Report on

Hygrothermal Performance Assessment for Super SSR Modular Block Wall System

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Prepared for
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INTRODUCTION

JustBioFiber requested the assistance of just*Smart*Solutions to determine the hygrothermal performance assessment for their product Super SSR Modular Block Wall System, which is depicted in Fig. 1. Specifically, questions have been raised whether the wall system meets hygrothermal performance criteria in several climate zones without any additional vapor retarders.

Fig.1: The Super SSR Modular Block Wall System.

Investigations

To assess the hygrothermal performance for the Super SSR Modular Block Wall System, just*Smart*Solutions conducted a series of numerical simulation to evaluate the risk of moisture accumulation and possible mold growth using WUFI® Pro 5.3, a numerical simulation tool for the combined heat and moisture transport in building envelope assemblies under real conditions based on (Künzel 1995) and significantly improved by (Kehrer et al 2006) and (Künzel, Kehrer 2008).

The construction details which have been defined in agreement with the client can be seen in Fig. 2. The exterior paint has been assumed to be vapor permeable, silicate based having a permeance of about 41 perm (s_d value=0.08 m); the interior paint has been assumed to be latex paint having a permeance of about 7 perm (s_d value=0.46 m) according to (Kumaran 2002), which represents a primer and two coats of latex paint. The exterior paint is assumed to lower the liquid transport coefficients of the exterior plaster by factor 10 which associates with a water absorption coefficient according to (ASTM C1794) of $1.4\cdot10^{-6}$ lb/(in$^2\cdot\sqrt{s}$) (0.001 kg/(m$^2\cdot\sqrt{s}$)) for the exterior plaster + paint.

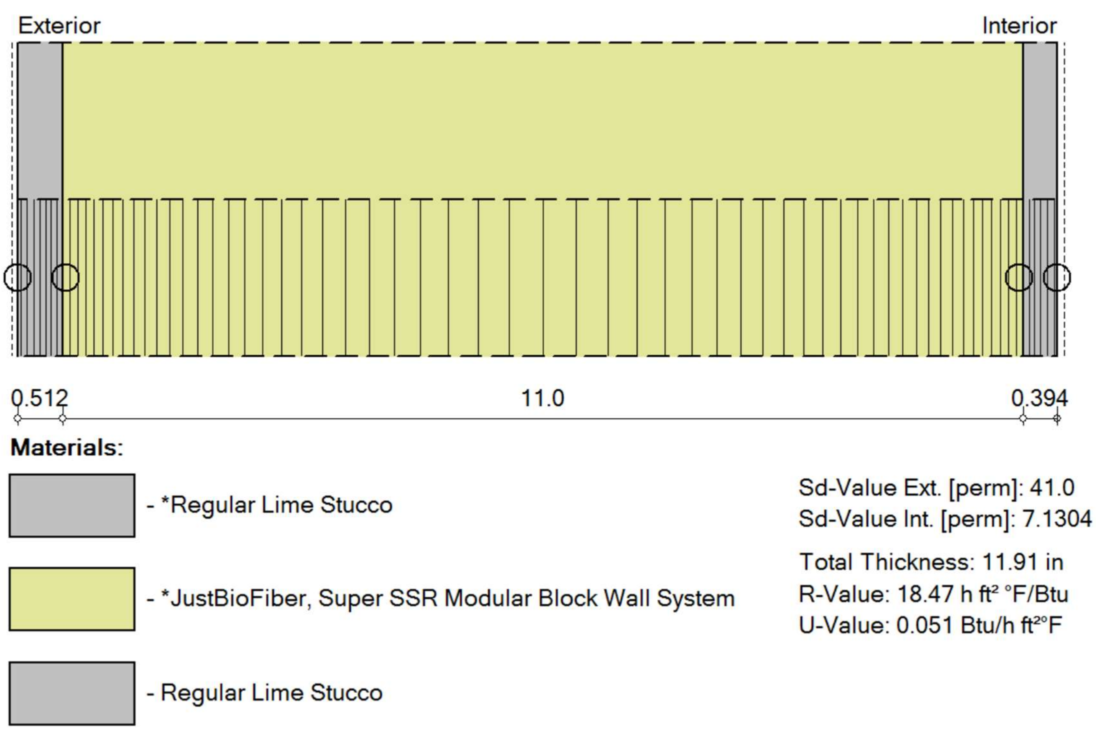


Fig.2: Construction details for the hygrothermal performance assessment.

The indoor climate assumptions are based on (EN 15026) using normal moisture load. This model is also accepted in (ASHRAE 160) as the simplified method. However, in contrast to the ASHRAE specification, where a high moisture load is defined, for this study a normal moisture load has been selected as this result in more realistic data compared with measurements performed in IECC climate zones 2, 4, and 5 (Arena et al 2010). Elevated indoor moisture loads are not taken into account in this study.

No rain intrusion through the exterior plaster is assumed, which also means the roof constructions on top of the walls are expected to be rain water tight. Simulations have been carried out for a 3-year period starting on Oct. 1st. According to (ASHRAE 160) the initial water content for all materials were set to the equilibrium moisture content at 80% relative humidity. Further details on the construction and other WUFI® input data are listed in the Appendix B. Since WUFI® Pro 5.3 is a one-dimensional simulation tool, no other areas inside the wall assembly, such as joints, window connections and other thermal bridges have been accounted for.

Table 1 Variation matrix of the numerical simulation.

Case	Location	Orientation	Exterior Color
1	Miami	N	medium
2			bright
3		E	medium
4			bright
5	Phoenix	N	medium
6			bright
7		NE	medium
8			bright
9	Chicago	N	medium
10			bright
11		NE	medium
12			bright
13	Seattle	N	medium
14			bright
15		S	medium
16			bright
17	Edmonton	N	medium
18			bright
19		NW	medium
20			bright

Several variations have been applied to this construction in order to cover the hygrothermal performance for a broad application. These variations are mainly location, orientation, and exterior color as these variations are known to affect the hygrothermal performance. In Table 1 the variation matrix is compiled. The variation for the locations are supposed to cover all typical climate conditions in North America including warm, cold, dry, and wet areas. To also cover extremes, a 10%-percentile warm year has been selected for the locations Miami and Phoenix, and a 10%-percentile cold year for the locations Seattle and Chicago. For Edmonton, the WUFI® database contains only a standard year which has been selected. To investigate both, the risk of condensation of the interior moisture and the liquid water uptake due to driving rain, the simulations have been conducted for a north oriented wall and a wall oriented to the max. driving rain, respectively. To study the impact of the solar absorptivity of the exterior paint a medium and bright color has been selected which associates with a solar absorptivity of 0.5 and 0.2, respectively.

The evaluation of the hygrothermal results have been carried out using a mold growth model published in (Ojanen et al 2010) at the intersections of the wall system with the interior and exterior plaster. In this model, the risk of mold growth is estimated using a mold growth index (MGI). This performance indicator has values from 0 to 6, with each value corresponding to a level of mold growth according to Table 2. This model is in the process now to be adopted in the (ASHRAE 160) evaluation criteria with the requirement that the (MGI) to stay below 3.0. The (ASHRAE 160) board has already agreed to that evaluation criteria and the changes are out for public review now. Within the MGI calculation, organic based materials are typically rated as "Very Sensitive" for mold growth, unless additives to increase the mold growth resistance are applied to those materials. As the Super SSR Modular Block Wall System contains those additives, it is rated in this study as "Sensitive". Furthermore, a decay coefficient of 0.3 has been selected according to (Ojanen et al 2010).

After the simulations, additional variations have been carried out to study the impact of sensible input data to the results in situation where an MGI close to 3.0 have been found in order to create the final conclusions and recommendations.

Table 2. Mold growth index (Ojanen et al 2010)

Index	Description of growth rate
0	No growth
1	Small amounts of mold on surface (microscope), initial stages of local growth
2	Several local mold growth colonies on surface (microscope)
3	Visual findings of mold on surface, <10% coverage or <50% coverage of mold (microscope)
4	Visual findings of mold on surface, 10–50% coverage or >50% coverage of mold (microscope)
5	Plenty of growth on surface, >50% coverage (visual)
6	Heavy and tight growth, coverage approximately 100%

Results

Table 3 shows the MGI results for the several variations at the intersections of the wall system with the interior and exterior plaster. It can be seen that in all cases the max. MGI stays below 3.0, which means that they can be rated as durable according to the new evaluation criteria in (ASHRAE 160) under the assumed conditions. The Appendix A show the average annual hygrothermal conditions and variations after 2-year settling time for all cases.

Table 3. MGI Results for the several variations

				Max MGI	
Case	Location	Orientation	Exterior Color	Exterior	Interior
1	Miami	N	medium	0.2	0
2			bright	0.8	0
3		E	medium	0	0
4			bright	0.4	0
5	Phoenix	N	medium	0	0
6			bright	0	0
7		NE	medium	0	0
8			bright	0	0
9	Chicago	N	medium	1.0	0
10			bright	1.5	0
11		NE	medium	0.9	0
12			bright	1.3	0
13	Seattle	N	medium	1.4	0
14			bright	1.9	0
15		S	medium	1.4	0
16			bright	2.9	0
17	Edmonton	N	medium	1.2	0
18			bright	2.3	0
19		NW	medium	0.9	0
20			bright	1.7	0

Fig. 2 to 5 show more details for the cases where an MGI greater than zero has been found. Fig. 2 shows that in Miami the MGI peaks to values below 1.0 in the first year due to the initial built-in moisture and that after the drying out process the MGI tends to stay at very low values.

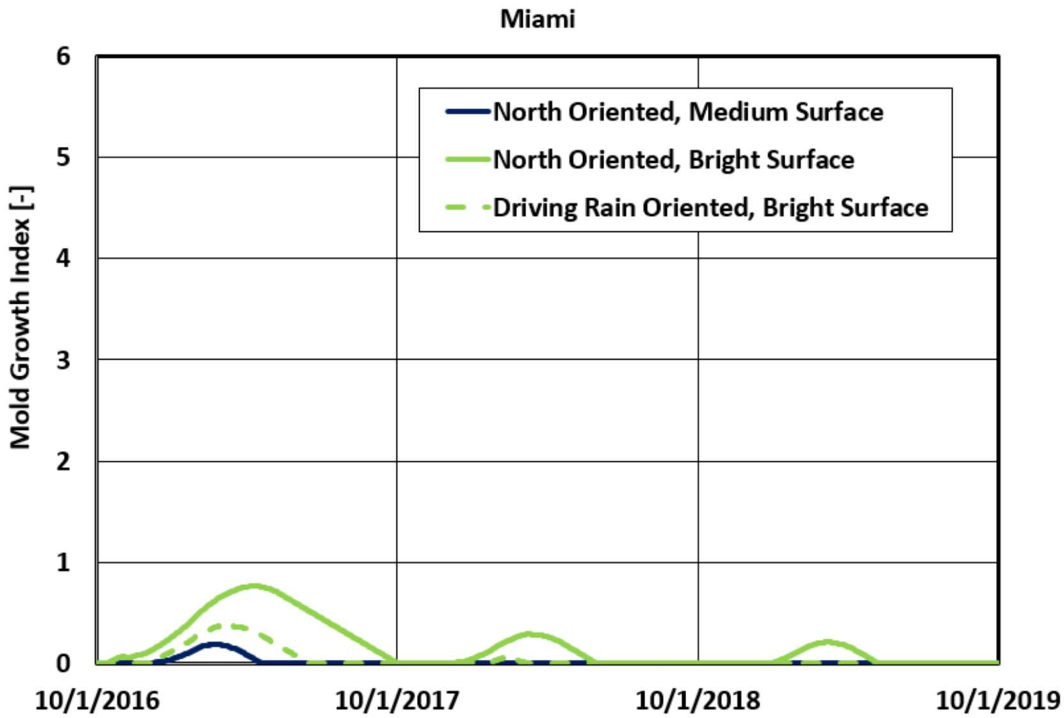


Fig. 2: Courses of the MGI over the simulated 3-year period for location Miami

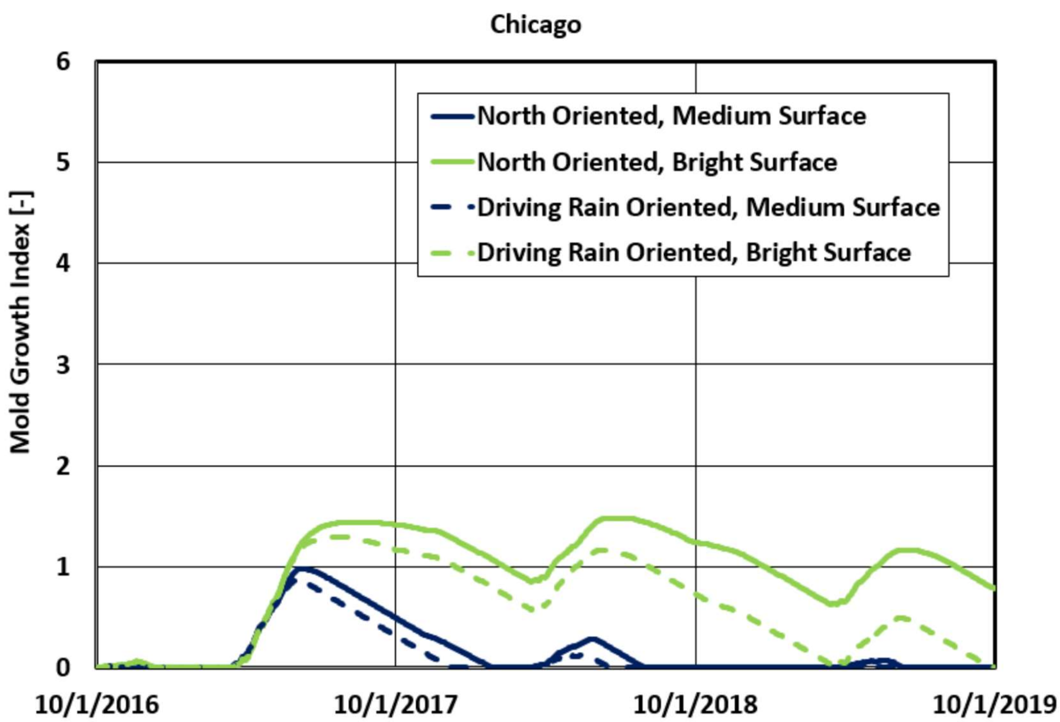


Fig. 3: Courses of the MGI over the simulated 3-year period for location Chicago

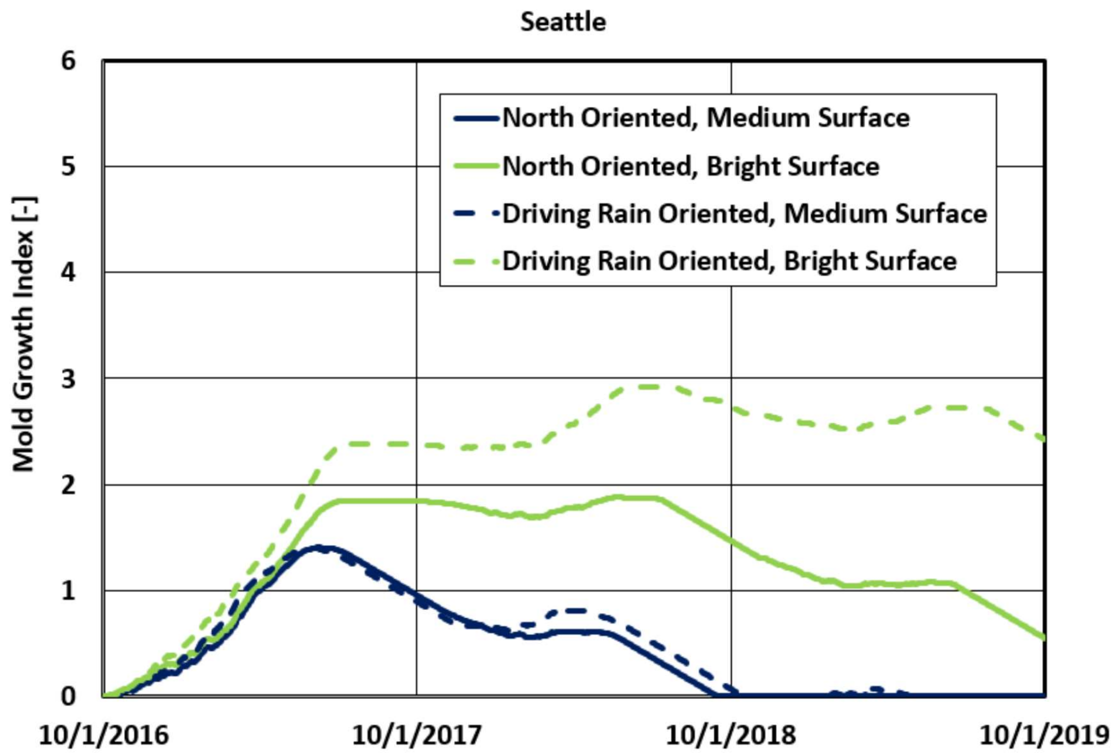


Fig. 4: Courses of the MGI over the simulated 3-year period for location Seattle

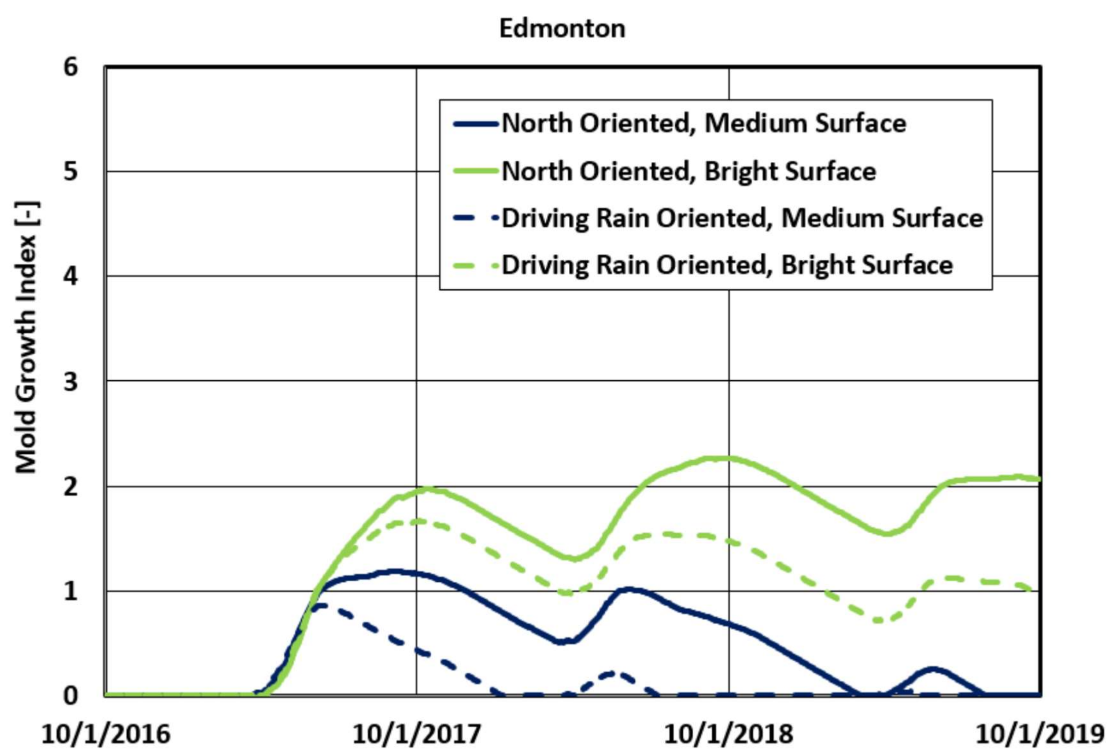


Fig. 5: Courses of the MGI over the simulated 3-year period for location Edmonton

Fig. 3 shows as similar behavior regarding the drying out process for the location Chicago. The max. MGI is found to be for a north oriented bright surface as this combination captures the least amount of solar radiation and has therefore the slowest drying out process, though harmless for the construction as all MGI values stay below 3.0.

In Fig. 4 we can see that for the location Seattle apparently, the high amount of driving rain to a south oriented wall system with a bright surface color (case 16) results in the highest peak value for the MGI close to 3.0

Fig. 5 shows the MGI results for Edmonton, where we see the highest MGI value of 2.3 for a north oriented bright surface (case 18).

To investigate the more critical combinations in terms of driving rain absorption (case 16) and indoor moisture condensation (case 18), additional variations have been carried out to receive more data for the final conclusions and recommendation which are shown in Table 4.

Table 4. Additional variations and their impact on the results

			Max. MGI	
Case	Ancestor	Change	Exterior	Interior
16a	16	No Driving Rain Repellency of the Exterior Paint	4.3	0
16c	16a	Medium Bright Exterior Color	2.9	0
18a	18	Location Fairbanks	1.5	0
18b	18	Exterior Plaster Thickness 3/4"	3.0	0

In case 16 it appears that a less functional water repellency of the exterior paint could result in more liquid rain uptake, hence may result in critical MGI values greater than 3.0. In Therefore, in case 16a it has been assumed that the exterior paint has no positive impact on the water repellency of the exterior plaster. The results in Table 4 and Fig. 6 show that MGI values in this case are critical. Only if additionally, a medium exterior bright color is applied (Case 16c), the system stays below critical MGI values. That means if a water absorption coefficient according to (ASTM C1794) of $1.4 \cdot 10^{-6}$ lb/(in$^2 \cdot \sqrt{s}$) (0.001 kg/(m$^2 \cdot \sqrt{s}$)) or less for the exterior plaster + paint cannot be guaranteed, a solar absorptivity of the exterior paint of at least 0.5 is required.

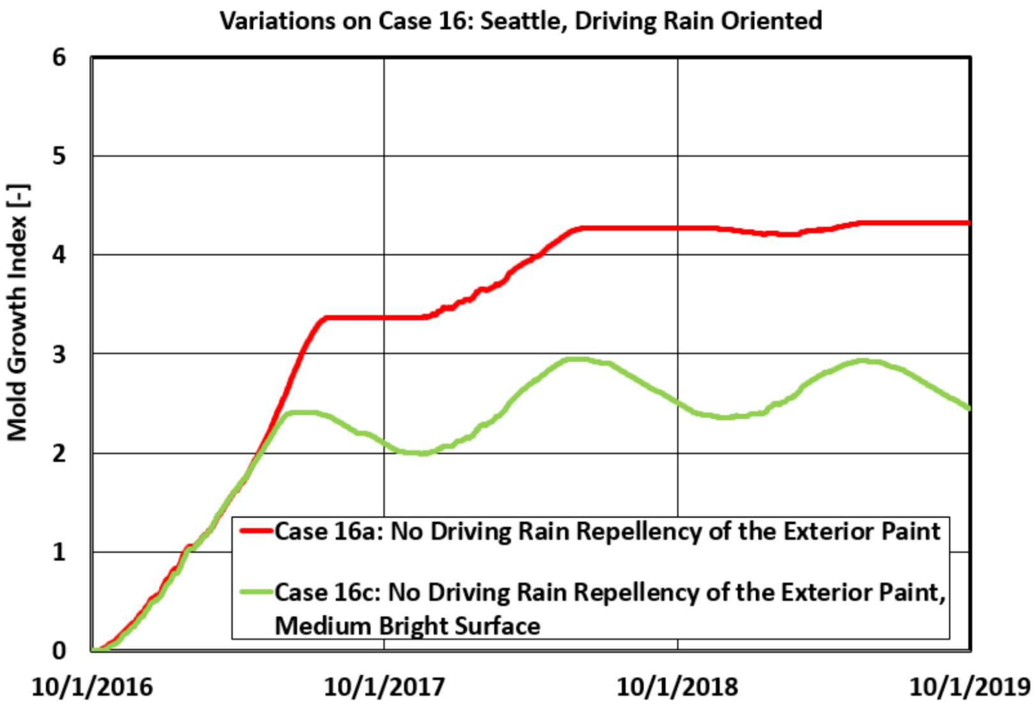


Fig. 6: Variations on Case 16 to illustrate the impact of water repellency and solar absorptivity.

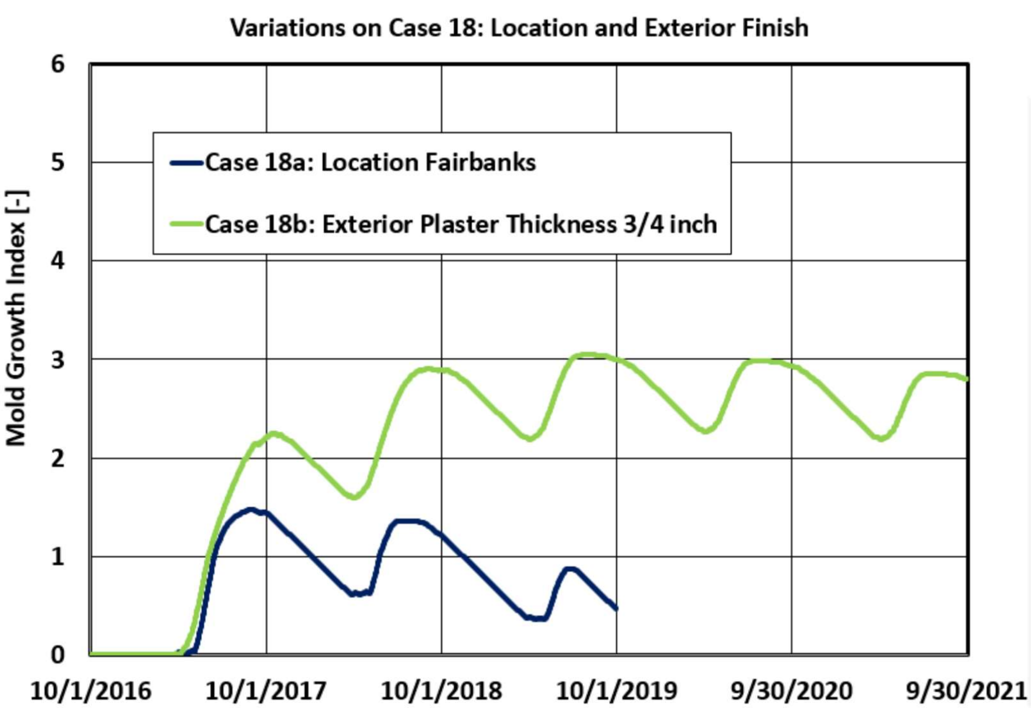


Fig. 7: Variations on Case 18 to illustrate the impact of very cold location and permeance of the exterior finish.

Case 18a, shown in Table 4 and Fig. 7, shows that the variation of an even colder location does not harm the system. But the thickness of the exterior plaster has an impact (Case 18b), which means this plaster should not exceed a thickness of ¾" to stay below critical MGI values. To generalize this conclusion, in cold climate zones the water vapor permeance of the exterior plaster + paint should be higher than 3.5 perm (means s_d value lower than 0.93 m).

Conclusion

Under the applied assumptions, boundary conditions, and input data, the hygrothermal performance assessment for the Super SSR Modular Block Wall System comes to the conclusion that this system works without any additional vapor retarder. Furthermore, the following recommendation regarding sensitive input data should be followed:

- For location with high driving rain loads, the water absorption coefficient of the exterior plaster +paint according to (ASTM C1794) should stay below $1.4 \cdot 10^{-6}$ lb/(in$^2 \cdot \sqrt{s}$) (0.001 kg/(m$^2 \cdot \sqrt{s}$)). If this cannot be guaranteed, a solar absorptivity of the exterior paint of at least 0.5 is required.
- For cold climate zones, the water vapor permeance of the exterior plaster + paint should higher than 3.5 perm (s_d value lower than 0.93 m).

References

Arena, L.; Mantha, P.; Karagiozis A. (2010). Monitoring of Internal Moisture Loads in Residential Buildings. U.S. Department of Housing and Urban Development Washington, DC.

ASHRAE 160. ANSI/ASHRAE Standard 160-2009. “Criteria for Moisture-Control Design Analysis in Buildings”. ASHRAE, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305.

ASTM C1794:2015 Standard Test Methods for Determination of the Water Absorption Coefficient by Partial Immersion.

EN 15026:2007. European Standard. Hygrothermal performance of building components and building elements. Assessment of moisture transfer by numerical simulation

Hukka, A. and H. A. Viitanen (1999). "A mathematical model of mould growth on wooden material." Wood Science and Technology.

Kehrer M., Schmidt, T. (2006); Temperaturverhältnisse an Außenoberflächen unter Strahlungseinflüssen; IBPSA (International Simulation Building Performance Simulation) 2006; Munich.

Künzel, H.M. 1995. Simultaneous Heat and Moisture Transport in Building Components. IRB. Stuttgart.

Künzel, H.M. Kehrer, M. (2008) Einfluss der Hinterlüftung auf das Feuchteverhalten von Holzbauwänden. „Umweltbewusstes Bauen“ Hrsg. A. Maas, Fraunhofer IRB Verlag 2008, p.611-620.

Kumaran, M.K. (2002) A Thermal and Moisture Transport Property Database for Common Building and Insulating Materials. Final Report from ASHRAE Research Project 1018-RP

Ojanen, T., H. Viitanen, R. Peuhkuri, K. Lähdesmäki, J. Vinha, and K. Salminen. 2010. Mold growth modeling of building structures using sensitivity classes of materials. Thermal Performance of the Exterior Envelopes of Whole Buildings XI. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

APPENDIX A

Fig. 8 to 31
Average Annual Hygrothermal Conditions and Variations after 2-Year Settling Time for Super SSR

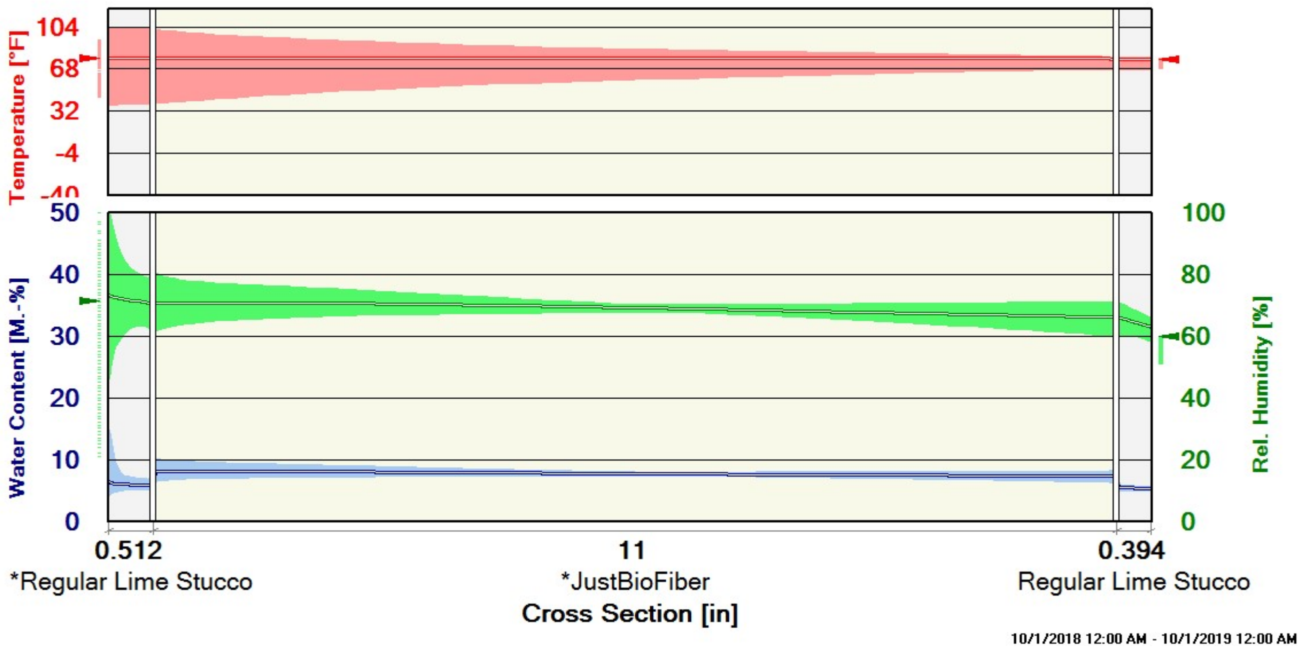


Fig. 8 Average Annual Hygrothermal Conditions and Variations for Case 1.

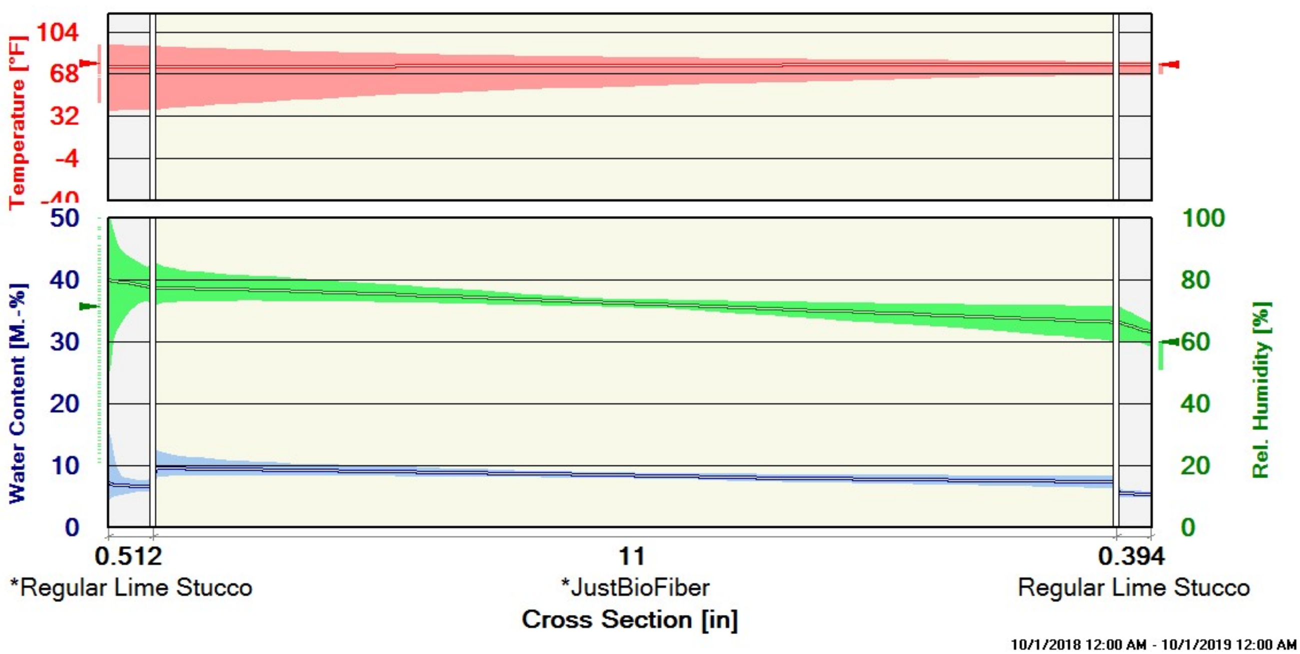


Fig. 9 Average Annual Hygrothermal Conditions and Variations for Case 2.

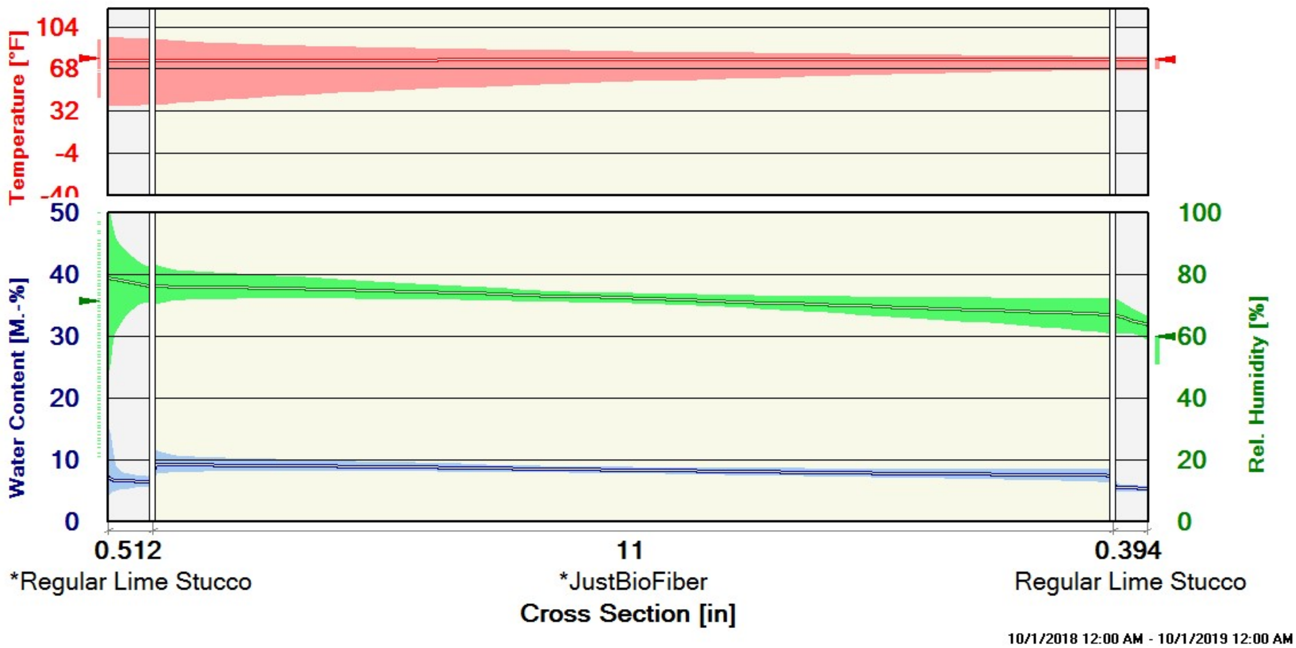


Fig. 10 Average Annual Hygrothermal Conditions and Variations for Case 3.

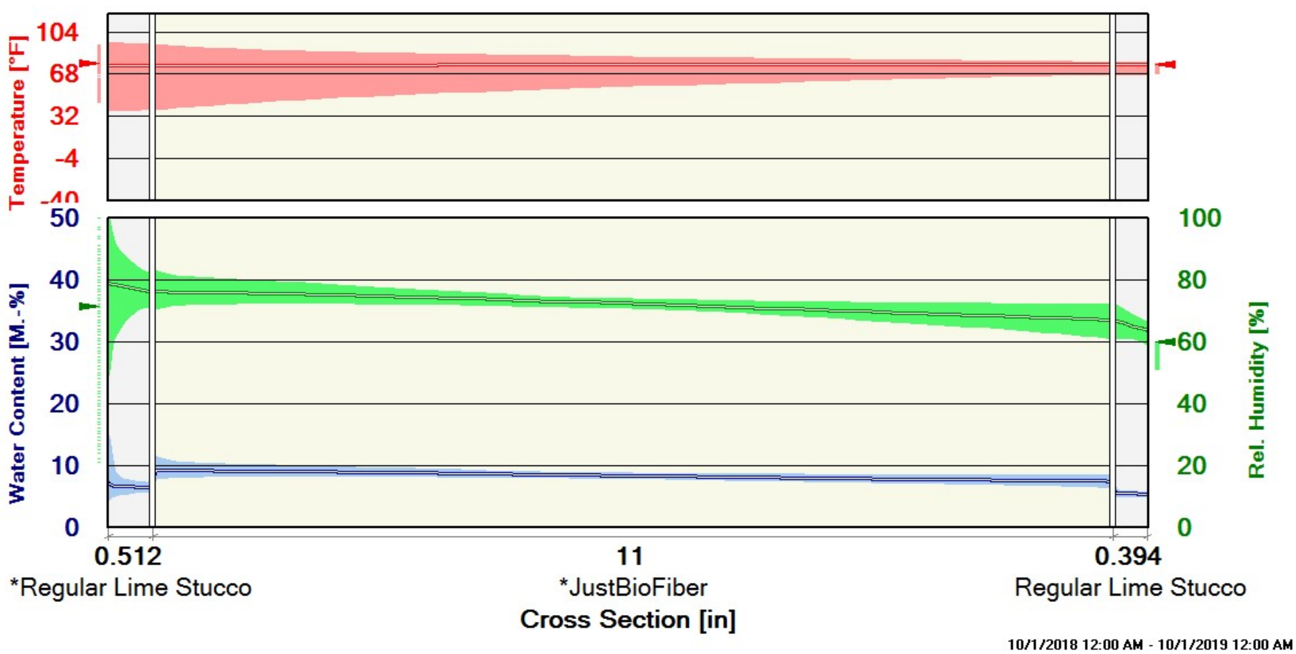


Fig. 11 Average Annual Hygrothermal Conditions and Variations for Case 4.

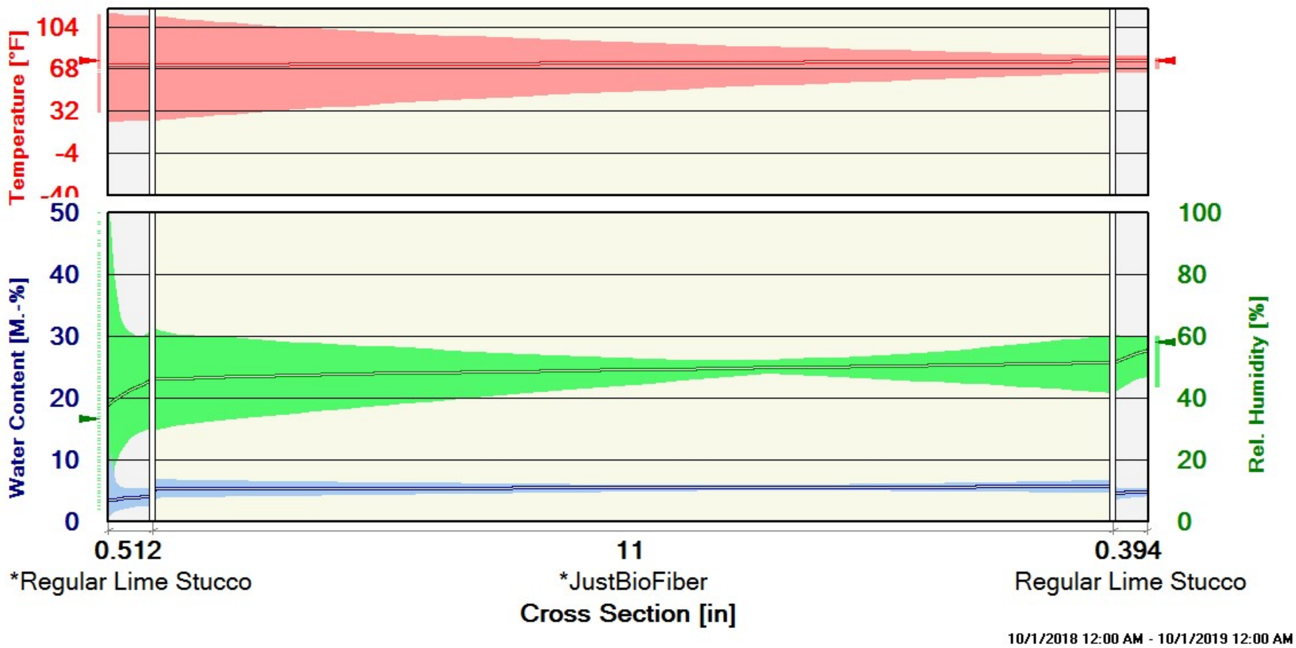


Fig. 12 Average Annual Hygrothermal Conditions and Variations for Case 5.

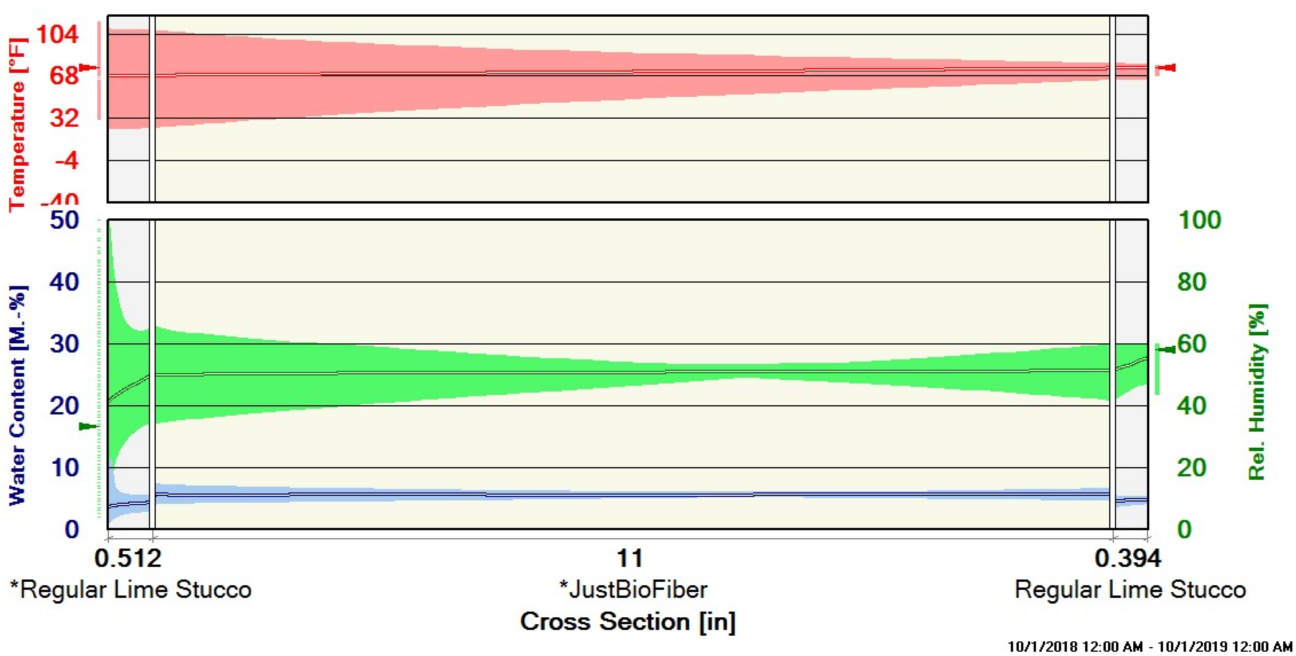


Fig. 13 Average Annual Hygrothermal Conditions and Variations for Case 6.

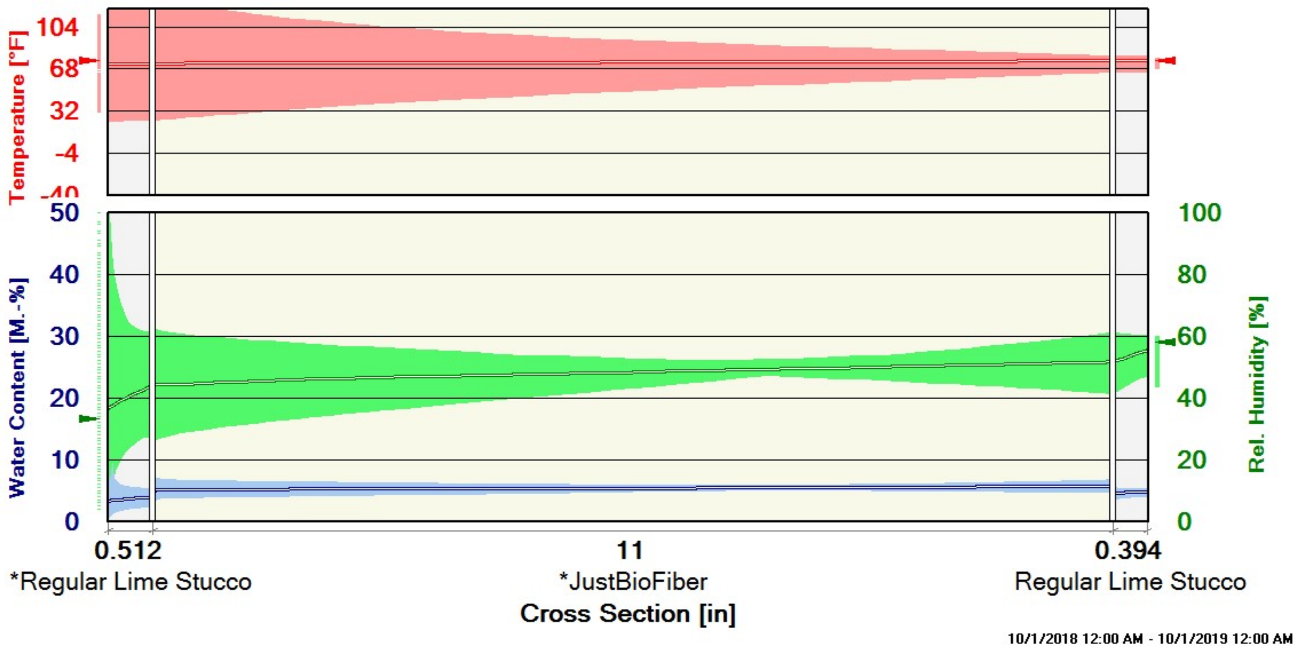


Fig. 14 Average Annual Hygrothermal Conditions and Variations for Case 7.

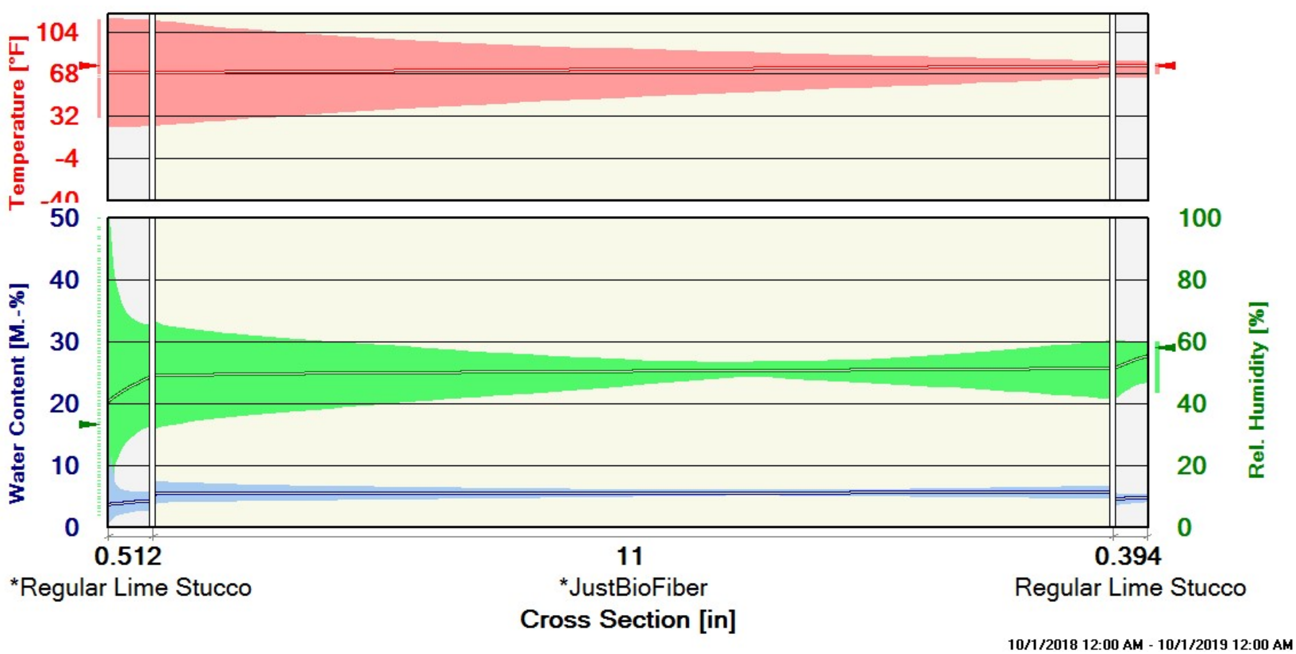


Fig. 15 Average Annual Hygrothermal Conditions and Variations for Case 8.

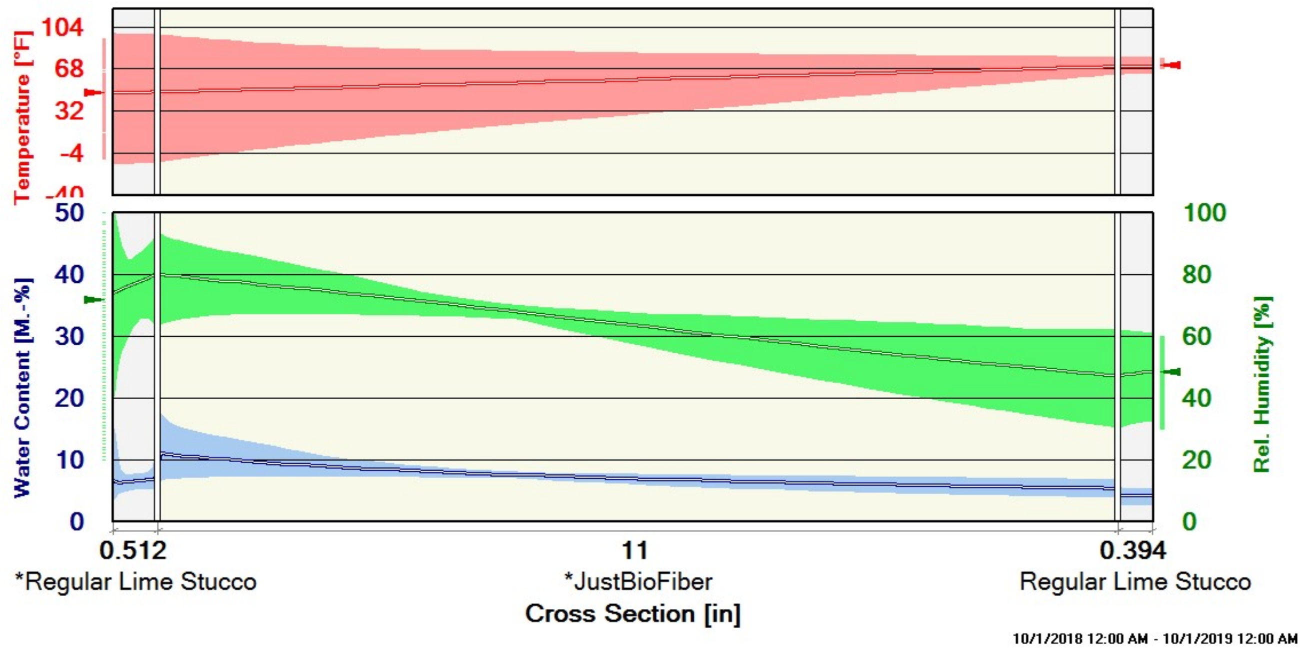


Fig. 16 Average Annual Hygrothermal Conditions and Variations for Case 9

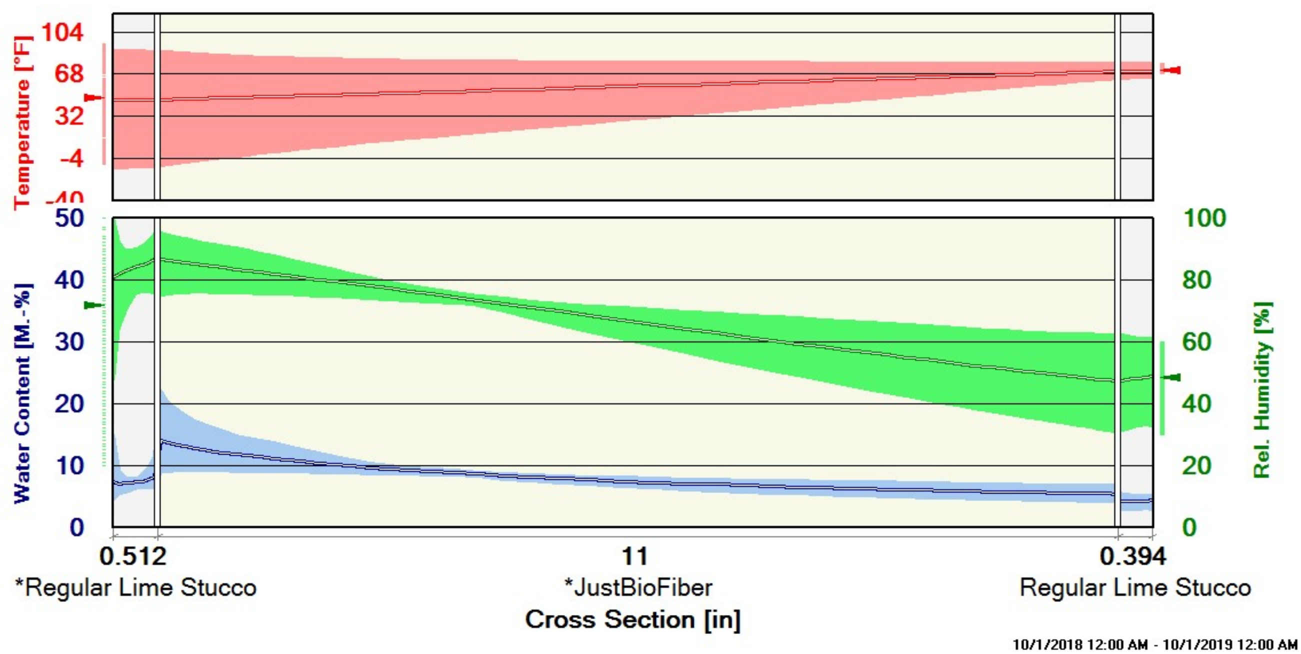


Fig. 17 Average Annual Hygrothermal Conditions and Variations for Case 10

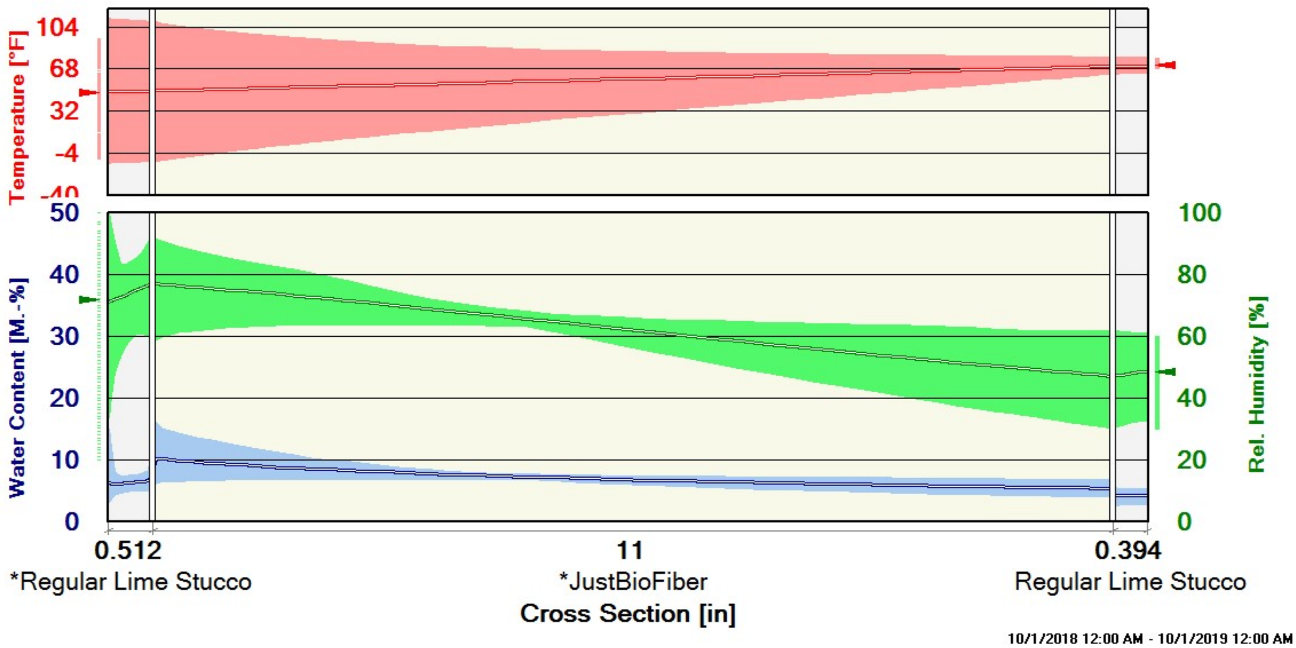


Fig. 18 Average Annual Hygrothermal Conditions and Variations for Case 11

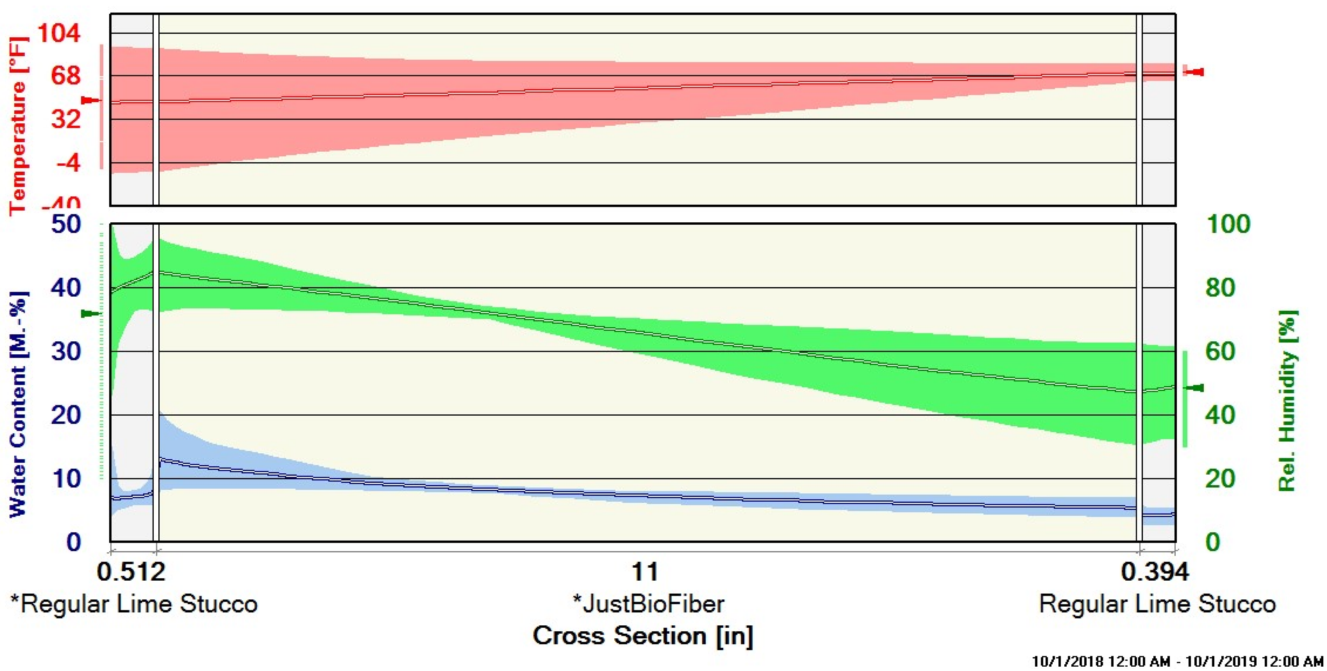


Fig. 19 Average Annual Hygrothermal Conditions and Variations for Case 12

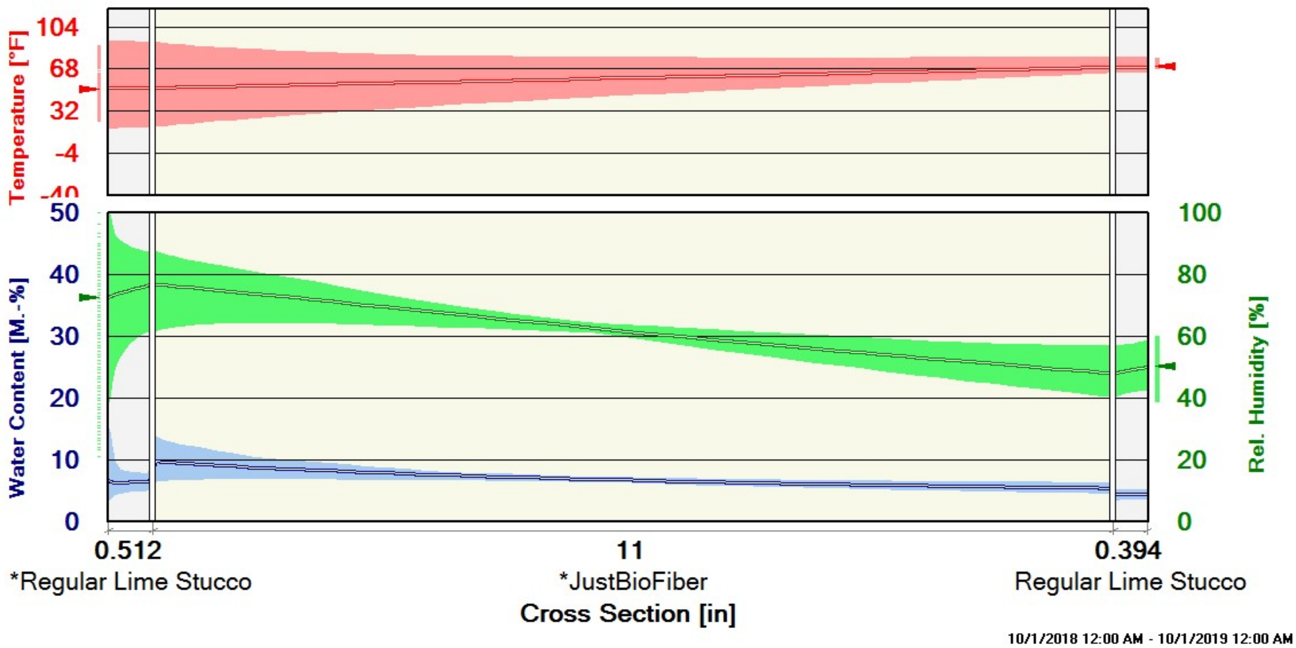


Fig. 20 Average Annual Hygrothermal Conditions and Variations for Case 13

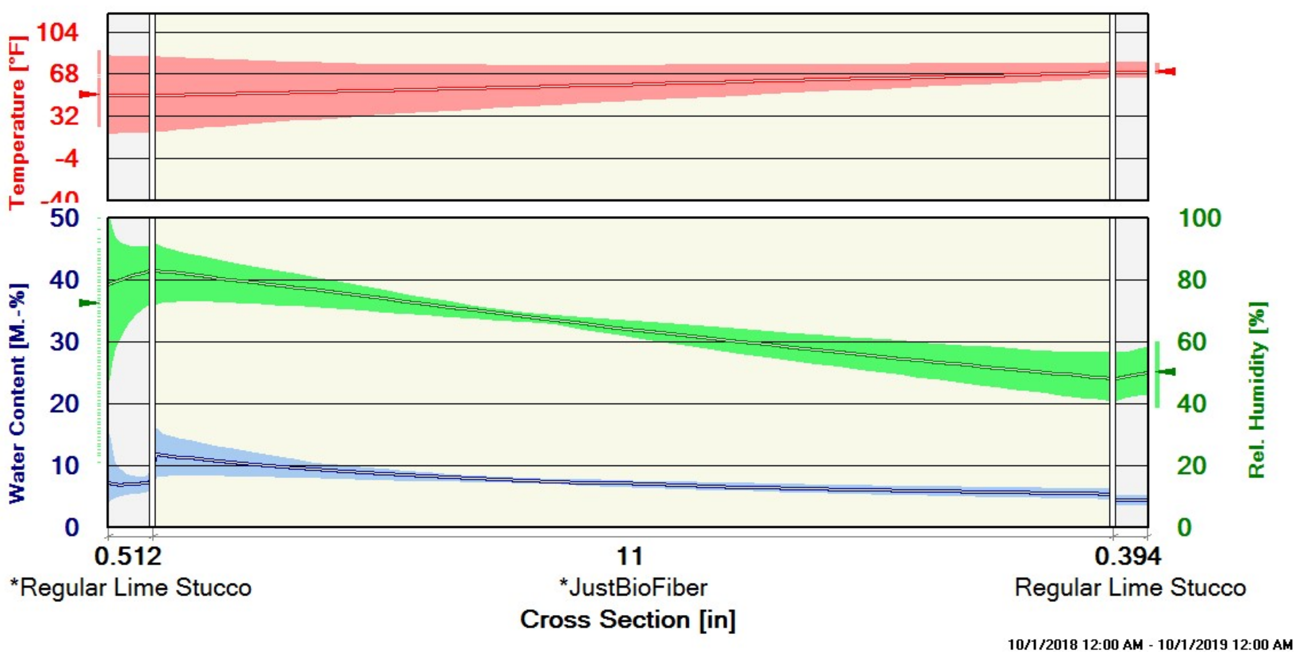


Fig. 21 Average Annual Hygrothermal Conditions and Variations for Case 14

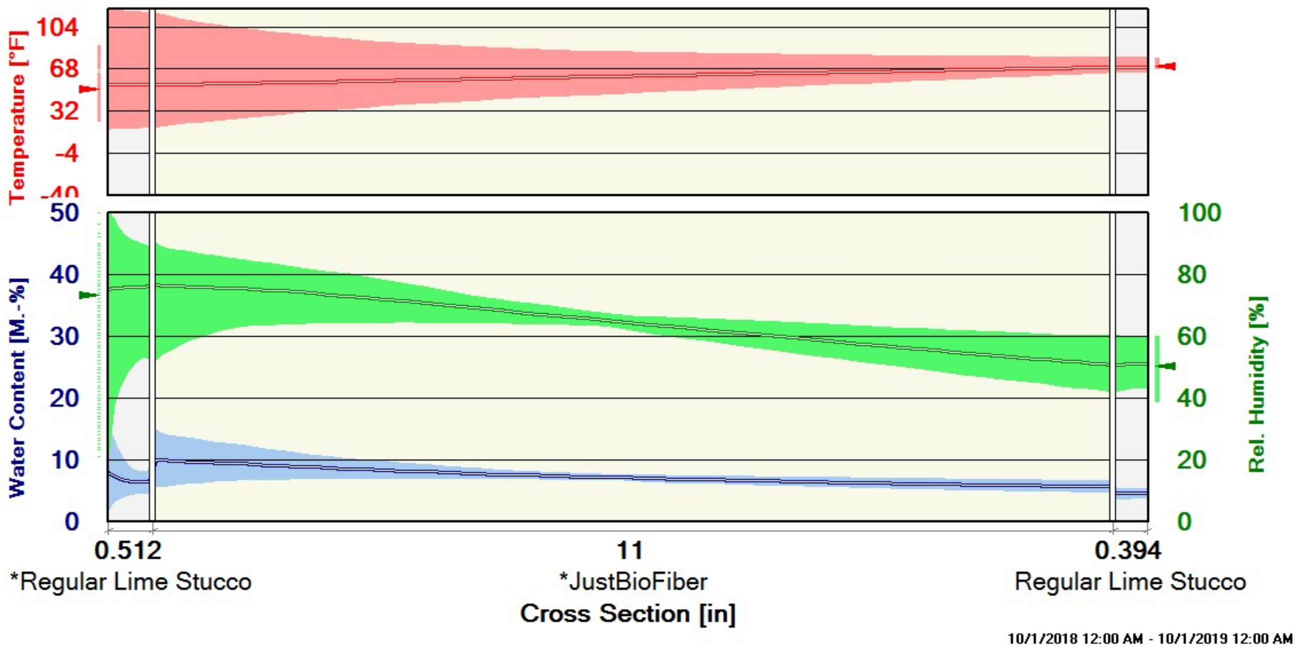


Fig. 22 Average Annual Hygrothermal Conditions and Variations for Case 15

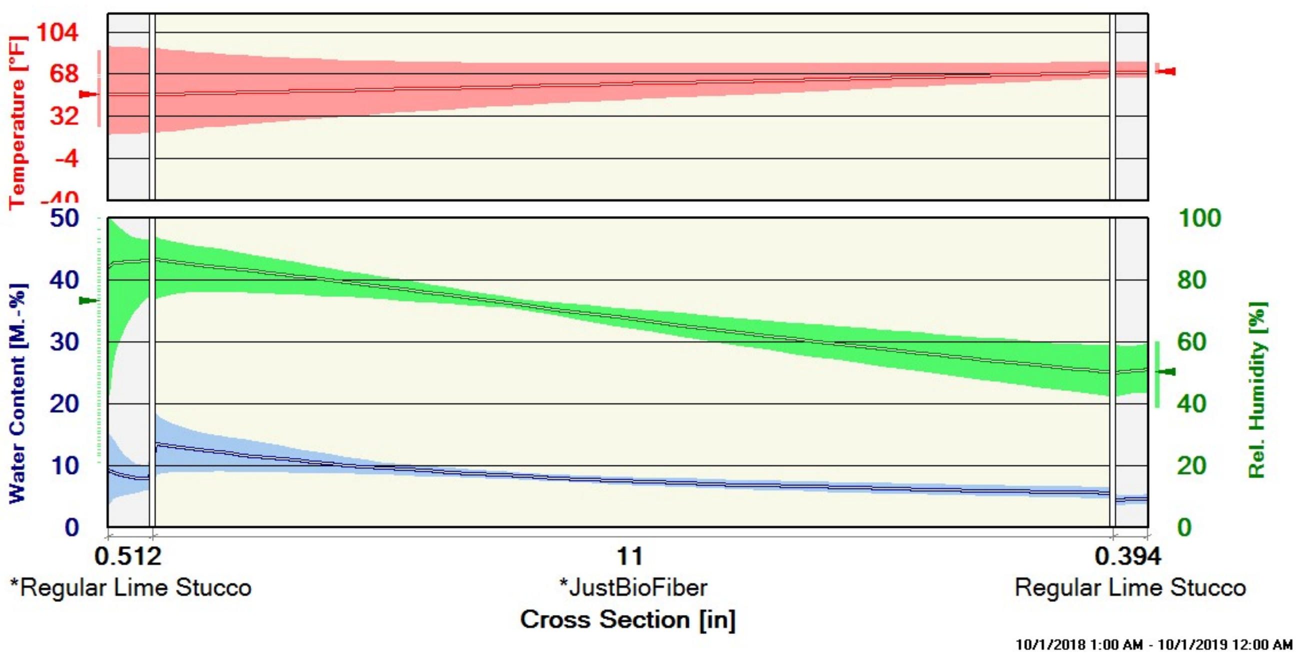


Fig. 23 Average Annual Hygrothermal Conditions and Variations for Case 16

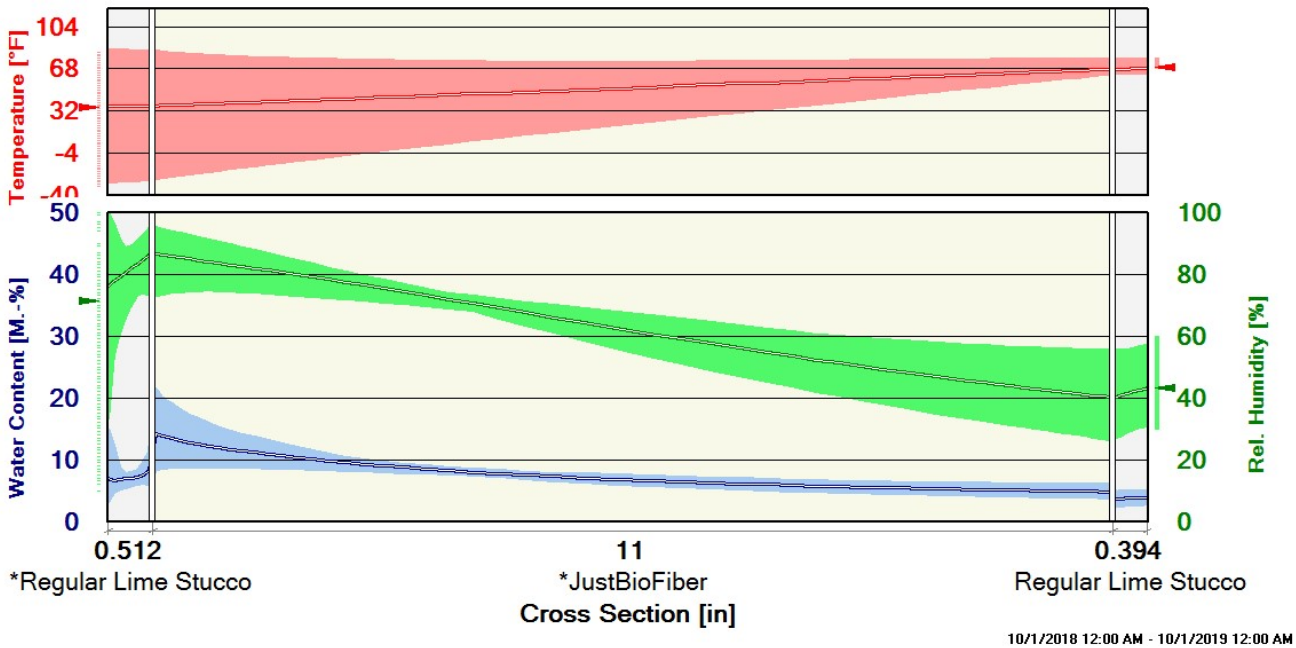


Fig. 24 Average Annual Hygrothermal Conditions and Variations for Case 17

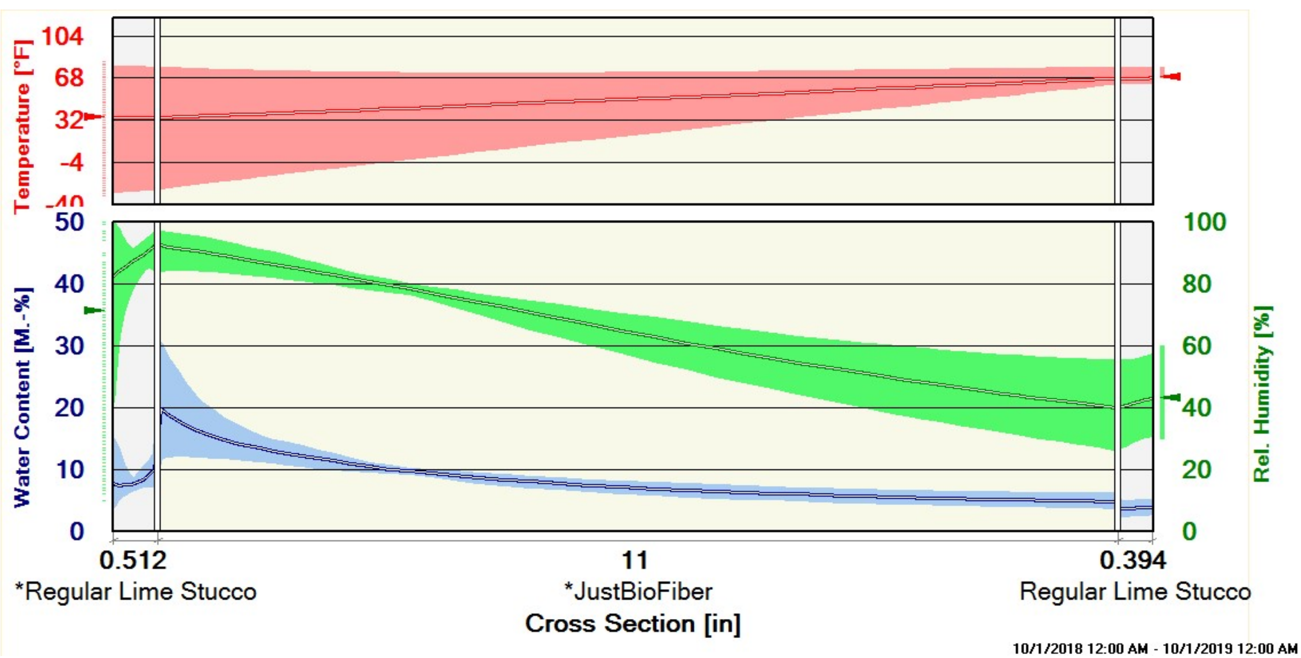


Fig. 25 Average Annual Hygrothermal Conditions and Variations for Case 18

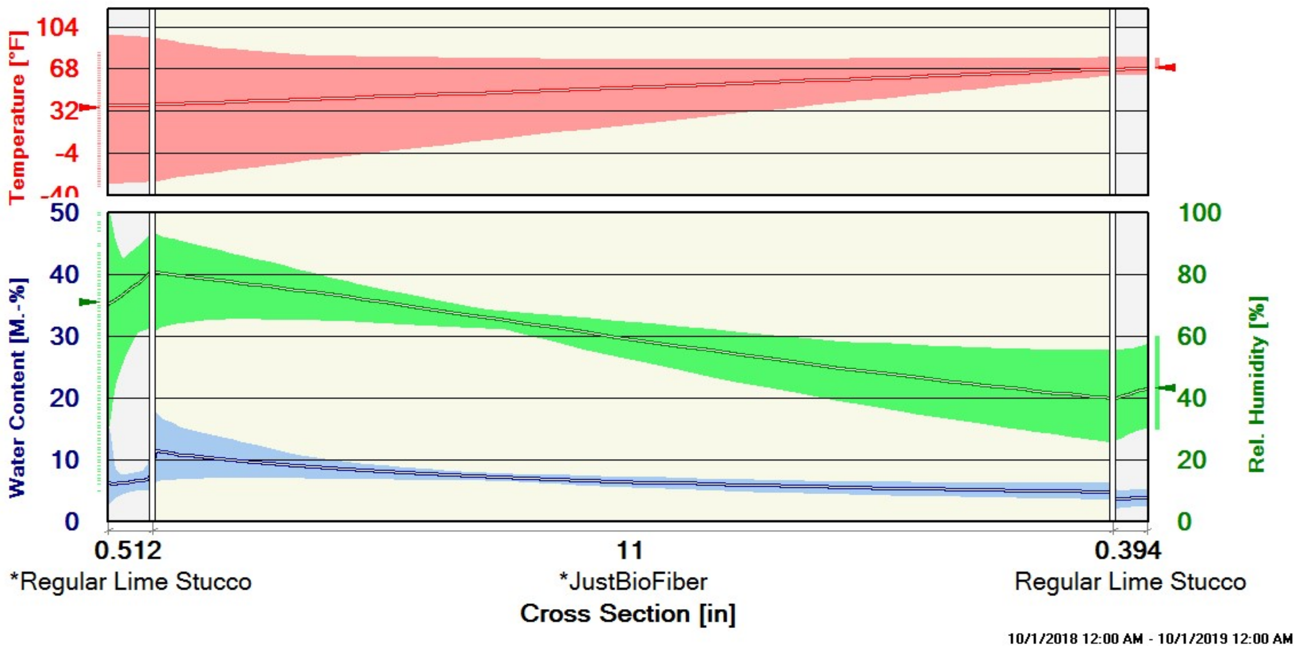


Fig. 26 Average Annual Hygrothermal Conditions and Variations for Case 19

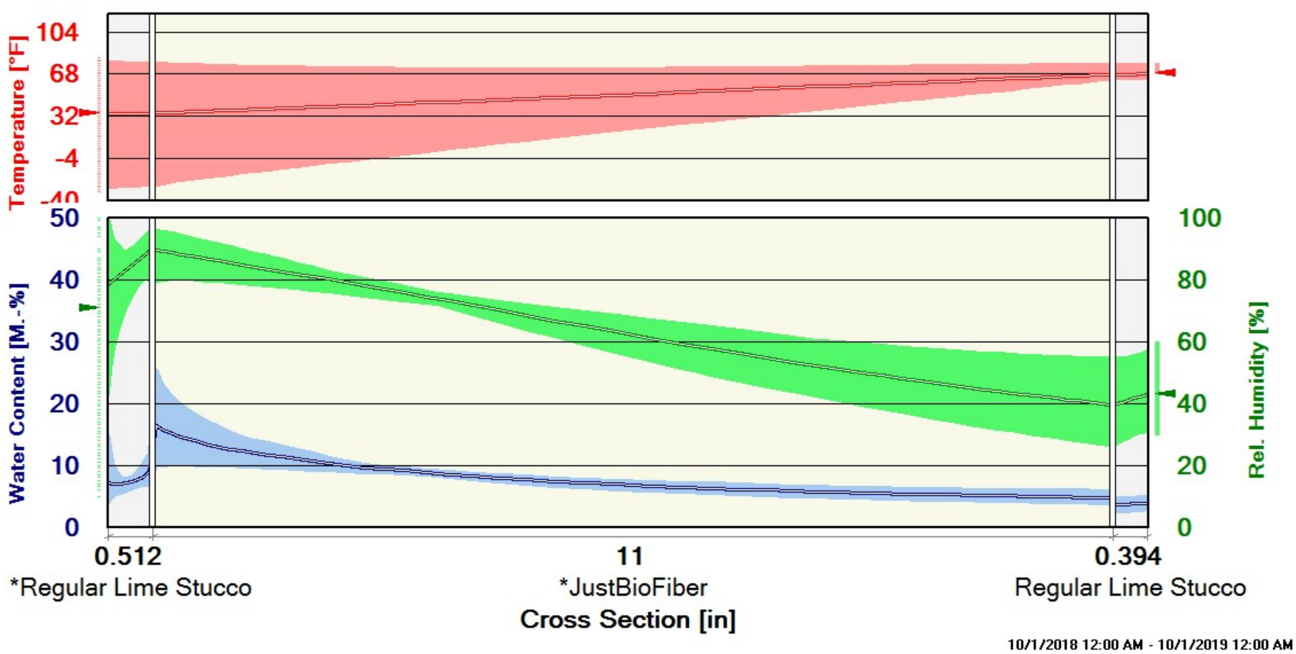


Fig. 27 Average Annual Hygrothermal Conditions and Variations for Case 20

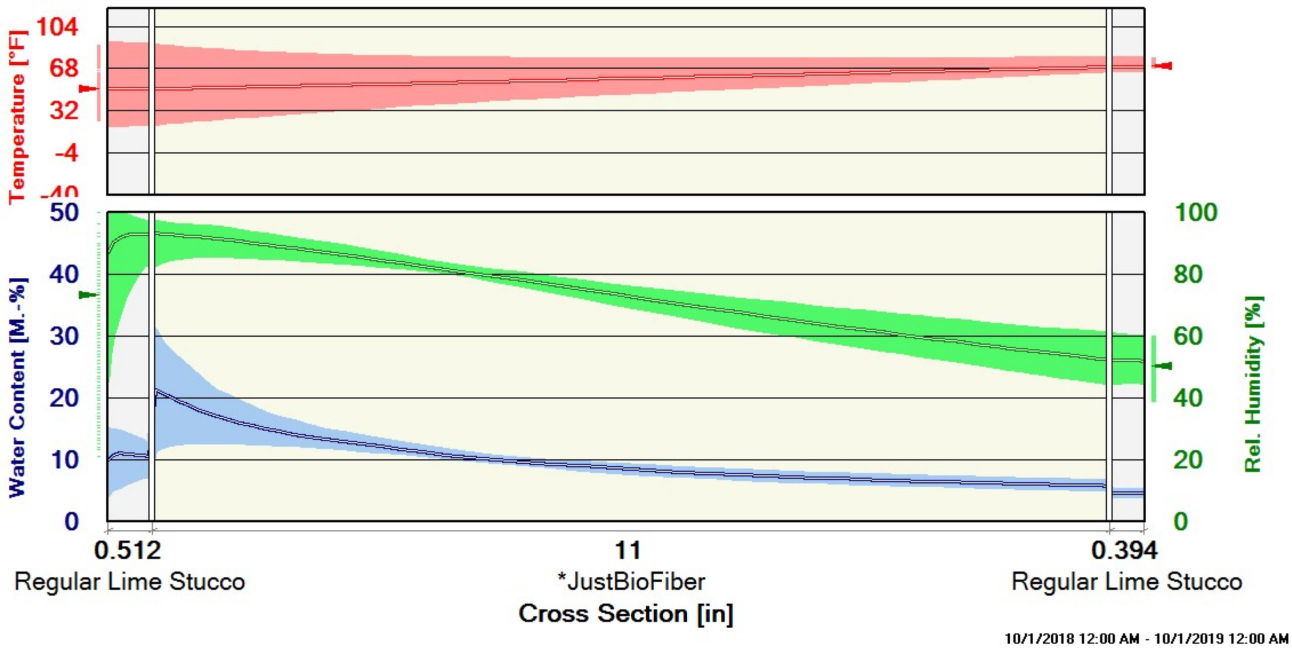


Fig. 28 Average Annual Hygrothermal Conditions and Variations for Case 16a

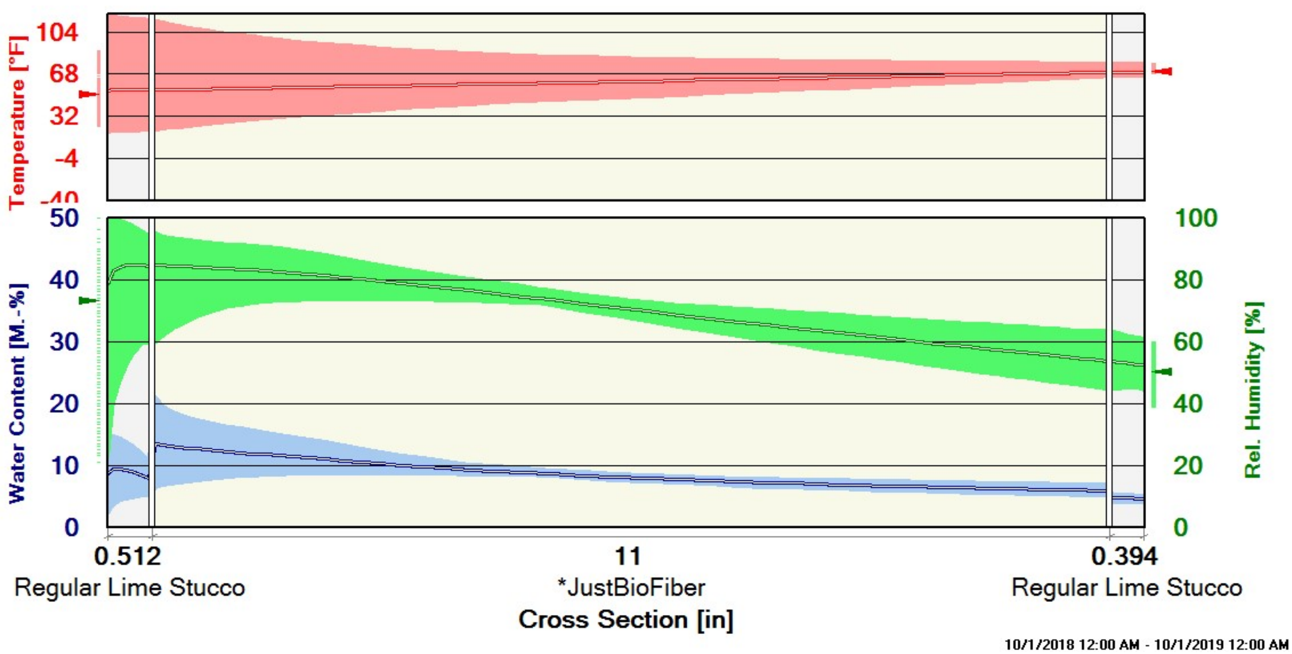


Fig. 29 Average Annual Hygrothermal Conditions and Variations for Case 16c

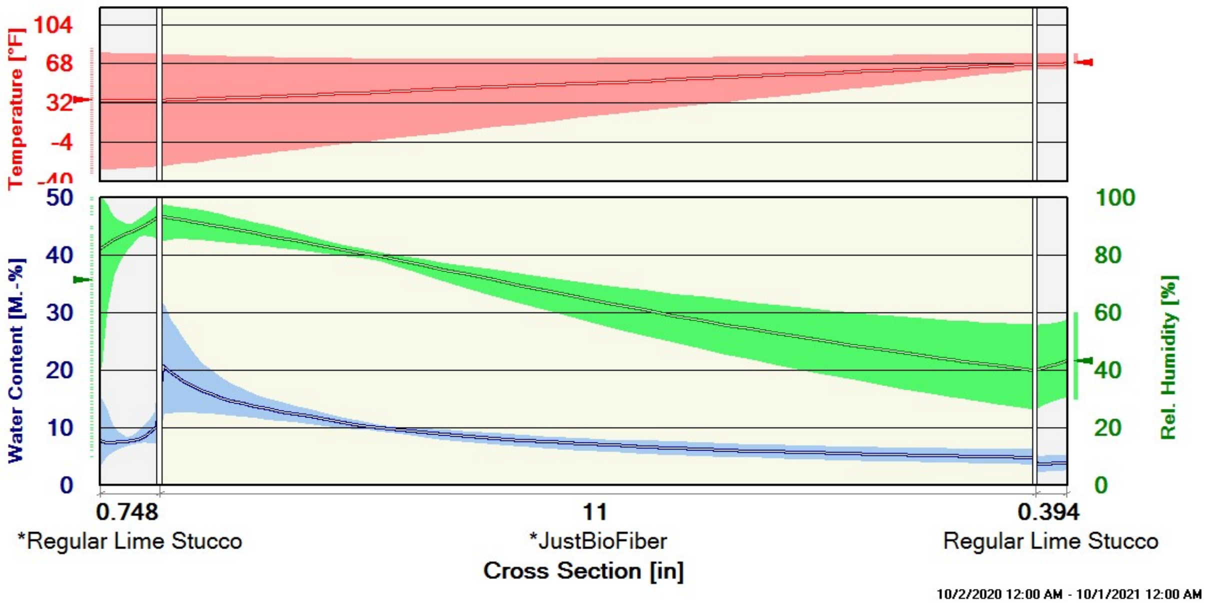


Fig. 30 Average Annual Hygrothermal Conditions and Variations for Case 18a

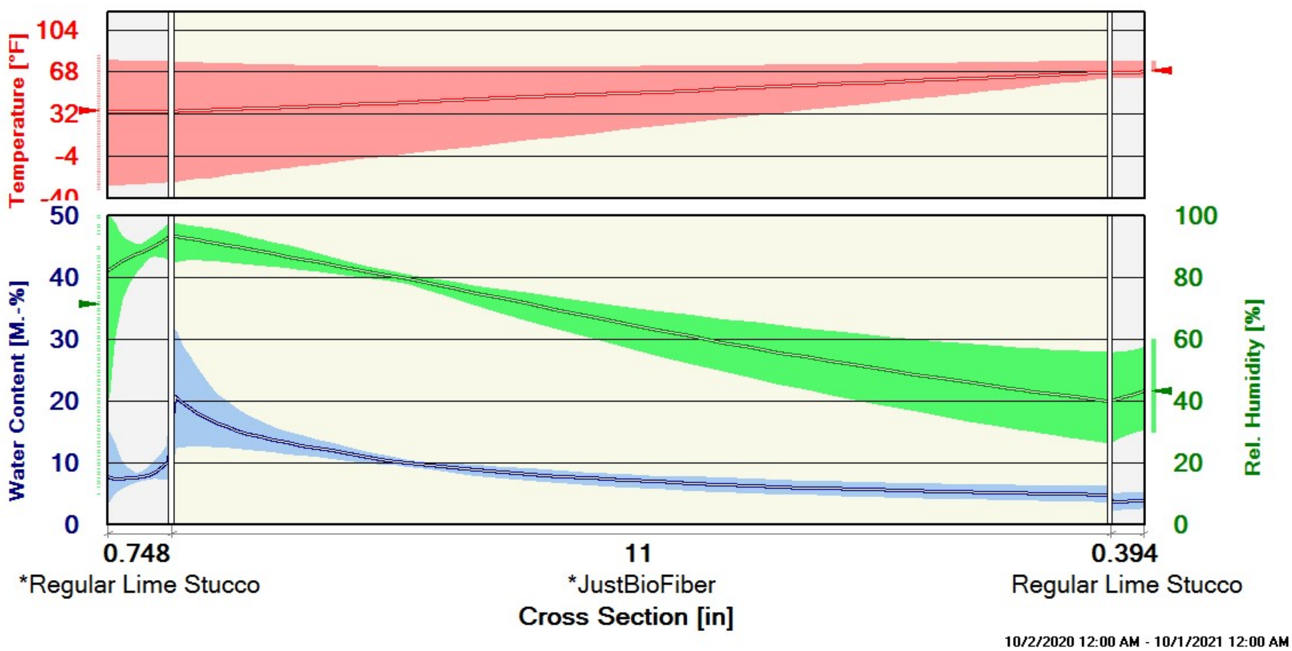


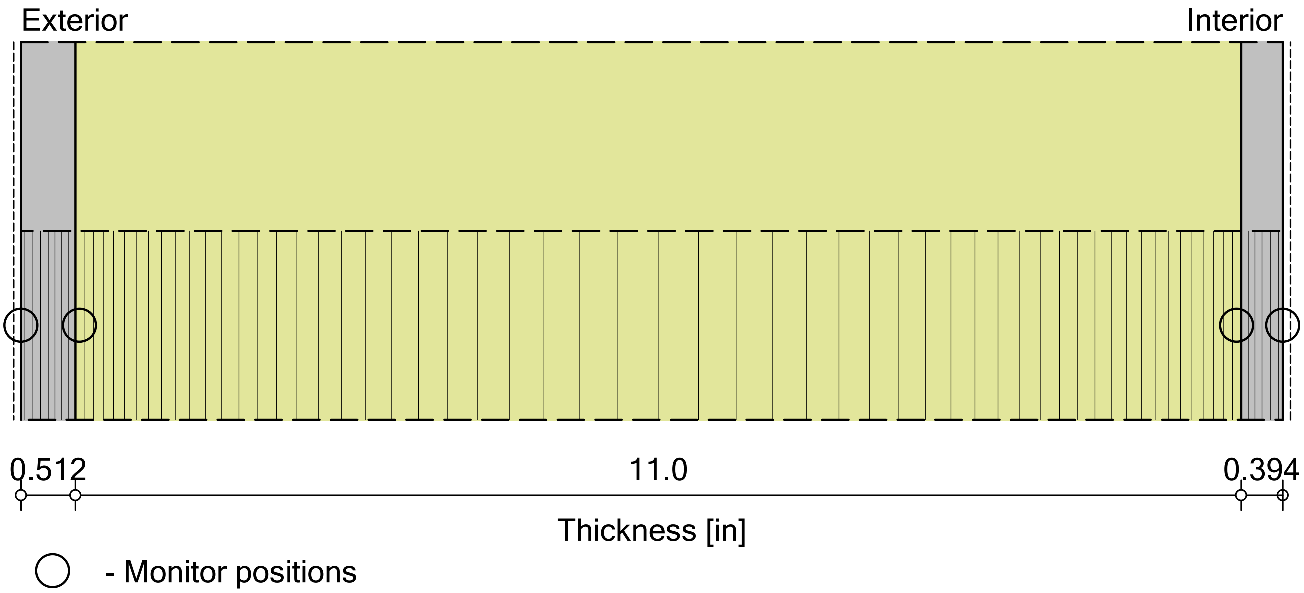
Fig. 31 Average Annual Hygrothermal Conditions and Variations for Case 18b

APPENDIX B

Exemplary WUFI® Data Sheet, Case 1

Component Assembly

Case:



Materials:

	- *Regular Lime Stucco	0.512 in
	- *JustBioFiber, Super SSR Modular Block Wall System	11.0 in
	- Regular Lime Stucco	0.394 in

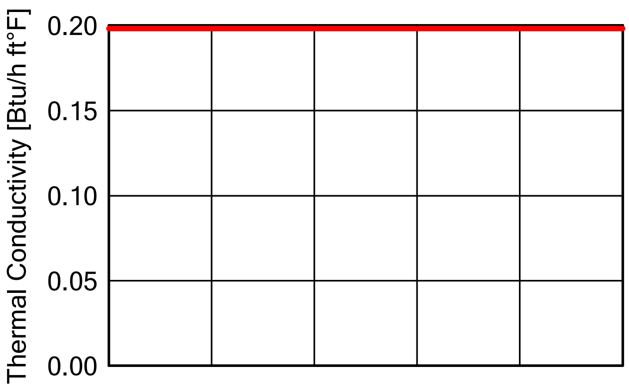
Sd-Value Ext. [perm]: 41.0
Sd-Value Int. [perm]: 7.1304

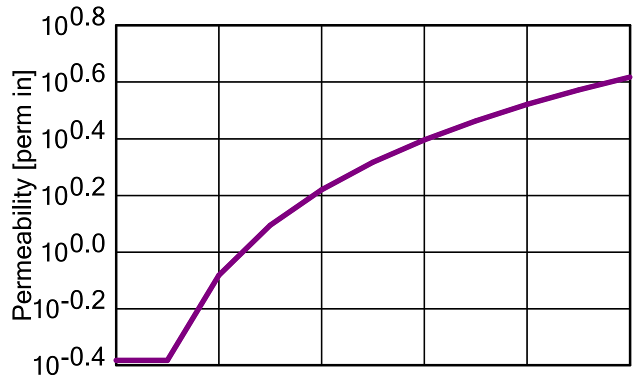
Total Thickness: 11.91 in
R-Value: 18.47 h ft² °F/Btu
U-Value: 0.051 Btu/h ft²°F

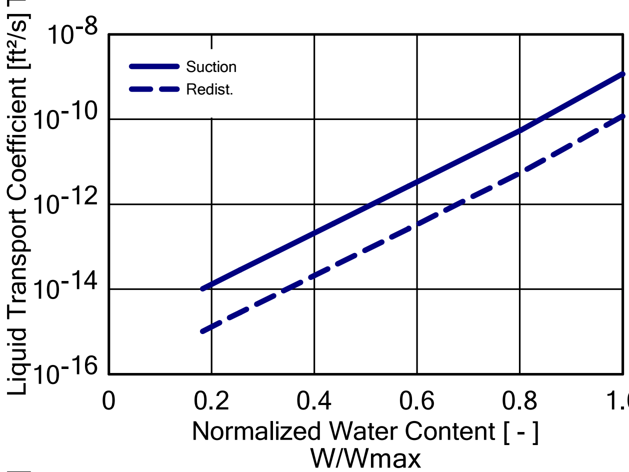
Material: *Regular Lime Stucco

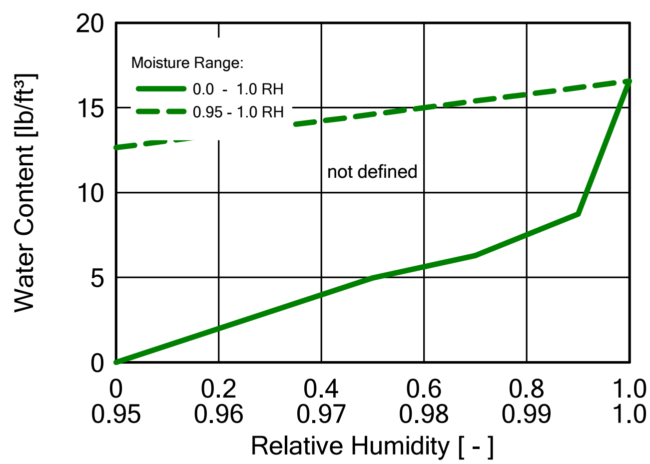
Checking Input Data

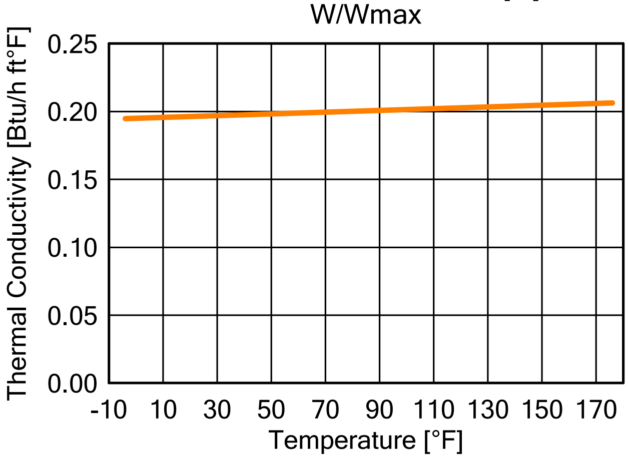
Property	Unit	Value
Bulk density	[lb/ft³]	110.4351
Porosity	[ft³/ft³]	0.274
Specific Heat Capacity, Dry	[Btu/lb°F]	0.2006
Thermal Conductivity, Dry, 50°F	[Btu/h ft°F]	0.1982
Permeability	[perm in]	0.4147
Temp-dep. Thermal Cond. Supplement	[Btu/h ft°F²]	0.0000642









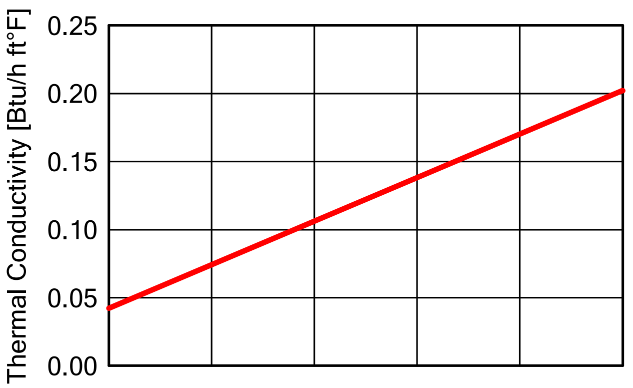


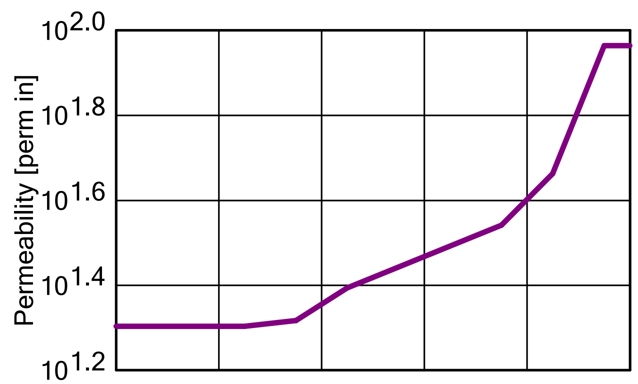
WUFI® Pro 5.3

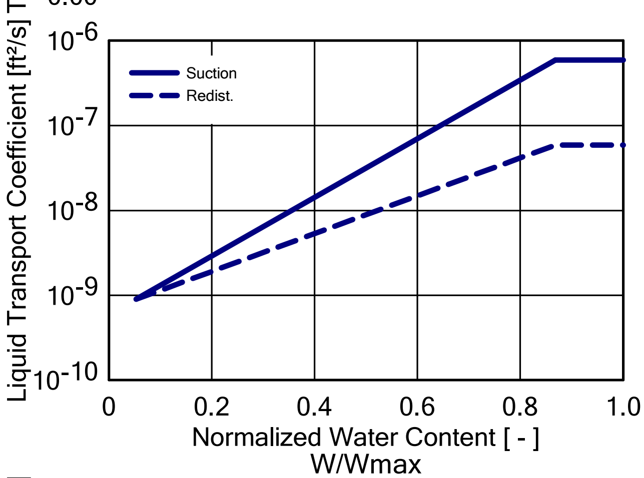
Material: *JustBioFiber, Super SSR Modular Block Wall System

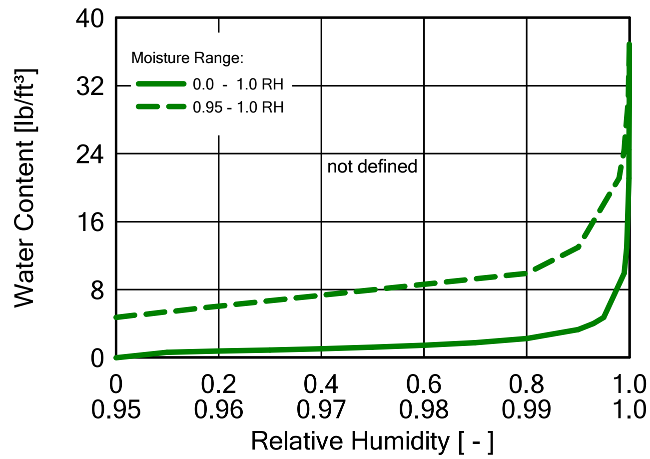
Checking Input Data

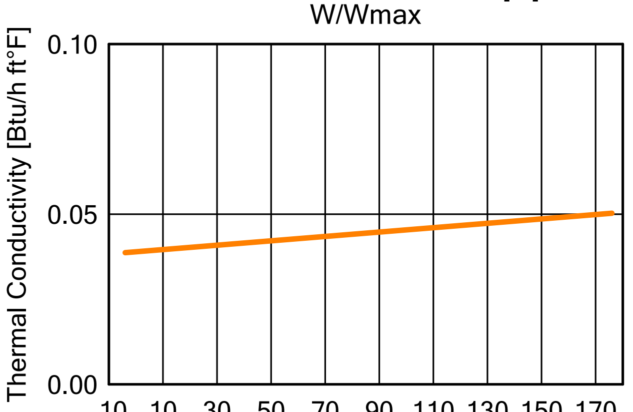
Property	Unit	Value
Bulk density	[lb/ft³]	22.4741
Porosity	[ft³/ft³]	0.68
Specific Heat Capacity, Dry	[Btu/lb°F]	0.283
Thermal Conductivity, Dry, 50°F	[Btu/h ft°F]	0.0422
Permeability	[perm in]	20.125
Reference Water Content	[lb/ft³]	2.2536
Free Water Saturation	[lb/ft³]	36.8949
Water Absorption Coefficient	[lb/in²s^0.5]	0.0001011
Moisture-dep. Thermal Cond. Supplement	[%/M.-%]	2.0
Temp-dep. Thermal Cond. Supplement	[Btu/h ft°F²]	0.0000642









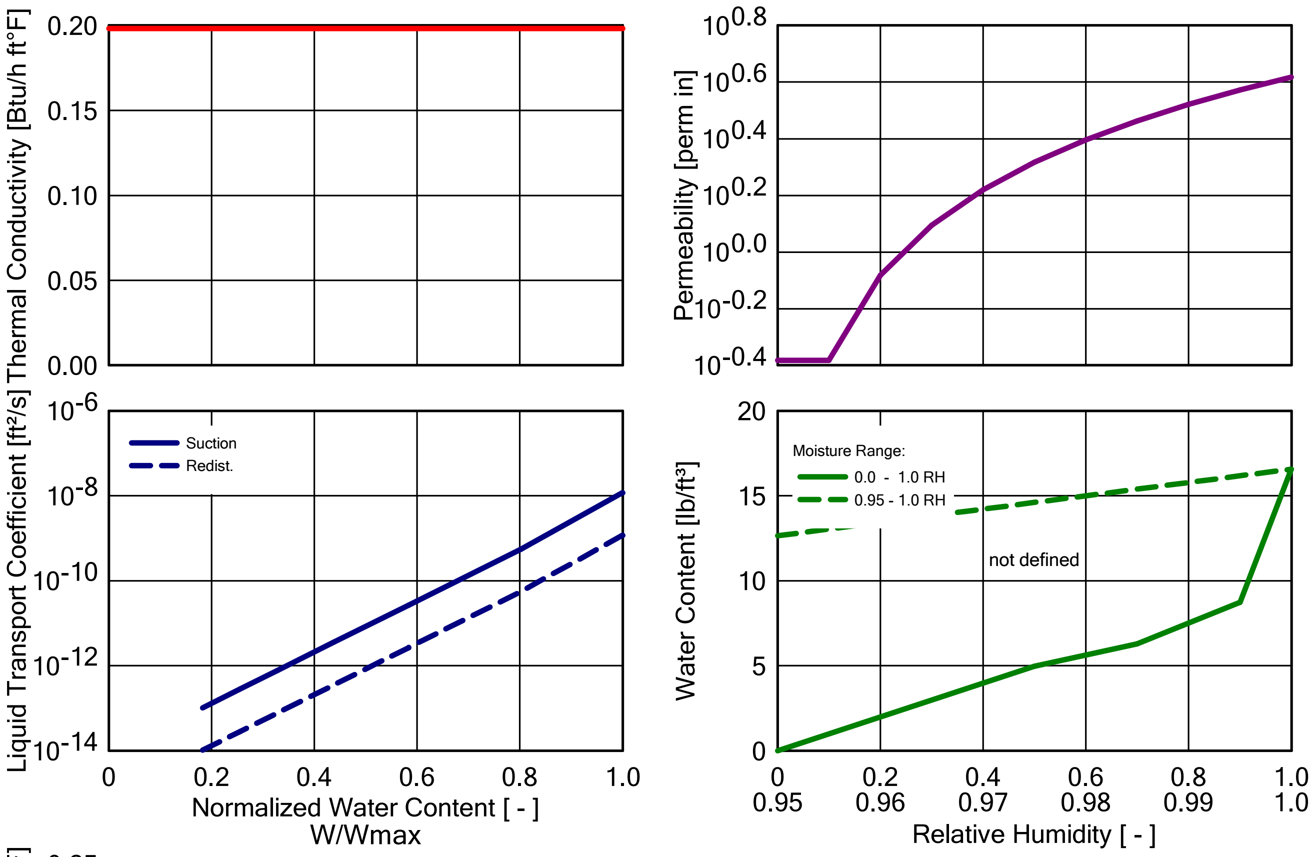


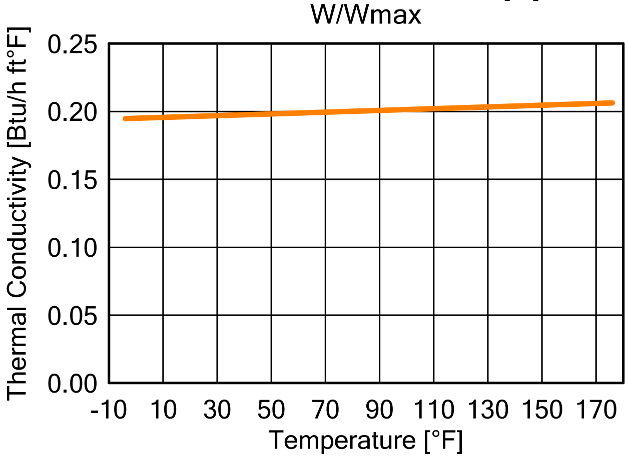
WUFI® Pro 5.3

Material: Regular Lime Stucco

Checking Input Data

Property	Unit	Value
Bulk density	[lb/ft³]	110.4351
Porosity	[ft³/ft³]	0.274
Specific Heat Capacity, Dry	[Btu/lb°F]	0.2006
Thermal Conductivity, Dry, 50°F	[Btu/h ft°F]	0.1982
Permeability	[perm in]	0.4147
Temp-dep. Thermal Cond. Supplement	[Btu/h ft°F²]	0.0000642





Boundary Conditions

Exterior (Left Side)

Location: Miami, FL; warm year
Orientation / Inclination: North / 90 °

Interior (Right Side)

Indoor Climate: EN 15026
Normal Moisture Load

Surface Transfer Coefficients

Exterior (Left Side)

Name	Description	Unit	Value
Heat Resistance - includes long-wave radiation	External Wall	[h ft² °F/Btu]	0.3339 yes
Permeance		[perm]	41.0
Short-Wave Radiation Absorptivity		[-]	0.5
Long-Wave Radiation Emissivity		[-]	0.9
Adhering Fraction of Rain	Depending on inclination o	[-]	0.7
Explicit Radiation Balance			yes
Terrestrial Short-Wave Reflectivity		[-]	0.2
Terrestrial Long-Wave Emissivity		[-]	0.9
Terrestrial Long-Wave Reflectivity		[-]	0.1
Cloud Index		[-]	0.66

Interior (Right Side)

Name	Description	Unit	Value
Heat Resistance	External Wall	[h ft² °F/Btu]	0.7098
Permeance		[perm]	7.1304