer flashing materials such as sheet metal. If the specified flashing materials are made of composite, plastic or rubber, a sheet metal drip edge should be used. The practice of placing flashing one course above the shelf angle is not recommended, as this can increase the potential for movement and moisture entry.

Lipped brick also may be inverted and placed on the last course of brickwork below a shelf angle, as shown in Figure 9b. While installing an inverted lipped brick course allows the flashing of the brickwork above to maintain a straight profile through the brickwork, it also allows the lipped brick course to move independent of the shelf angle. Thus, there is an increased possibility of the shelf angle coming in contact with the lipped brick course, resulting in cracking at the lip. It is difficult, if not impossible, to install compressible material below the shelf angle. Further, it is likely that temporary shims may be left in place between the lipped brick and the shelf angle.

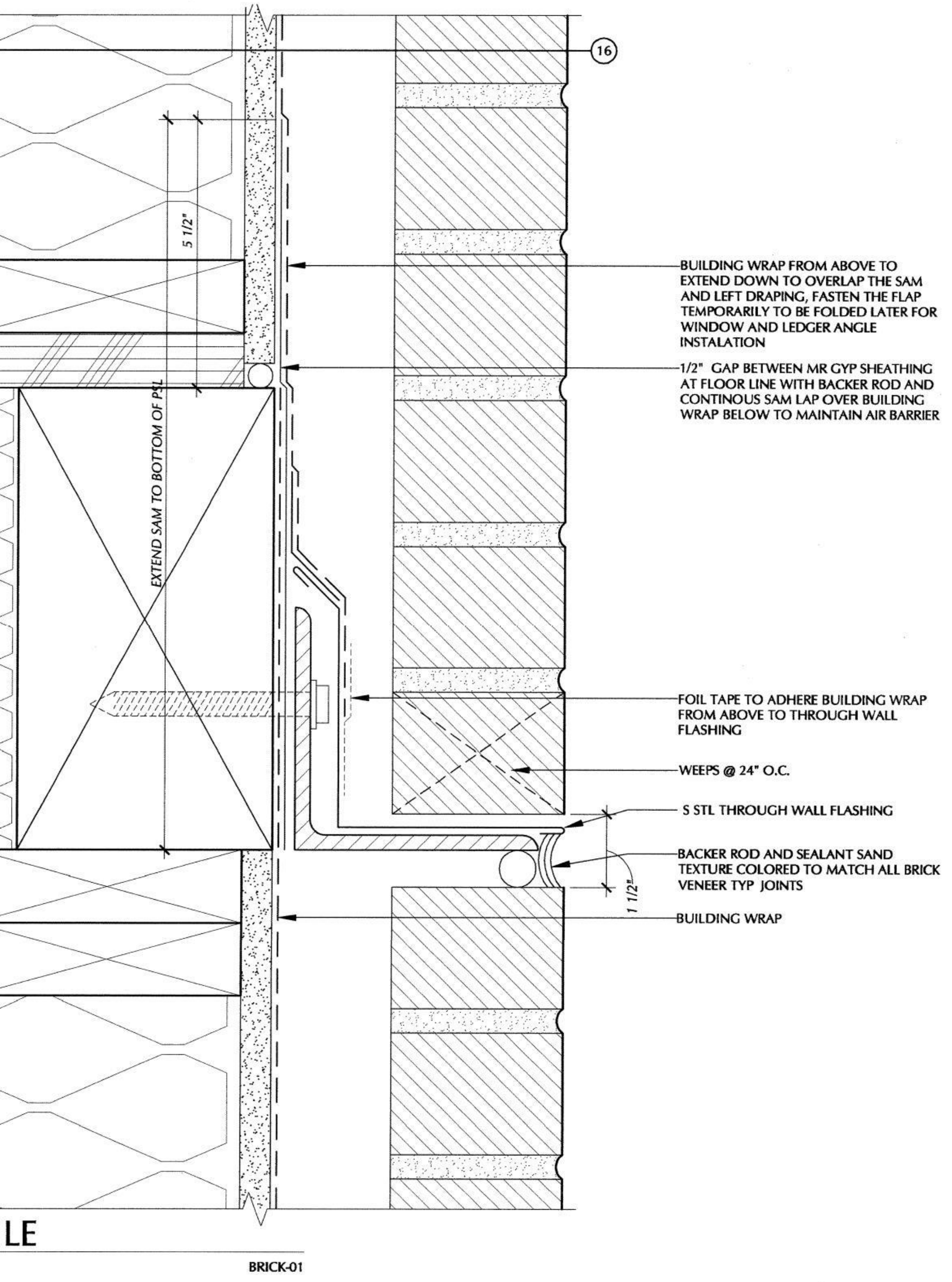


Lipped Brick
(a)



Inverted Lipped Brick
(b)

Figure 9
Alternate Expansion Joint Detail


16
5 1/2"
EXTEND SAM TO BOTTOM OF PSL
BUILDING WRAP FROM ABOVE TO EXTEND DOWN TO OVERLAP THE SAM AND LEFT DRAPING, FASTEN THE FLAP TEMPORARILY TO BE FOLDED LATER FOR WINDOW AND LEDGER ANGLE INSTALATION
1/2" GAP BETWEEN MR GYP SHEATHING AT FLOOR LINE WITH BACKER ROD AND CONTINOUS SAM LAP OVER BUILDING WRAP BELOW TO MAINTAIN AIR BARRIER
FOIL TAPE TO ADHERE BUILDING WRAP FROM ABOVE TO THROUGH WALL FLASHING
WEEPS @ 24" O.C.
S STL THROUGH WALL FLASHING
BACKER ROD AND SEALANT SAND TEXTURE COLORED TO MATCH ALL BRICK VENEER TYP JOINTS
1 1/2"
BUILDING WRAP
LE
BRICK-01

Shrinkage and Settlement Effects on MEP

Shrinkage and Settlement Effects on MEP

Shrinkage and Settlement Effects on MEP

Shrinkage and Settlement Effects on MEP

canplas

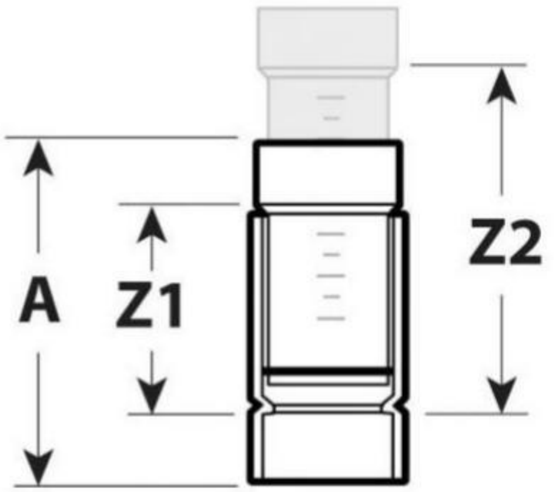
SUBMITTAL SHEET

Part Description:
PVC DWV WHT 3 EXP JOINT

Part Number:
213813AWBC

Canplas Industries Ltd
500 Veterans Drive
Barrie, Ontario, 1-800-461-5300

Canplas LLC
11402 East 53rd Ave.
Denver, CO 1-888-461-5307



Better!

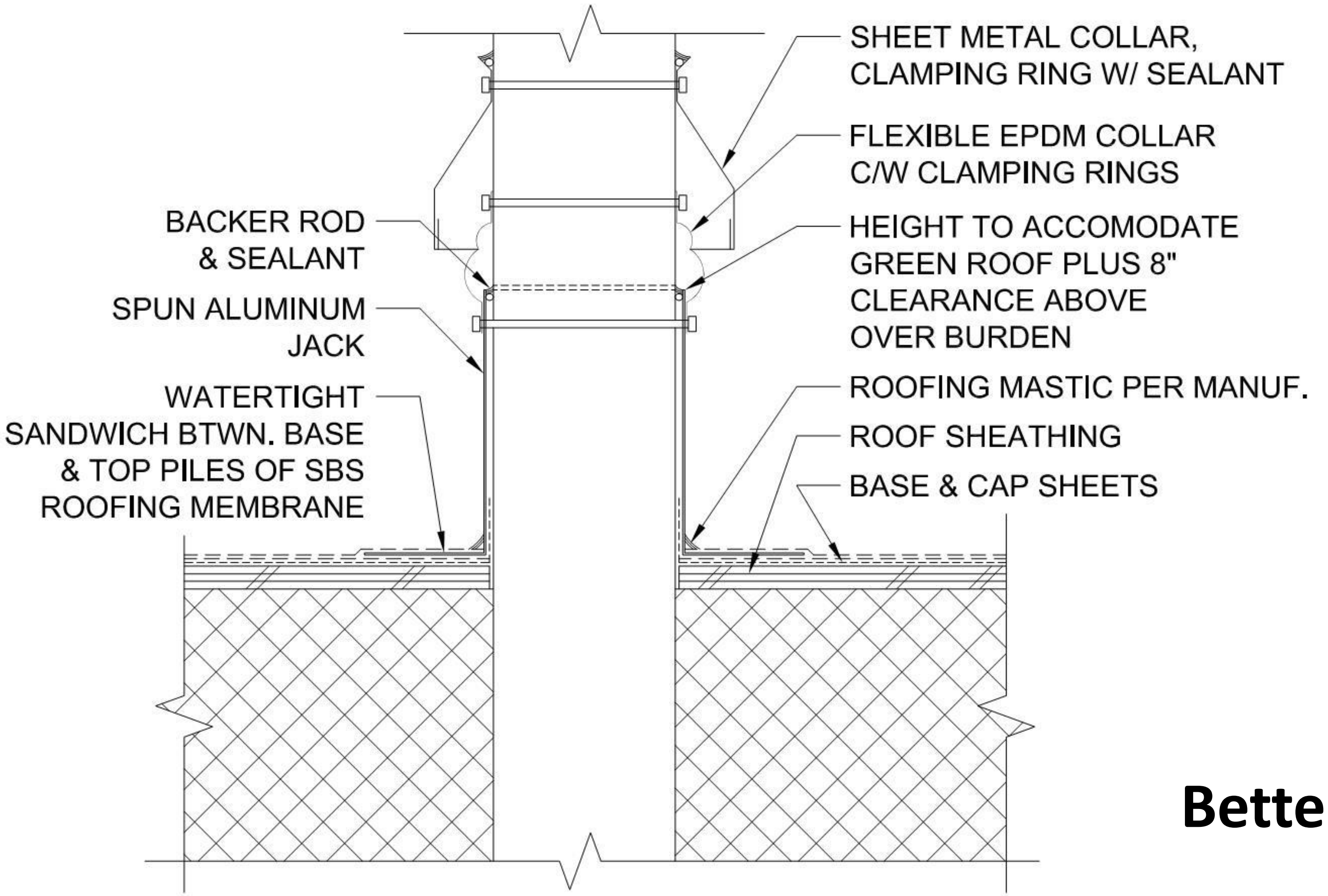
Part #	Part UPC	Color	Material	Size (Inches)	Ctn Qty	Ctn Bar Code	Ctn Wt (Kgs)	Ctn Wt (lbs)	Skid Cubic (m)	Skid Cubic (ft)	Ctns/Skid
213813AWBC	662671190611	WHITE	PVC	3	15	30662671190612	12.80	28.22	1.86	65.82	32

Dimensions (Inches)

A	Z1	Z2
8.50	5.50	8.50

Shrinkage and Settlement Effects on MEP


PM-1125
ASPHALT PRIMER
3"-620
VICTAULIC



ROOF PENETRATION @ STANDPIPES

SCALE: 3" = 1'-0"

Better!

Shrinkage and Settlement Effects on MEP

Image Source: RDH/Ankrom Moisan

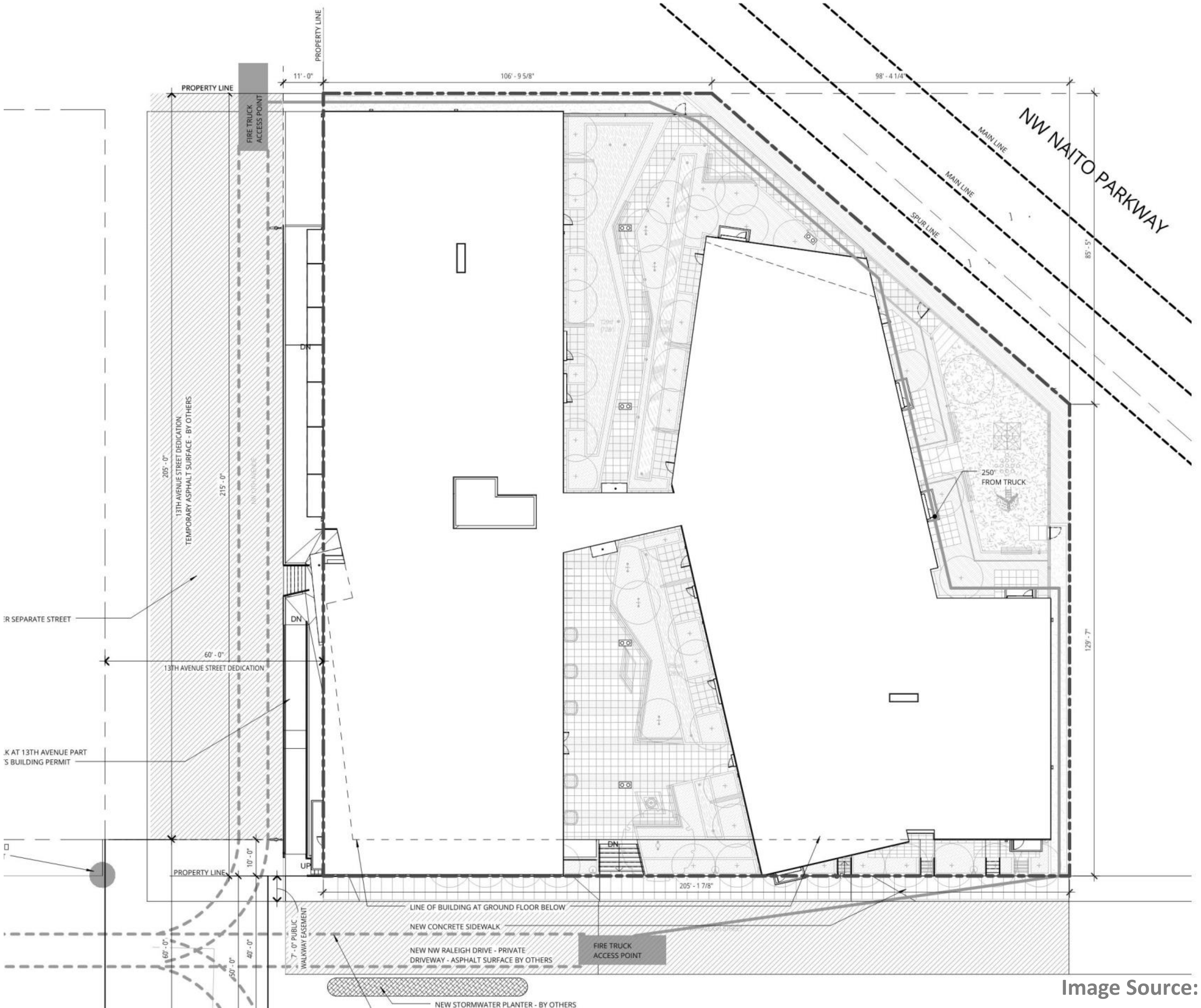


Image Source: Ankrom Moisan

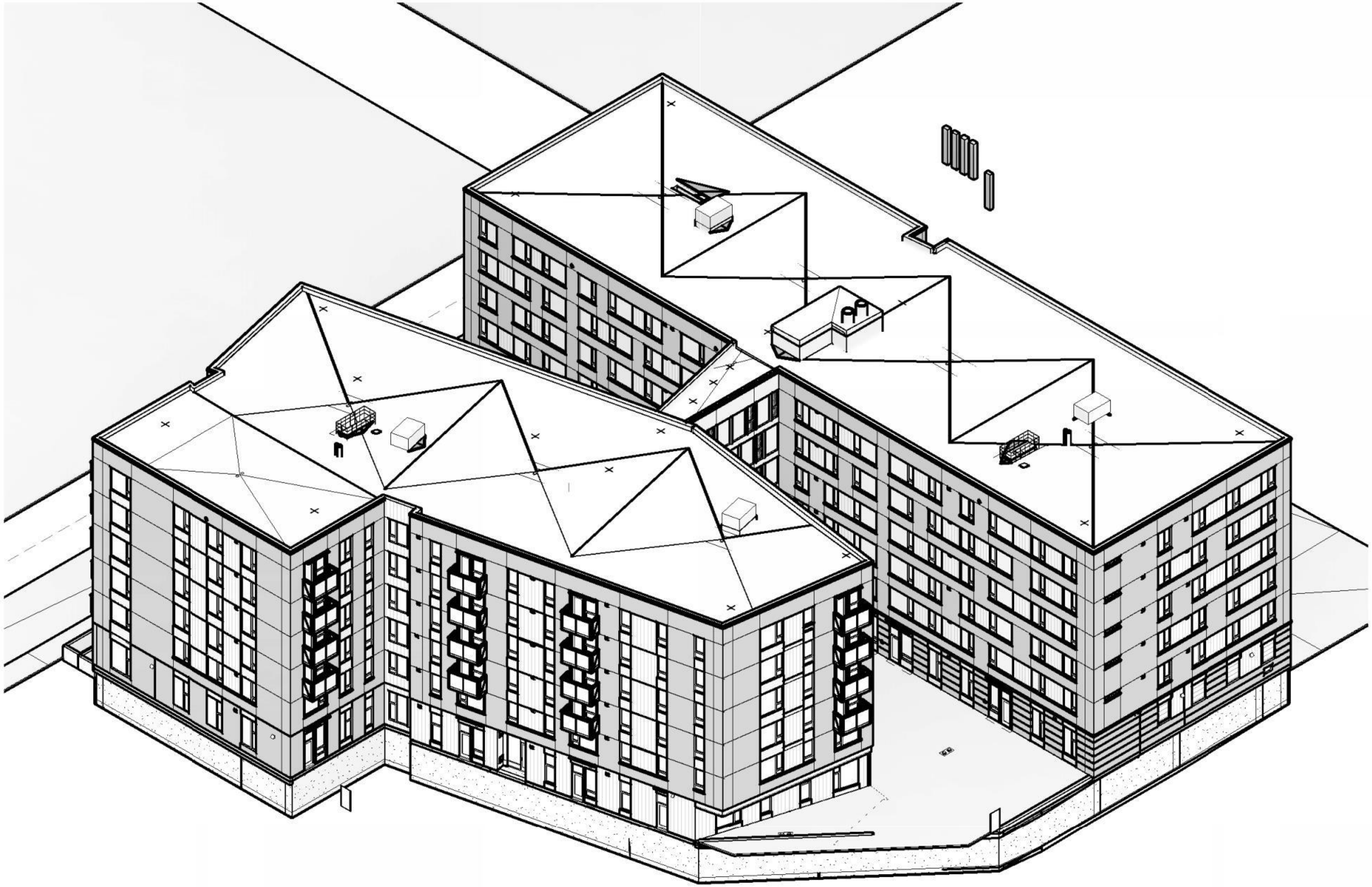
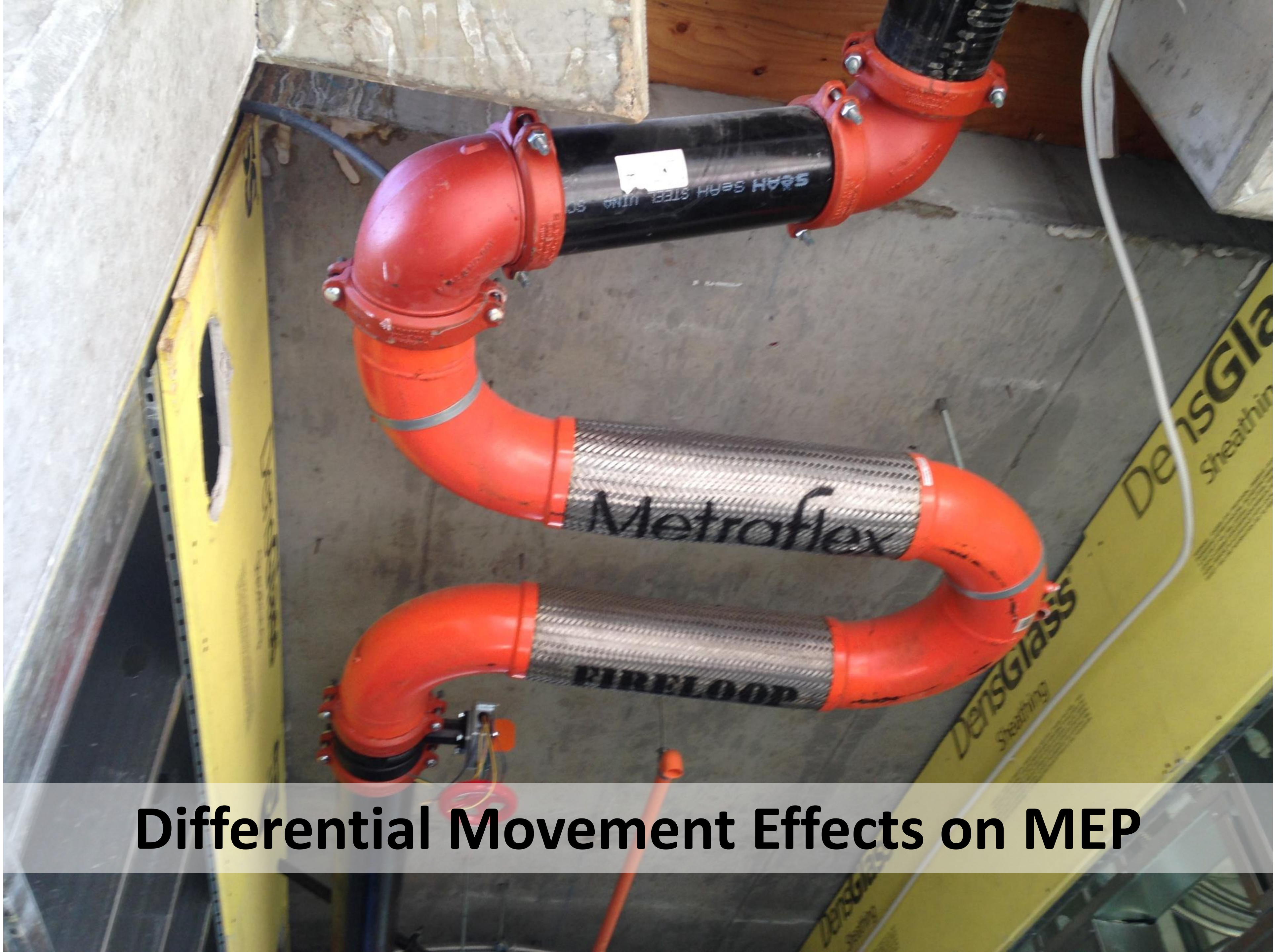


Image Source: Ankrom Moisan

Differential Movement



Differential Movement Effects on MEP