DEEP, CHEAP AND EASY: CREATING A WALL ASSEMBLY FOR THE CASL HOUSE RETROFIT

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ABSTRACT

The Center for the Advancement of Sustainable Living (CASL) is a student organization at the University of Oregon. Their main purpose is to demonstrate sustainable living from a model home being renovated near the campus in Eugene. This study proposes and analyzes one wall assembly for the house. It is our hypothesis that this new assembly will be twice as effective as code-required R-values for new residential construction and prevent moisture entrapment while keeping within CASL's goals of low-cost, simple, sustainable living by using off-the-shelf products that can be installed by non-professionals. R-value was calculated based on the material data of the assembly components. Moisture content was analyzed using computer modeling with WUFI-ORNL/IBP. We then calculated $CO2_e$, Embodied Energy, and estimated cost for the proposed assembly. Finally, we built a mock-up assembly in the CASL house to document the construction process and ease of installation. Afterwards, we compared our results with other groups doing a similar case study, and used these results to make a proposal to CASL for construction later this year.

1. INTRODUCTION

The Center for the Advancement of Sustainable Living (CASL), a University of Oregon student organization founded in 2003, strives to demonstrate sustainable living at their model home on Moss Street in Eugene, Oregon. Currently under renovation, this house, when completed, will host workshops, demonstrations, classes and tours, as well as housing three students working with CASL. There will be an eventual addition to the back of the house, and Design-Bridge, a design-build studio and student organization within the University of Oregon's School of Architecture and Allied Arts (A&AA), intends to run a tech-build class to construct new wall assemblies for the existing house in the upcoming spring term.

Most of the CASL house is currently gutted. In the portion of the house's walls this study focuses on, only the exterior wooden siding and 2x4 stud walls remain, with compromised tar paper interior to the siding. CASL's new home needs a high-efficiency and ecologically-friendly wall assembly that is at the same time cost-effective and easy to install. Due to cost issues and in keeping with CASL's mission, the existing structure will be incorporated into any new construction. A few groups tested various wall assemblies based on these conditions. We tested our proposed wall assembly (Fig. 1), examined its cost and ease of installation, and compared this to the other groups' results. All groups started with the existing conditions and agreed on a maximum wall cavity depth of 9 inches. We then presented CASL with a cross-group, comparative analysis of the different choices available to them. The results of this paper will be useful not only for CASL, but for any homeowner looking to do a deep wall retrofit.

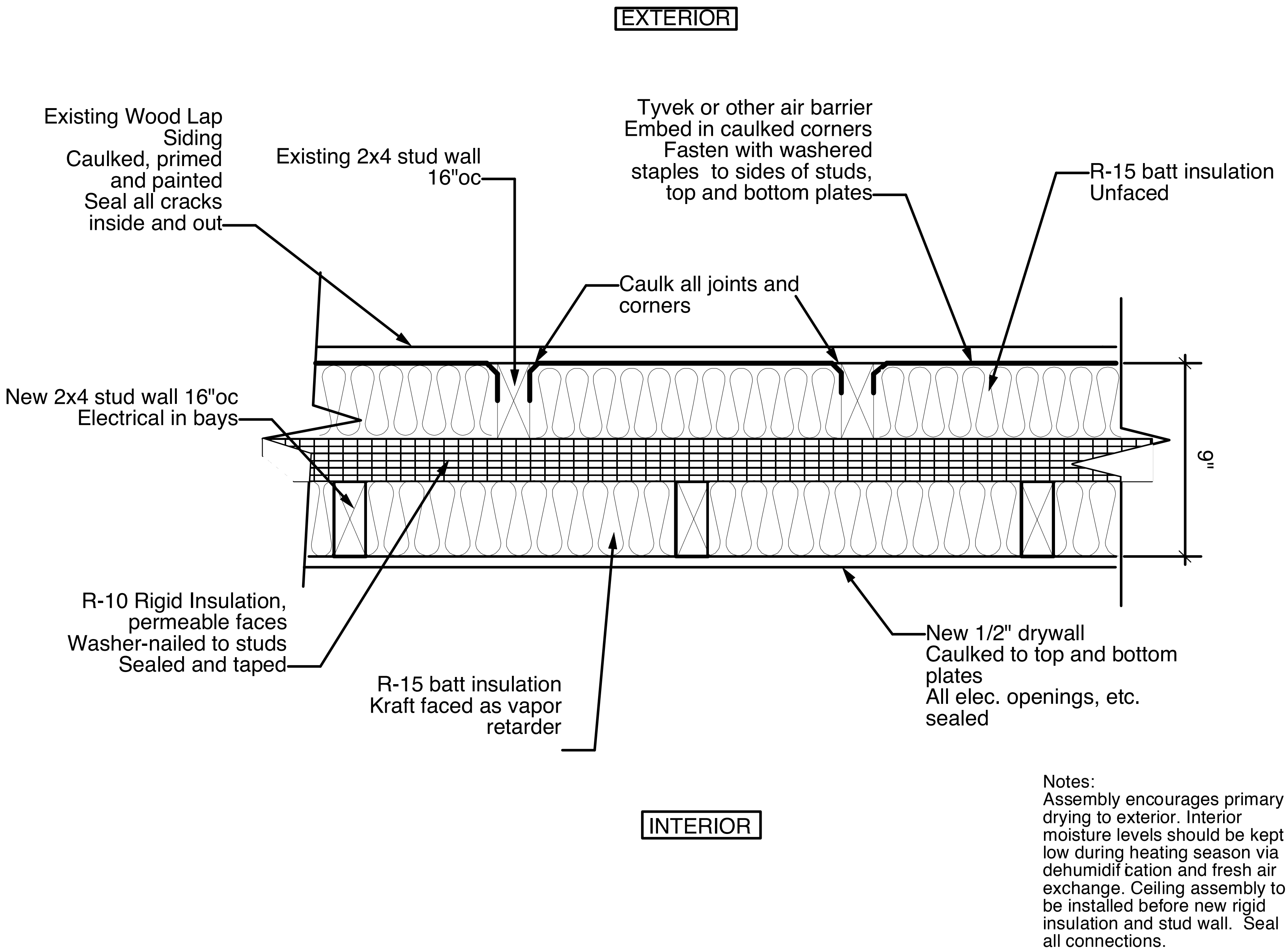

Fig. 1: Proposed Wall Assembly

Local building code for Eugene (1) requires new residential construction with 2x6 walls to have an R-value of 21. Residential renovations with existing 2x4 walls are only required to have an R-value of 15. We intended to construct a wall assembly that would exceed the requirement for new construction by at least 100%. This requires a thicker wall to provide room for the extra insulation. We propose creating a second 2x4 wall on the interior, to create a 9" deep internal cavity. By doing this, we provide enough room for 2" rigid insulation to be placed between the walls to provide a thermal break to prevent heat loss through structural elements to the exterior.

Since Eugene is a generally damp climate with quite a bit of rain throughout the year (2), moisture entrapment is a major concern, especially with wood construction. The existing siding is almost 80 years old and has been acting as a rain screen for the house, which allowed in water vapor, but also enough air infiltration for the wall to dry. This is important to keep the structure from rotting as well as to prevent mold from growing inside of the walls, a serious health issue. We believe that what the house is currently doing is a very effective strategy, but it prevents the house from retaining heat because of the high levels of air infiltration. We propose a breathable wall which can dry to both sides, primarily to the exterior. An air barrier is attached to the inside of the existing studs against the siding, while a kraft-faced insulation doubles as a vapor retarder on the interior of the new stud wall, covered in drywall. The three layers of insulation fill a space of 9" and all materials are easily obtainable from local retailers. The new wall assembly requires that CASL keep all wall openings well-sealed and control interior moisture levels during the heating season.

2. HYPOTHESES

Primary Hypothesis:
This retrofit wall assembly will outperform code-required R-values for new residential construction by double (R-42 vs. R-21).

Secondary Hypotheses:
A. This retrofit wall assembly will retard moisture infiltration from the interior while promoting drying to the exterior.

B. This retrofit wall assembly will be in keeping within CASL's goals of low-cost, simple, sustainable living by using as off-the-shelf materials that are as "green" as possible and can be easily installed by students.

3. METHODOLOGY

First, we researched and devised an appropriate wall assembly based on the preconditions and the parameters set by this test (Fig 1). Second, we found readily available, locally sourced materials that fit the assembly specifications and parameters. Third, we measured the CASL House in order to do material take-offs and price calculations for the total retrofit

In order to test R-value, we used the different material component specifications to calculate a total estimated value of the assembly as whole.

Moisture content and infiltration was analyzed using computer modeling with WUFI-ORNL/IBP.
We then calculated $CO2_e$, Embodied Energy, and estimated cost for the proposed assembly based on data from individual components and tables in MEEB, the Embodied Energy Coefficient spreadsheet (3), and the Athena Eco Calculator (4).
We then built a mock-up assembly in the CASL house to document the assembly order and to test the ease of installation. No tests were directly run on the mock-up assembly due to the difficulty and expense of thermally isolating the assembly within the CASL House, which at present has extreme air and moisture infiltration. It would have been very difficult to simulate a post-renovation and occupied house.

4. DATA & ANALYSIS

4.1 Wall Assembly Calculations

Material Embodied Energy Value: 34,524.21 Btu/sf (3).

Material $CO2_e$ Values: 0.386 lbs/sf/yr over 60 years (4).

CASL House Area Calculations

Total Existing Floor Area	928 sf
Total New Floor Area (after retrofit)	863 sf (57 sf/-6.2% diff.)
Exterior Wall Perimeter	132 lf
Exterior Wall Area (@ 8' H)	1056 sf
Aperture Area (Doors, Windows, Fireplace)	287 sf
Total Retrofit Wall Area	**769 sf**

Wall Assembly R-Values (Exterior to Interior)
See Fig. 1 and Material Specifications Section

	Component	R-Value
1	Existing 3/4" Fir Lap Siding	1.05
2	Existing Compromised Tar Paper	n/a
3	Dupont AirTite Siliconized Acrylic Caulk	n/a
4	Dupont Tyvek Home Wrap	n/a
5	Roxul Stonewool 3 1/2" Batt Insulation	15
6	Insulfoam Expanded Polystyrene 2" Rigid Foam Insulation	7
7	FSC Certified Doug Fir 2x4 Studs for new interior wall construction	n/a
8	CertainTeed Kraft-faced 3 1/2" Fiberglass Batt Insulation	15
9	1/2" Gypsum Board	0.45
10	Air Films	0.17
	Total R-Value For Wall Assembly	**38.67**

Wall Assembly Cost Estimates

Component	Price	Quantity	Cost
Caulk	$2.98/tube	60	$178.80
Tyvek	$115/roll	1	$115
Tyvek Tape	$12/roll	3	$36
Spray Foam	$8.67/can	10	$86.70
1" washered nails	$6.68/box	10	$66.80
Stonewool Insulation	$1.99/sf	769 sf	$1,530.31
EPS Rigid Foam	$1.21/sf	769 sf	$930.49
3" washered nails	$6.68/box	10	$66.80
2 x 4 studs	$0.30/lf	1300 lf	$390
Wall Nails	$100/box	1	$100
CertainTeed Insulation	$2.38/sf	769 sf	$1,830.22
Insulation Staples	$30/box	1	$30
1/2" Drywall	$2.90/sf	769 sf	2230.1
		Total	**$7,591.22**

Estimate Does Not Include:
- caulk/primer/paint for interior/exterior of existing siding
- drywall screws, tape, mud and finishing materials
- window and door jam extention/trim materials
- primer and paint for interior walls

4.2 WUFI Results

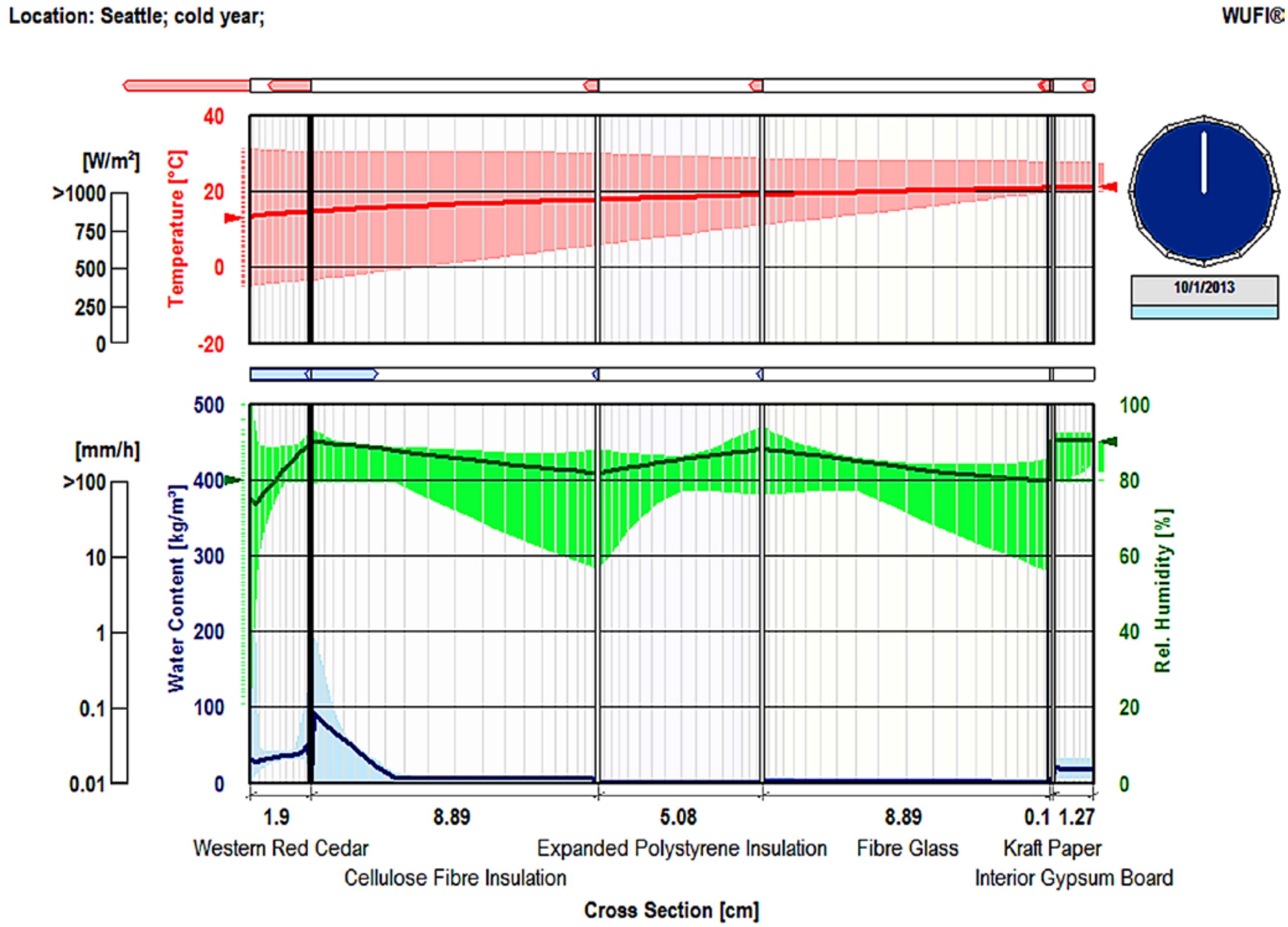

Fig. 2: Cross Section through wall assembly showing water content and temperature over two years (5).

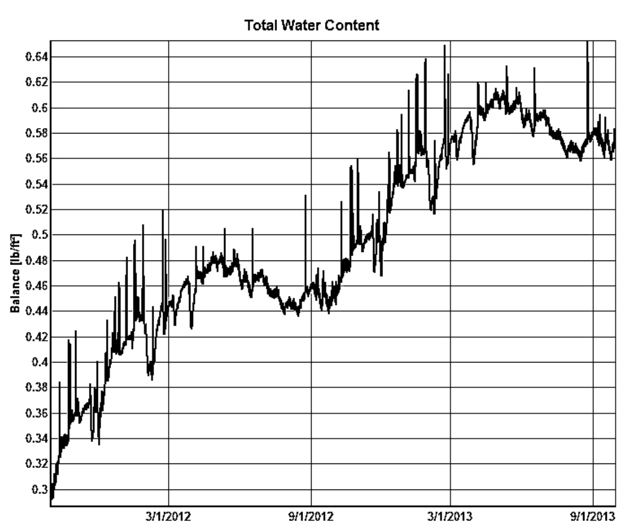

Fig. 3: Water Content in wall assembly over two years (5).

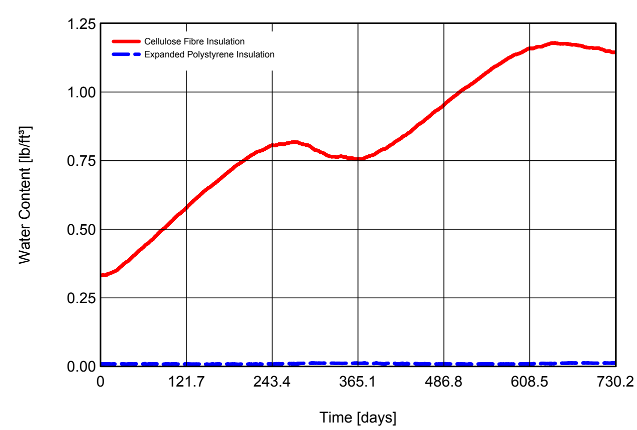

Fig. 4: Water content in cellulose fiber and expanded polystyrene insulations over two years (5).

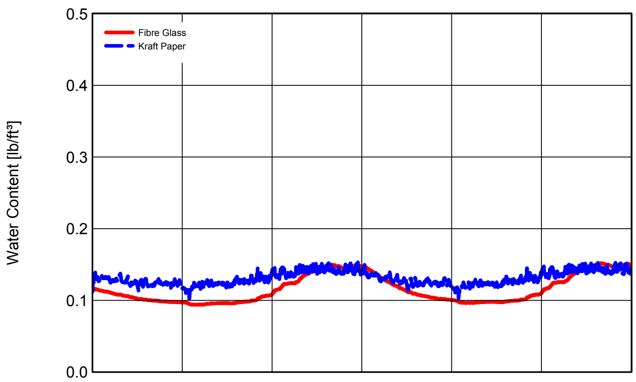

Fig. 5: Water content in fiber glass insulation and Kraft paper over two years (5).

Water Content [lb/ft³]

Layer/Material	Start of Calc.	End of Calc.	Min.	Max.
Western Red Cedar	2,10	2,24	1,87	4,15
Spun Bonded Polyolefine Membrane (SBI	0,00	0,00	0,00	0,00
Cellulose Fibre Insulation	0,33	1,15	0,33	1,18
Expanded Polystyrene Insulation	0,01	0,01	0,01	0,01
Fibre Glass	0,12	0,15	0,09	0,15
Kraft Paper	0,11	0,14	0,10	0,15
Interior Gypsum Board	0,54	1,21	0,54	1,92
Total Water Content [lb/ft²]	0,29	0,57	0,29	0,65

Fig. 6: Water content at start and end of two-year calculations by wall assembly component (5).

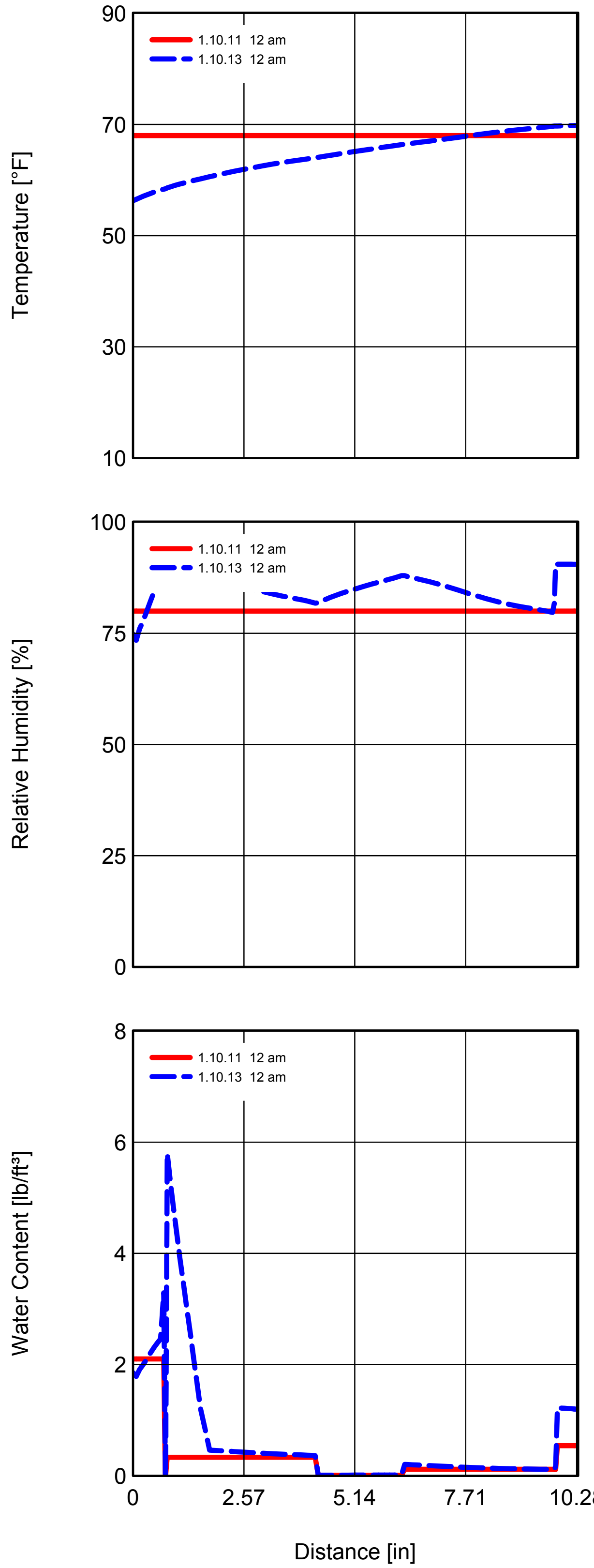

Fig. 7: Water content, temperature, and relative humidity in a cross section of wall assembly on start and finish dates of testing (5).

5. CONCLUSIONS

Designing a retrofit wall assembly for this climate is no easy matter. While our assembly did not achieve our R-Value goal of 42, our final assembly achieved R-38, which still doubles the code requirements for retrofits of this size. We achieved our goals of providing an affordable, easily purchased and installed assembly, making it desirable both for CASL and other homeowners. Our concerted effort to include the most sustainable off-the-shelf materials was validated by our EE and $CO2_e$ results.

The data provided by WUFI was informative but somewhat inconclusive. The climate data provided was for Seattle, WA, which receives on average more rain than Eugene. Also, the specific components we used were not the exact ones offered in the WUFI program, so the results are approximate for both our local climate and our particular wall assembly. However, given that the tests show accumulation of moisture in the wall over time, its obvious that attention must be paid to both installation and placement of the water vapor barrier within the assembly.

6. DESIGN LESSONS LEARNED

Extreme attention to detail must occur when retrofitting a house with a high performance wall assembly. It is possible to design for deconstruction or replacement of pre-existing or unchanged components at a later time (like the siding of the CASL house). Designing a wall assembly that will breathe properly is only half the battle. Occupant participation in controlling moisture is key, and homeowner education must accompany a retrofit of this type.

7. REFERENCES

1. Lane County Public Works, Residential Energy Efficiency, <http://www.lanecounty.org/departments/pw/lmd/build/documents/residentialenergyefficiency.pdf>.
2. Eugene, Oregon Weather Data, <http://www.climate-zone.com/climate/united-states/oregon/eugene/>.
3. Centre for Building Performance Research, Victoria University of Wellington, New Zealand, Embodied Energy Coefficient Spreadsheet, <http://www.vuw.ac.nz/cbpr/>.
4. Athena Institute, Athena® EcoCalculator for residential assemblies, <http://www.athenasmi.org/tools/ecocalculator/index.html>.
5. WUFI-ORNL/IBP, <http://www.ornl.gov/sci/ees/etsd/btric/wufi.shtml>.
6. Grondzik, Walter et al., *Mechanical and Electrical Equipment for Buildings,* New Jersey: John Wiley & Sons, 2010.
7. Lstiburk, Joseph. *Builder's Guide to Mixed Climates: Details for Design and Construction,* Connecticut, Tauton, 2000.
8. Burnett, Eric and Straube, John, *Building Science for Building Enclosures,* Massachusetts: Building Science Press, Inc., 2005.
9. Bomberg, Mark and Trechsel, Heinz, eds., *Moisture Control in Buildings: The Key Factor in Mold Prevention,* Pennsylvania: ASTM International, 2009.

8. ACKNOWLEDGEMENTS

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Installing the Wal Assembly in the CASL House

1. Caulk to existing framing

2. Embed Tyvek in caulk for each bay

3. Fasten Tyvek to studs

4. Fill with R-15 Rockwool Batt Insulation

5. Caulk studs for 2" Rigid Foam EPS

6. Fasten Rigid Foam EPS Insulation to studs

7. Install New 2x4 stud wall against EPS

8. Install R-15 Kraft-faced fiberglass batt insulation

9. Install new 1/2" gypsum board to new stud wall