General Shale
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Engineering Services

Thin Brick/Loxon WUFI Analysis Clemson - NBRC

Technical Bulletin

To assess the water penetration performance of thin brick adhered veneer installations General Shale conducted a testing and analysis program of various thin brick configurations.

The testing and analysis was performed by the National Brick Research Center at Clemson University. This bulletin summarizes the results of the testing and analysis.

The first step of this program consisted of WUFI computer analysis of simulated thin brick installations. WUFI is a sophisticated computer software program developed by the Oak Ridge National Laboratory and the Institute of Biophysics in Germany. Installations analyzed include typical lath-mortar configurations and configurations using Loxon metal panels The analysis simulated weather conditions in five different severe climatological areas including Houston, Chicago, Winnipeg, Lexington and Phoenix. Details of the analysis as well as more discussion are summarized in Attachment B.

In general the results of the WUFI analysis resulted in two important conclusions: 1) Moisture conditions in none of the configurations resulted in levels that are known to produce or maintain mold growth. 2) Loxon panels in conjunction with typical water resistance barriers (WRB), building papers or house wrap did not result in conditions that trap and hold moisture.

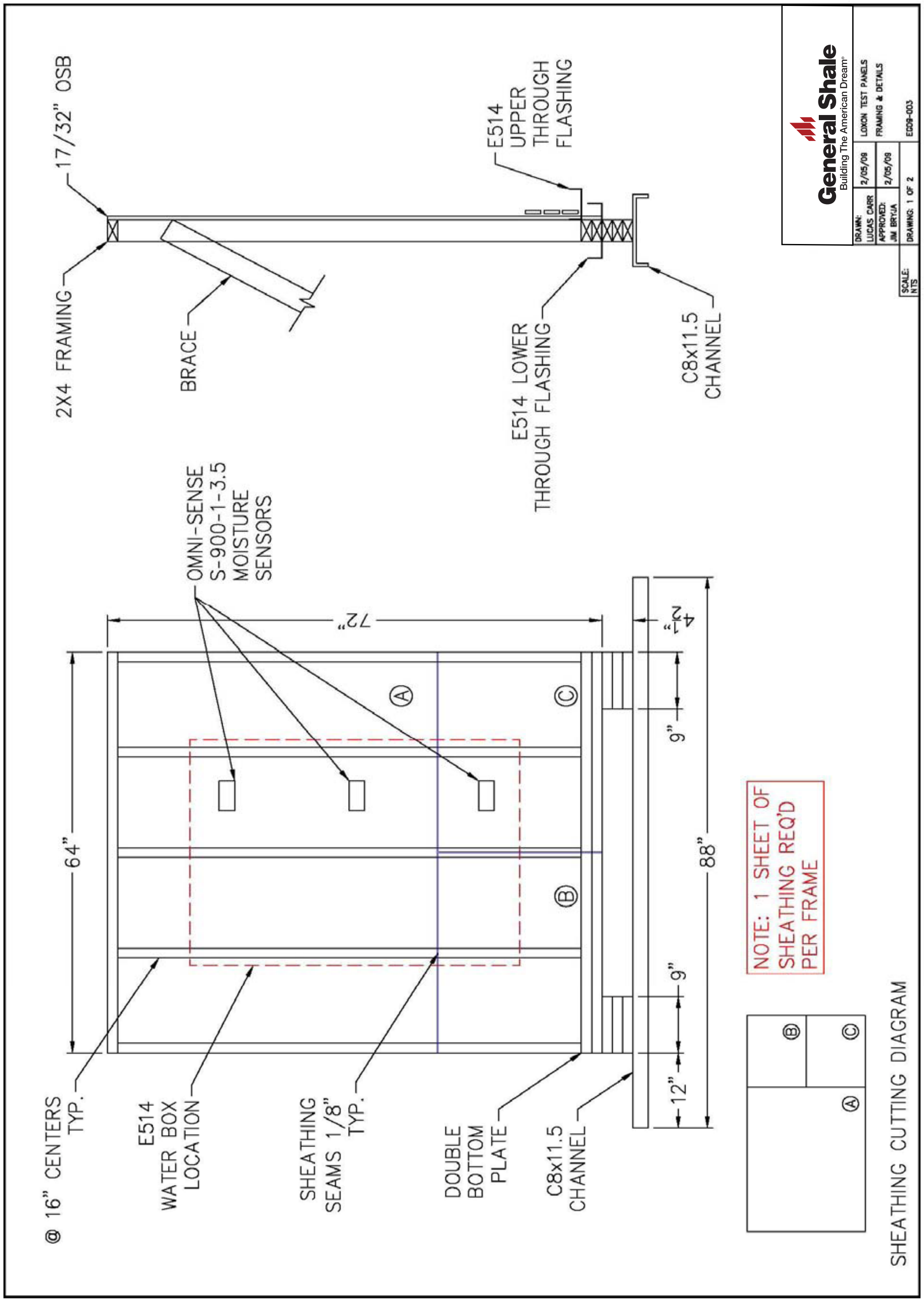
The second step of the program consisted of performing pressurized water spray tests on various thin brick configurations. The test included typical scratch coat/lath installations and Loxon panel installations. A total of six panels were tested with configurations in the following table.

TEST PANEL CONFIGURATIONS					
PANEL NO.	HOUSEWRAP	SUTCCO WRAP	SCRATCH COAT W/ LATH	LOXON	SHEATHING PENETRATION
1	X			X	
2	X		X		
3	X			X	X
4	X		X		X
5	X	X	X		
6	X	X		X	

Testing was performed using a water chamber pressurized to 10 psf with water spray applied at the rate of 3.4 gal/sq. ft. of wall per hour.

The results of the water testing showed excellent water permeance performance for all 6 panels tested, and the following 3 important conclusions: 1) None of the 6 panels showed any signs of water penetration. 2) The Loxon panels showed excellent water drainage (see attachment C and photo 4 in Attachment D). These results indicate that the Loxon do indeed provide a functioning drainage space. Additional information, discussion and results can be found in Attachment C.

Attachment A



Attachment B

Research Report

General Shale LOXON WUFI Modelling Summary – Phase 4

Special Member Report to General Shale Brick

29 January 2009

Corrected – 9 September 2009

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Center Report Number: 0902

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General Shale – Additional WUFI Modelling
29 January 2009

Simulated wall sections using the LOXON thin brick system were modelled using WUFI 3.3 Pro to assess the movement of moisture through the system. Results for the LOXON system were calculated using building paper and Tyvek (spun bonded polyolefin). The results for the LOXON panels were compared to panels using a more traditional thin brick installation. It is important to note that WUFI is only capable of modelling the movement of moisture in one dimension. The simulated wall sections were constructed with data from the WUFI material database and other sources when no data was available in WUFI. A summary of the layers used in the models and the assumptions required to model each layer is given in Table 1.

Table 1. Summary of Layers in Simulated Wall Section

Layer	Thickness (in)	Comments
Thin Brick	0.5	Data from WUFI for red, extruded brick was modified to accommodate the thickness of a thin brick.
Acrylic Adhesive/Air	0.125	Data for acrylic was combined with data for a 5 mm air gap (from WUFI) to model this layer. It was assumed that the acrylic accounted for 2% of the layer and air accounted for 98% of the layer.
Mortar	0.375	Date from WUFI for Type N mortar was used.
LOXON Steel Panel/Air	0.125	Data for galvanized steel was combined with data for a 5 mm air gap (from WUFI) to model this layer. Based on calculations of open area in the sample LOXON wall section, it was determined that the steel accounted for 82% of this layer and air accounted for 18% of this layer.
Metal Lathe/Air	0.125	Data for the metal lathe was generated similarly to the LOXON panel. The lathe was estimated to be 80% airspace and 20% galvanized steel.
Tyvek (Spun Bonded Polyolefin)	0.03937	Data from WUFI.
Building Paper	0.01575	Data from WUFI.
OSB	0.53 (17/32)	Data from WUFI for Medium Density OSB (37.5 lb/ft^3). A starting moisture content of 7% (2.6 lb/ft^3) was assumed.
Fiberglass Insulation	4	Data from WUFI. Since WUFI is a one dimensional model, the studs were not included. The data in WUFI for fibreglass insulation does not include a vapor barrier.
Kraft Paper	0.039	Data from WUFI.
Sheetrock	0.5	Data from WUFI.

The simulated wall section was tested for north facing orientations for Chicago, Houston, Lexington (KY), Phoenix, and Winnepeg using typical climate data for each city from the WUFI climate database. Each model was tested for one year, and the results are summarized in Table 2. For each simulation, a summary graph which shows the range of temperature, humidity and water content in the simulated wall section, over the course of a year, is also included.

For each of the simulations, water appeared to collect in the OSB, particularly at the OSB/fiber glass insulation interface. According to industry sources, OSB is typically shipped with a moisture content around 5%, but the equilibrium moisture content of the OSB is between 7 and 9% for most typical construction. These same sources state that moisture contents in excess of 20% will promote mold growth and ultimately decay.

The panel configuration appears to have little effect on the final OSB moisture content for each of the climates. None of the simulations indicate that the moisture content exceeds 20% in the OSB over the course of the year long simulation.

These simulations are an indication of the potential performance of this wall system. Given the assumptions required to develop this simulation, these findings cannot be considered as definitive. It is also possible to modify various components in the simulated wall panel, if required. Any opinions or results expressed or implied are the sole opinion of the investigator and does not reflect any opinion of the Trustees, Officers, or other employees of Clemson University.

Table 2 – Modelling Summary

Case	Description	Location	Orientation	Climate	Initial Moisture Content (%)*	Final Moisture Content (%)*
1	LOXON Panel System with building paper and 7% OSB starting moisture content (See Figure 1)	Houston	North	Hot Typical Year	7	10.9
2	LOXON Panel System with building paper and 7% OSB starting moisture content (See Figure 1)	Chicago	North	Cold Typical Year	7	13.3
3	LOXON Panel System with building paper and 7% OSB starting moisture content (See Figure 1)	Lexington, KY	North	Cold Typical Year	7	13.1
4	LOXON Panel System with building paper and 7% OSB starting moisture content (See Figure 1)	Phoenix	North	Hot Typical Year	7	6.1
5	LOXON Panel System with building paper and 7% OSB starting moisture content (See Figure 1)	Winnipeg	North	Cold Typical Year	7	15.2
6	LOXON Panel System with spun bonded polyolefin house wrap and 7% OSB starting moisture content (See Figure 6)	Houston	North	Hot Typical Year	7	10.9
7	LOXON Panel System with spun bonded polyolefin house wrap and 7% OSB starting moisture content (See Figure 6)	Chicago	North	Cold Typical Year	7	13.3
8	LOXON Panel System with spun bonded polyolefin house wrap and 7% OSB starting moisture content (See Figure 6)	Lexington, KY	North	Cold Typical Year	7	13.1
9	LOXON Panel System with spun bonded polyolefin house wrap and 7% OSB starting moisture content (See Figure 6)	Phoenix	North	Hot Typical Year	7	6.1
10	LOXON Panel System with spun bonded polyolefin house wrap and 7% OSB starting moisture content (See Figure 6)	Winnipeg	North	Cold Typical Year	7	15.2

Table 2 – Modelling Summary (Continued)

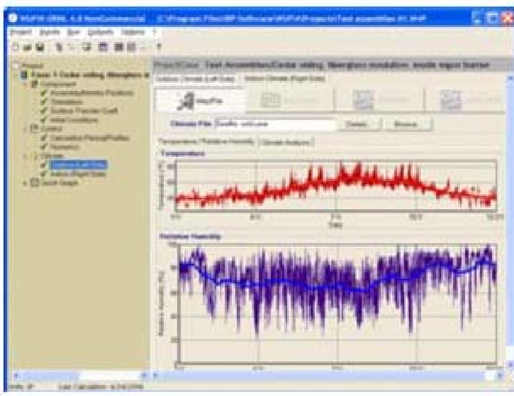
Case	Description	Location	Orientation	Climate	Initial Moisture Content (%)*	Final Moisture Content (%)*
11	Thin Brick, Mortar Bed, Metal Lathe with Building Paper (See Figure 11)	Houston	North	Hot Typical Year	Mortar-4.6 OSB-7	Mortar-3.3 OSB-10.7
12	Thin Brick, Mortar Bed, Metal Lathe with Building Paper (See Figure 11)	Chicago	North	Cold Typical Year	Mortar-4.6 OSB-7	Mortar-3.5 OSB-13.1
13	Thin Brick, Mortar Bed, Metal Lathe with Building Paper (See Figure 11)	Lexington, KY	North	Cold Typical Year	Mortar-4.6 OSB-7	Mortar-3.4 OSB-12.8
14	Thin Brick, Mortar Bed, Metal Lathe with Building Paper (See Figure 11)	Phoenix	North	Hot Typical Year	Mortar-4.6 OSB-7	Mortar-1.4 OSB-6.1
15	Thin Brick, Mortar Bed, Metal Lathe with Building Paper (See Figure 11)	Winnipeg	North	Cold Typical Year	Mortar-5.4 OSB-7	Mortar-3.7 OSB-15.0

*Initial moisture content of the OSB was set at 7%

**The final moisture content after one year of simulated exposure (January to January)

WUFI Hygrothermic Modeling

WUFI-ORNL/IBP is a software program designed to model the dymanic movement of heat and moisture through building wall and roof assemblies. The software, developed jointly by Oak Ridge National Laboratory (ORNL) and Germany's Fraunhofer Institute of Bauphysics (IBP), is intended as a tool for researchers and building technologists to aid in the analysis and design of building envelope assemblies. This author's first impressions of the software after trying out a **freely available research and education version** of the program follow.



What is WUFI?

WUFI allows the user to model various building assemblies, run these assemblies through simulations of several years of typical climatic conditions for various locales (see the image at left), and analyze the performance of the assembly in terms of moisture flow, moisture accumulation, and other factors.

WUFI is a sophisticated yet relatively easy to use program. For example, it can simulate climatic conditions for different locals and account for differences in orientation of the building assembly. Assemblies themselves are modeled by selecting and arranging in the desired order components (such as sheetrock, plywood, vapor barrier sheet, etc.) from a database into which the relevant material properties have already been inputted. Once the initial conditions are established, simulations can be run and graphically observed at the push of a

Summer Condensation in Sandwich Construction

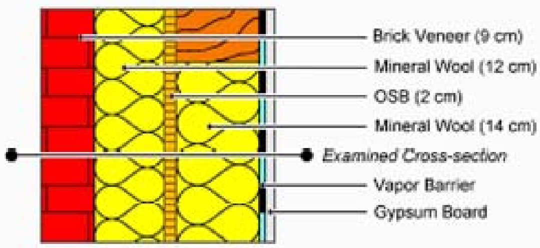


Fig. 1: The investigated lightweight construction with brick veneer.

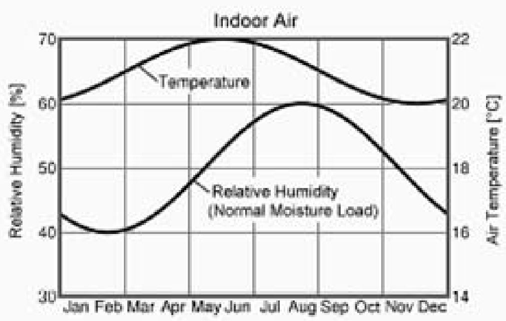


Fig. 2: Representative climate conditions for residential dwellings in Germany.

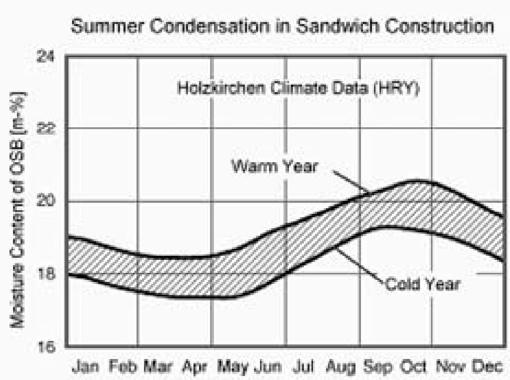


Fig. 3: Moisture in the OSB of the exterior wall in Fig. 1, calculated for five years with the Holzkirchen Hygrothermal Reference Years (HRY) for a warm and a cold year.

In sandwich wall constructions the outer leaf provides the weathering protection. Even if there is no air gap between the outer leaf and the core insulation, capillary infiltration of rain water is limited to the outer leaf if hydrophobic insulation materials are used and the whole construction is windproof [1]. Thus, if the wall is properly executed, the construction layers behind the facework are durably protected from precipitation water.

In summer, however, moisture may be transported into these deeper layers by so-called reverse diffusion (also known as summer condensation). If the outer leaf is heated by sunshine, the rain water it contains will be carried across the core insulation by vapor diffusion and condense in the cooler inner leaf. If the inner leaf is masonry, the condensation moisture is harmlessly absorbed as capillary water in its pore spaces and given off in cooler periods. However, if the inner leaf contains materials which are susceptible to moisture damage, such as wood, summer condensation may create problems.

The effect of summer condensation occurring in the wall construction shown in Fig. 1 has been investigated by computational simulation. The inner leaf is a simple wooden post-and-beam structure. The outer leaf is clinker facework with a relatively low water absorption coefficient (A-value) of 1,0 $kg/m^2h^{1/2}$. The 12-cm-thick cavity between the facework and the OSB board covering the inner leaf is completely filled with hydrophobic mineral wool insulation. The investigation considers a typical cross-section of the west-facing wall during the fifth year of exposure to weather and focuses on the moisture content of the OSB board. The indoor climate used for the calculations is shown in Fig. 2, a cold and a warm year measured in Holzkirchen (HRY - Hygrothermal Reference Years) were used for the outdoor climate conditions.

Fig. 3 shows the spread of moisture conditions that occur in the OSB board, depending on the outdoor climate. In contrast to what is usually expected, the OSB board dries out during winter, starts to continuously accumulate moisture around May, reaches a maximum in autumn and then starts to dry again. As described above, the moisture accumulation during

Assessment of mold growth risk

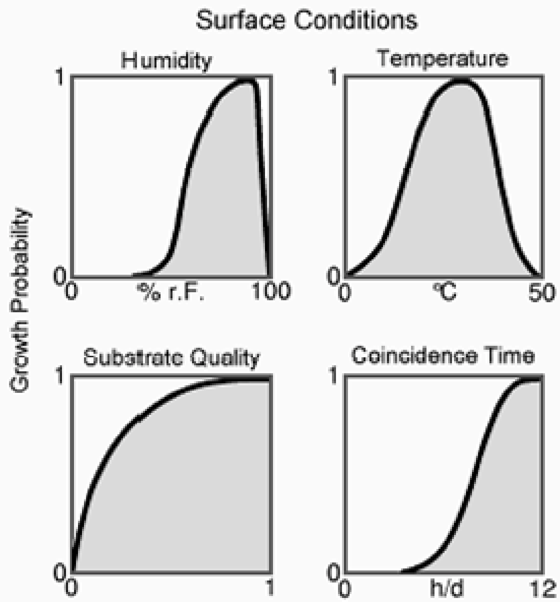


Fig. 1: Influence parameters for mold growth on building element surfaces.

Under unfavorable ambient conditions, microbial growth may occur on the surfaces of building components. The most important factors are temperature, relative humidity, a substrate with sufficient nutrients and the daily duration of the period where all growth conditions prevail simultaneously (coincidence time). While bacteria need relative humidities of at least 90% for being able to grow, certain xerophilic fungi can thrive at humidities as low as 65%, and most fungi can cope with humidities as low as 80%. Mold fungi also tolerate a larger temperature bandwidth than other organisms, they may grow between 0°C and 50°C. Therefore the whole range of humidities and temperatures mentioned above may be considered to pose a potential mold growth risk.

Fig. 1 shows a qualitative assessment of the growth conditions for mold in dependence of the above factors. These functional relationships served as the basis for a prediction method for assessing the mold growth risk which has already been applied repeatedly and has been validated by comparison with experiment [1]. The input data are the local temperature and humidity conditions resulting from a non-steady simulation. The influence factors are combined by fuzzy logic which allows for the natural uncertainty inherent in specifying e.g. the humidity interval favorable for growth. The output of the assessment is a measure for the amount of mold growth to be expected. Current work is aimed at extending the above non-steady method to create an encompassing safety concept as has been called for and developed in a steady-state version by [2].

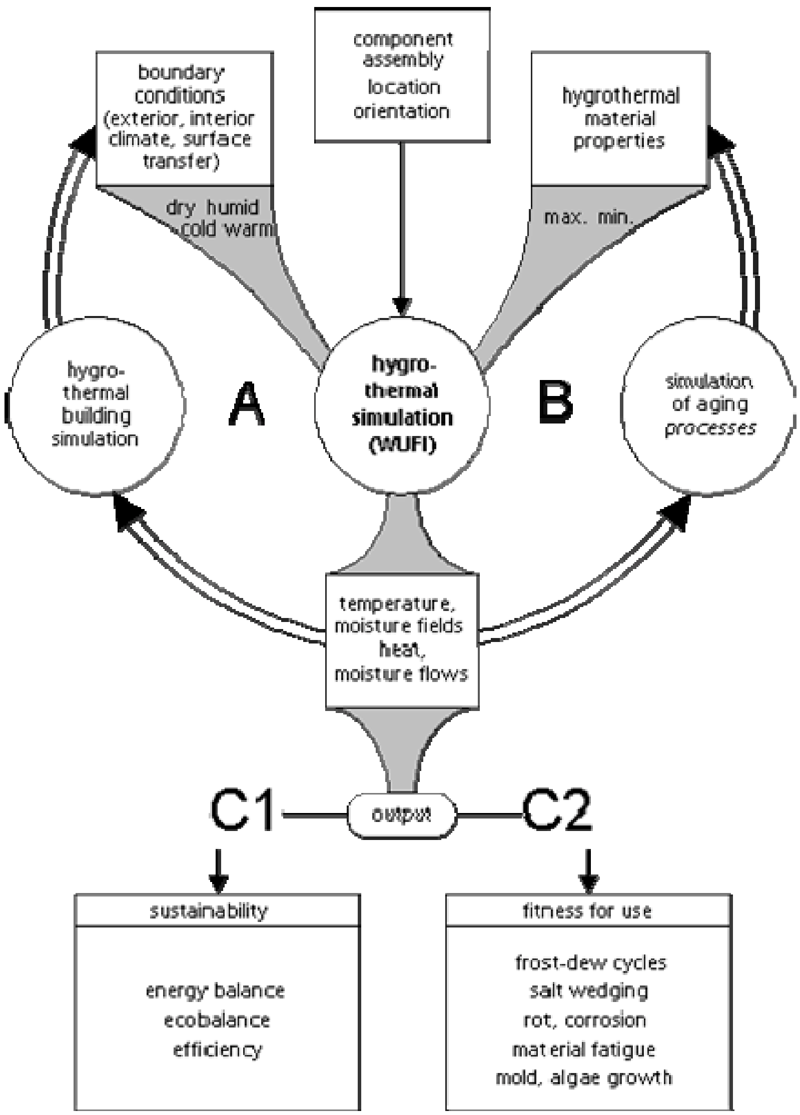
Literature

[1] **Sedlbauer, K.; Oswald, D.; König, N.:** Schimmelgefahr bei offenen Luftkreisläufen. Vorstellung einer Prognosemethode auf der Basis von Fuzzy-Algorithmen. Gesundheits-Ingenieur, Heft 5 (1998), S. 240 - 247.

[2] **Cziesielski, E.:** Schimmelpilz - ein komplexes Thema. Wo liegen die Fehler? wksb 44 (1999), H. 43, S. 25 - 28.

Future Developments for WUFI

In many cases detailed knowledge of the hygrothermal conditions in a building component is not sufficient to assess its fitness-for-use or its durability. What is needed then are specific assessment criteria or models which can use the computed transient temperature and moisture conditions to evaluate the durability of the component and the damage risk it is exposed to. Currently, building physics is but in the early stages of developing such methods and tools which in the future will allow much more specific and reliable hygric assessments and more efficient preventive measures. In the following, some current international lines of research in hygrothermal simulation and their interrelationships will be discussed.

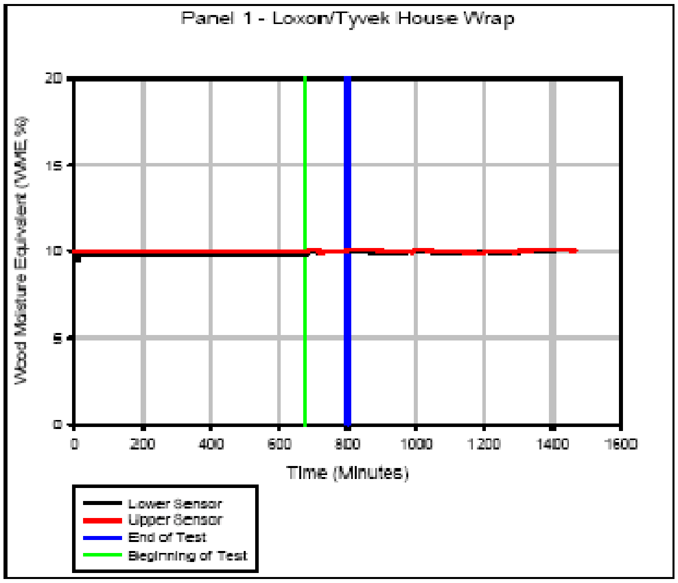


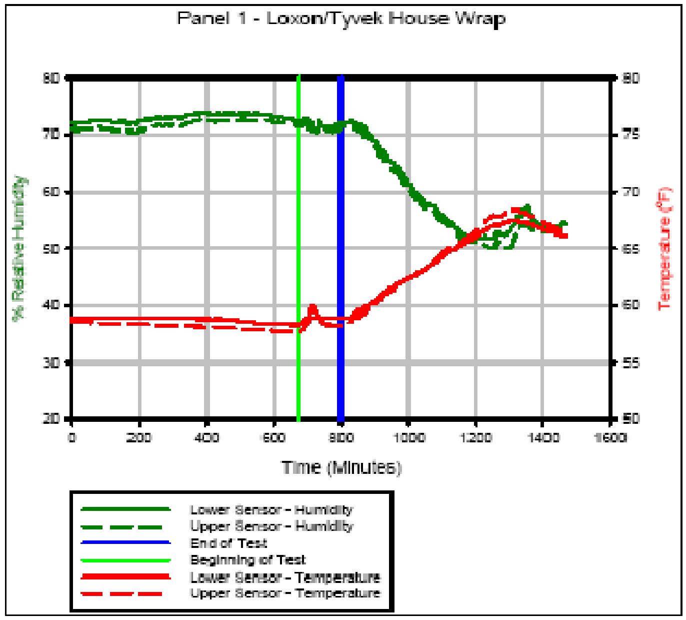
Stochastic Models

Attachment C

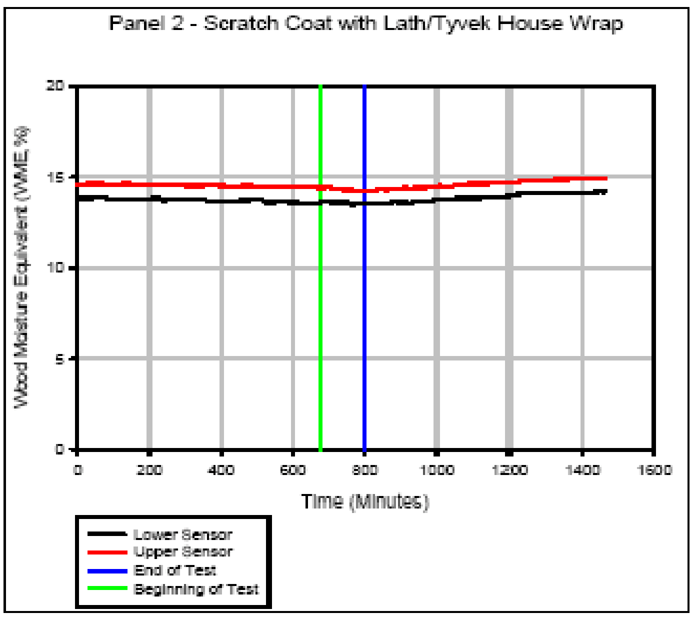
Panel	Housewrap	Stucco Wrap	Scratch Coat w/ Lath	Loxon	Sheating Penetration	Water Penetration Veneer	Water Penetration Veneer and Wrap	Water Exiting Test Frame
						gal/hr	gal/hr	gal/hr
1	X			X		30.1	0	1.7
2	X		X			5.7	0	27.8
3	X			X	X	28.1	0	6.2
4	X		X		X	5.8	0	31.9
5	X	X	X			7.8	0	30.3
6	X	X		X		35.5	0	0

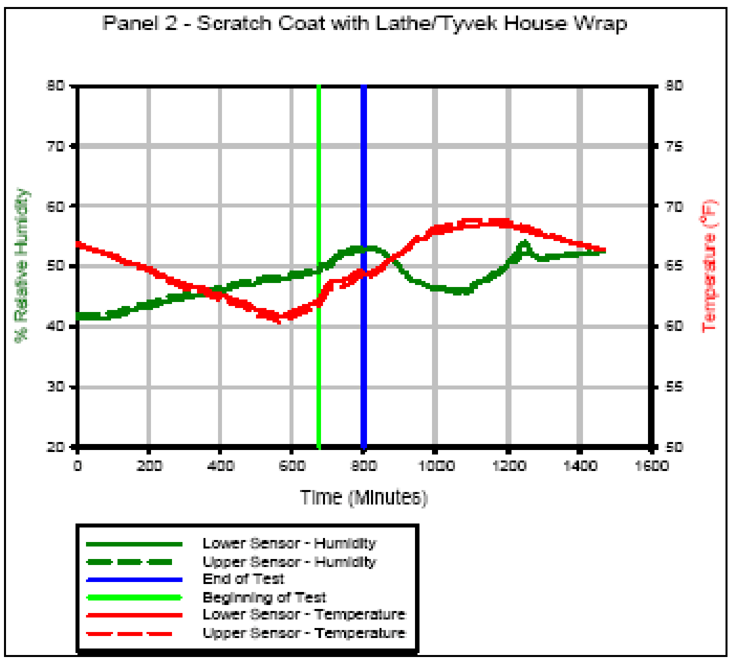
Panel 1 Loxon/House Wrap



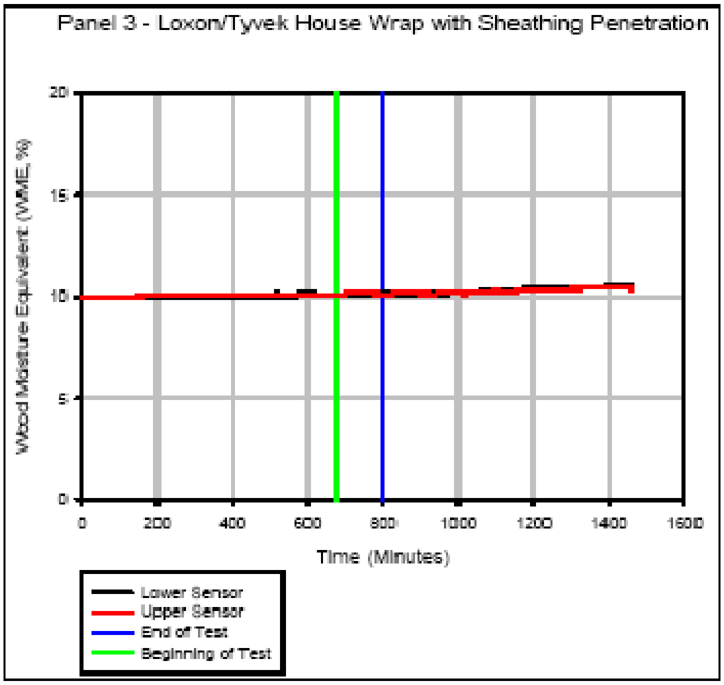


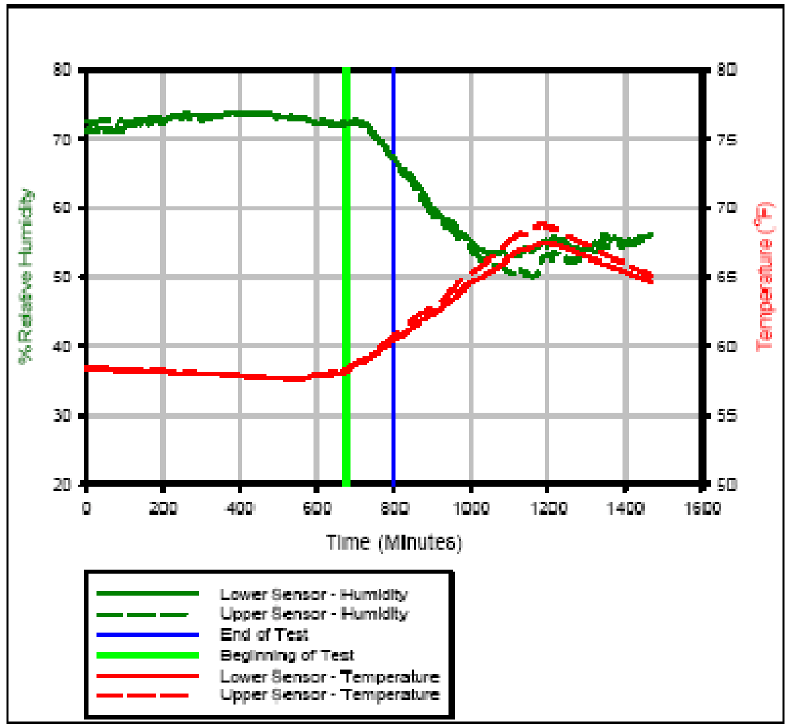
Panel 2 Scratch Coat with Lathe/Tyvek House Wrap



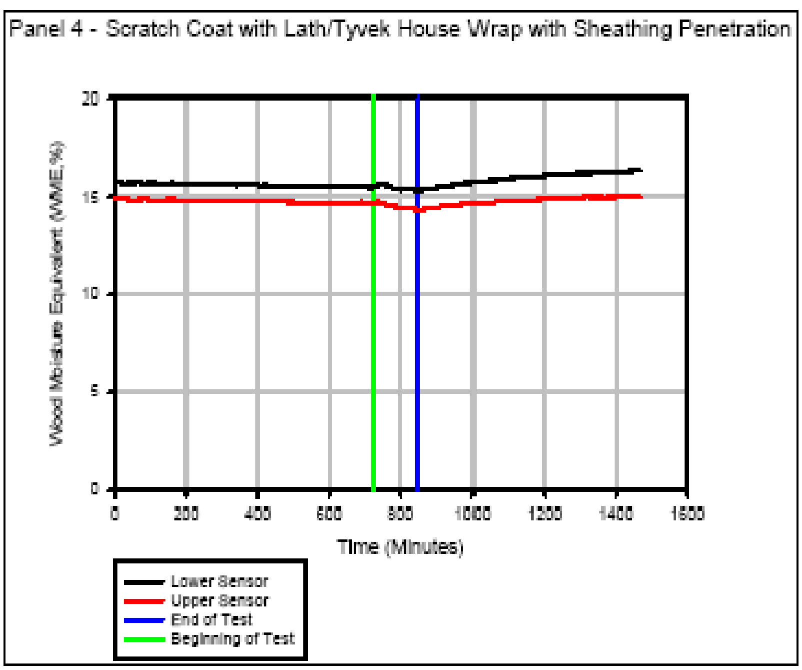


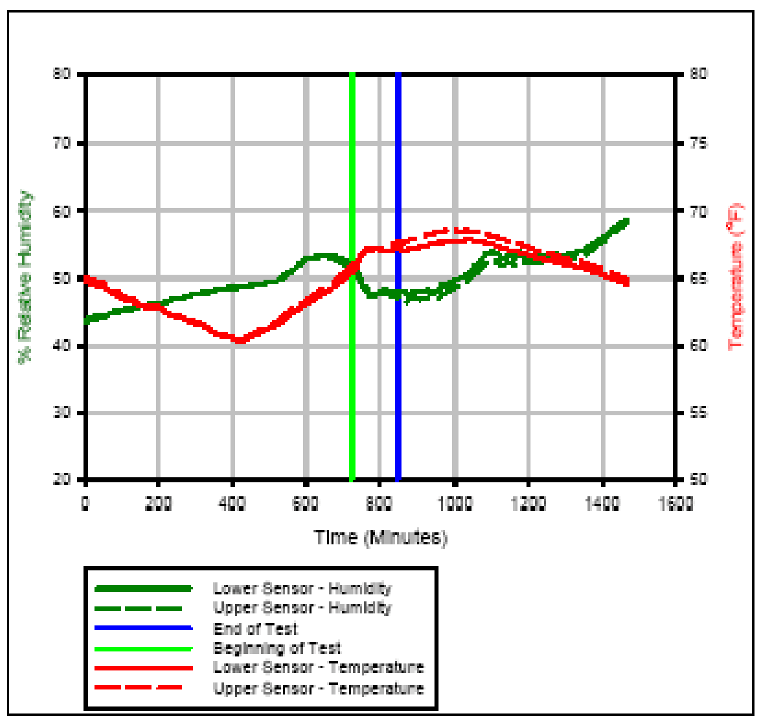
Panel 3 Loxon/Tyvek House Wrap with Sheathing Penetration



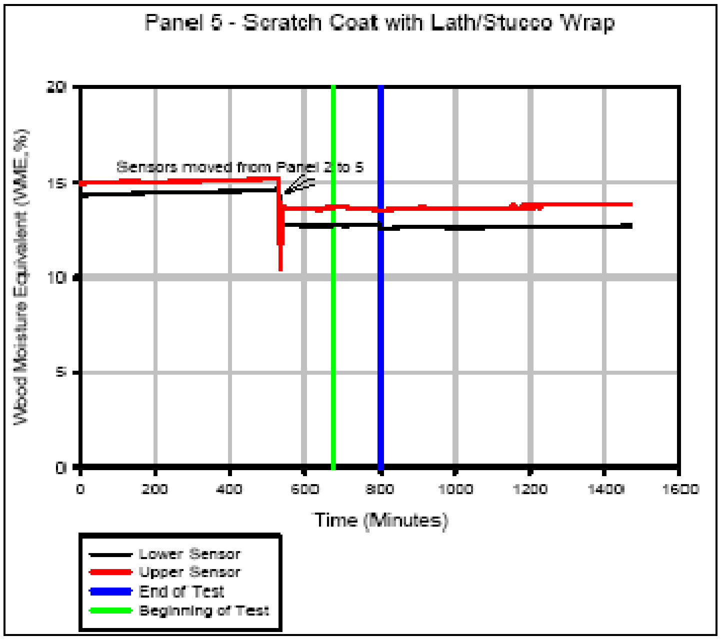


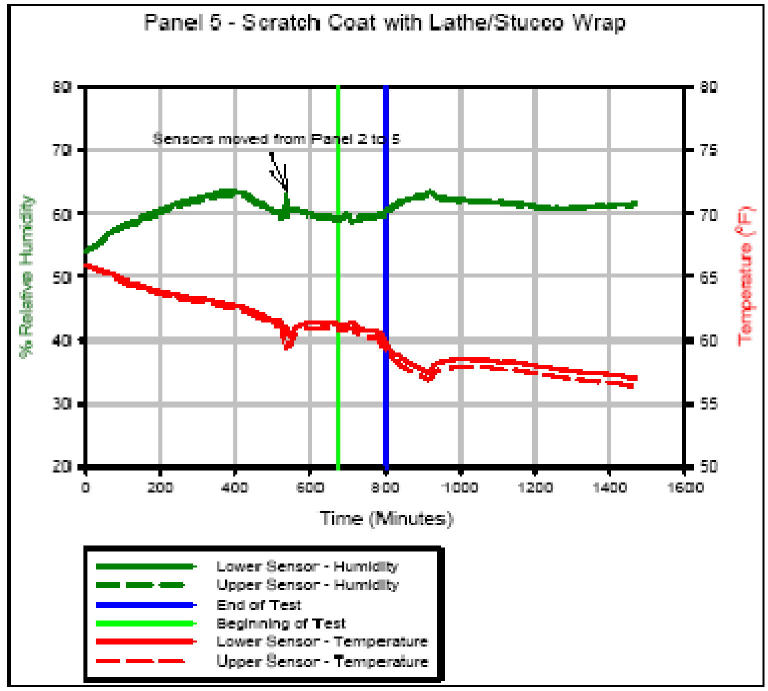
Panel 4 Scratch Coat with Lathe/Tyvek House Wrap with Sheathing Penetration



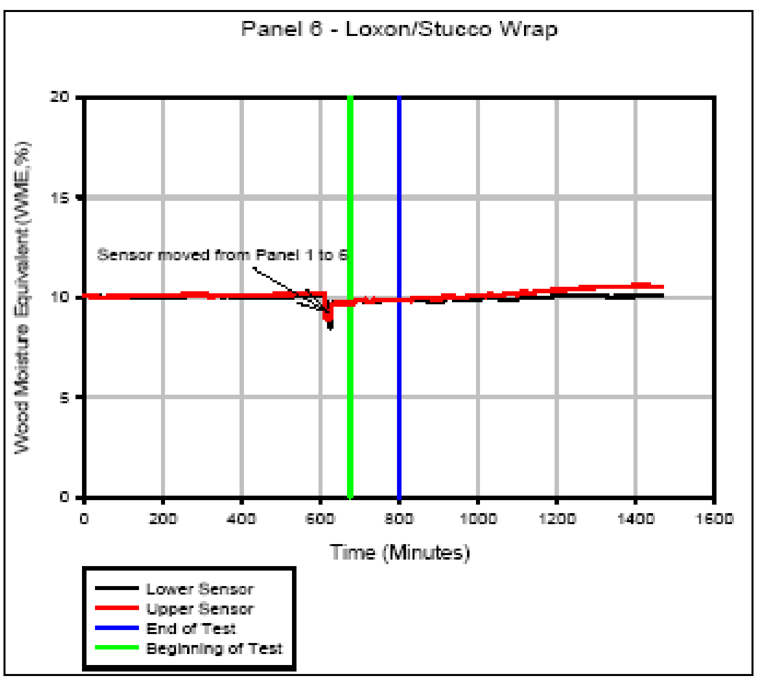


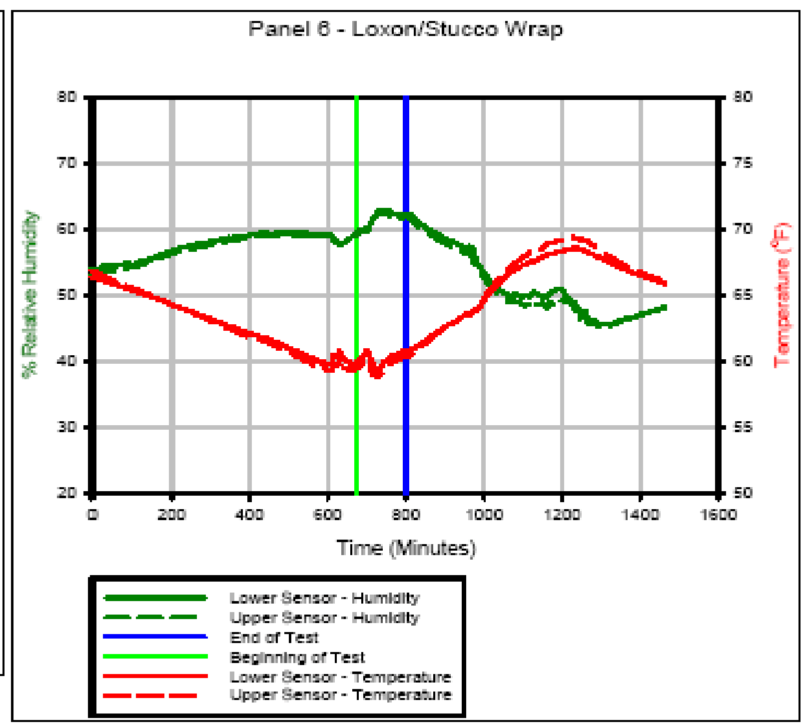
Panel 5 Scratch Coat with Lathe/Stucco Wrap





Panel 6 Loxon/Stucco Wrap





Attachment D

Water Penetration Panels (Photo 1)

Moisture Sensor (Photo 2)

Moisture Sensor (Photo 3)

Loxon Panel Drainage (Photo 4)

Test in Progress (Photo 5)