HYGROTHERMAL BUILDING ENVELOPE MODELING & ANALYSIS

G. Peter Vander Heide, AIA, LEED AP
Stephen Rymal, P.E. , Esq.

Hygrothermal

Hygro: moisture and humidity
Thermal: temperature

EIFS

Exterior Insulation and Finish System

Introduction

Building envelopes age and in due course they may require rehabilitation or retrofit to maintain effective serviceability.

At the same time, building construction technology and the materials used for construction have and will continue to change drastically over the years.

The chance to retrofit a building envelope offers a great opportunity to upgrade it for thermal (i.e. energy) and moisture performance.

These can be done by adding insulation, reducing air leakage, and improving the moisture control strategies that will enhance occupant comfort and durability of the building envelope.

However, to assess the extent to which this can be done and determine the best available methods to adopt are challenging tasks for building envelope designers.

Moisture Problems

- Mold, mildew and spore growth on both interior and exterior surfaces
- Wood rot and structural degradation
- Damage to interior and exterior painted surfaces
- Damage to carpeting and flooring
- Damage due to freeze/thaw expansion and contraction
- Visual discoloration and musty odors
- Insect infestation

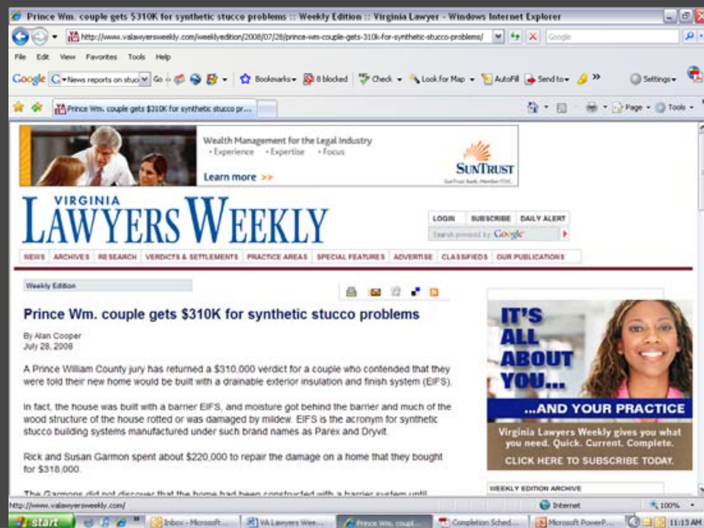
When should you use Hygrothermal Modeling?

- New Construction
- Renovation of existing construction
- Commercial Inspections
- Residential Inspections
- Real Estate Valuation
- Real Estate Sales
- Insurance Inspections and Loss Investigations – i.e. pre-existing conditions, damage due to water

Why should you use Hygrothermal Modeling?

- Despite the fact that manufacturers' subject their individual products to Building Code required testing, there are no Code required performance tests on Building Envelope systems as a whole.
- Individual products within traditional Building Envelope systems have changed over time and may no longer perform as they have in the past. For example, no lime in modern stucco, little asphalt in modern tar paper.
- Emphasis on insulation, super-insulation, spray foam and taping joints, and interior vapor barriers without understanding the importance of ventilation and drying of the envelope.

Litigation



Consumer Reports

Real Estate

ASHRAE (Dew Point) Analysis

These values are calculated based on the 1% ASHRAE Occurance Values. This means that only 1% of the total hours per year (or 1% of (24x365) = ~88 hours per year) where the ambient conditionws will exceed this value.

Summer Peak			Indoors		Outdoors				
	1% Occurrence Design Point	T (in) DB	75	T (out) DB	95	Dewpoint (out)	VP (out)	0.696	
	50% RH Indoor Design	T (in) WB	62.5	T(out) WB	76	Dewpoint (in)	VP (in)	0.437	
	RH Outdoors	RH	50		48.5				
Item No	Material Description	T - layer	ΔT - layer	R - layer	Thickness (Inches)	Conductivity	Vapour Permeance (Z)	Vapour Diffusion Resistance	
1	Indoor Air Layer	75.0	0.6	0.68	-		120		
2	Gypsum Wall Board	75.6	0.4	0.45	0.5	2.22	5.2		
3	Kraft Paper	76.0	0.1	0.06	0.04	0.005	0.3		
4	Fibreglass Batte	76.0	18.1	21	5.5	0.053	118		
5	Oriented Strand Board	94.1	0.6	0.685	0.5	1.37	1.16		
6	Kraft Paper	94.7	0.1	0.06	0.04	0.005	0.3		
7	Portland Cement Stucco	94.8	0.1	0.15	0.75	6.66	3.27		
8	Exterior Air Layer	94.9	0.1	0.11	0		1000		
				23.195	-		8.04		
Winter Peak									
	1% Occurance Design Point	T (in) DB	70	T (out) DB	15	Dewpoint (out)			
	30% RH Indoor Design	T (in) WB	53	T (out) WB	12.3	Dewpoint (in)			
Item No	Material Description	T - layer	ΔT - layer	R - layer	Thickness (Inches)	Conductivity			
1	Indoor Air Layer	70.0	-1.6	0.68	-				
2	Gypsum Wall Board	68.4	-1.1	0.45	0.5	0.9			
3	Kraft Paper	67.3	-0.1	0.06	0.04	0.005			
4	Fibreglass Batte	67.2	-49.8	21	5.5	0.053			
5	Oriented Strand Board	17.4	-1.6	0.685	0.5	1.37			
6	Kraft Paper	15.8	-0.1	0.06	0.04	0.005			
7	Portland Cement Stucco	15.6	-0.4	0.15	0.5	2.2			
8	Exterior Air Layer	15.3	-0.3	0.11	-				
				23.195					

Required Weather Data

hygIRC 1-D

- Year, Month Day
- Temperature (DB)
- Relative Humidity
- Wind Speed
- Wind Direction
- Solar Radiation
- Diffuse Radiation
- Reflected Radiation
- Rain
- Cloud Index

WUFI® PRO, 2D, Plus

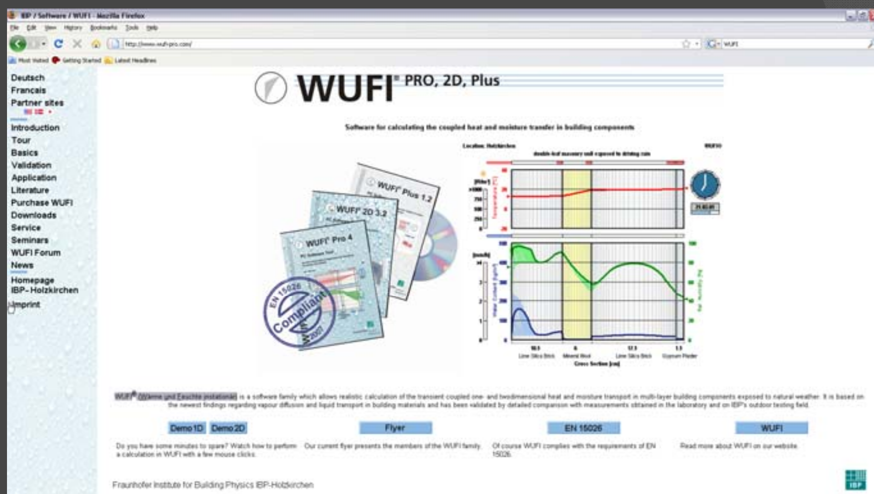
- Year, Month, Day
- Temperature (DB)
- Relative Humidity
- Wind Speed
- Wind Direction
- Solar Radiation
- Diffuse Radiation
- Reflected Radiation
- Rain
- Atmospheric Counterradiation

Material Properties Considered

- Bulk Density (lb/ft^3)
- Porosity (ft^3/ft^3)
- Specific Heat Capacity, Dry (Bth/lb ^{o}F)
- Thermal Conductivity, Dry (Bth/h lb ^{o}F)
- Permeability (Perm in)
- Moisture Storage Function (lb/ft^3) at %RH
- Liquid Transport Coefficient Suction
- Liquid Transport Coefficient Redistribution
- Thermal Conductivity, Moisture Dependent
- Permeability, Moisture Dependent

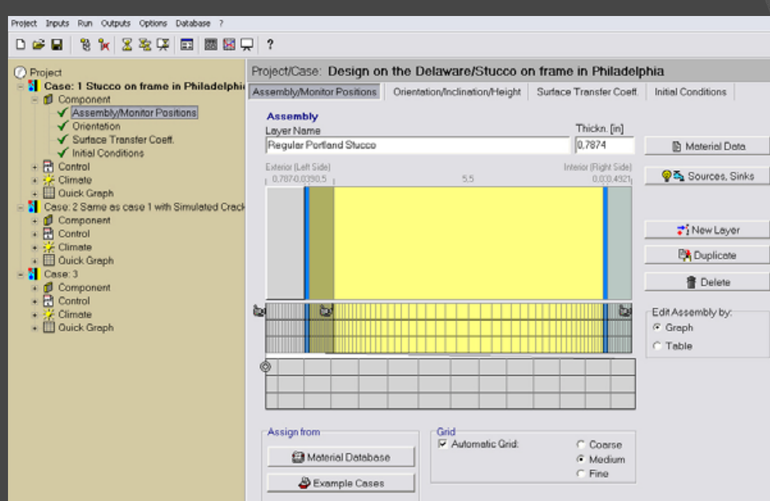
WUFI®

(Wärme und Feuchte instationär)



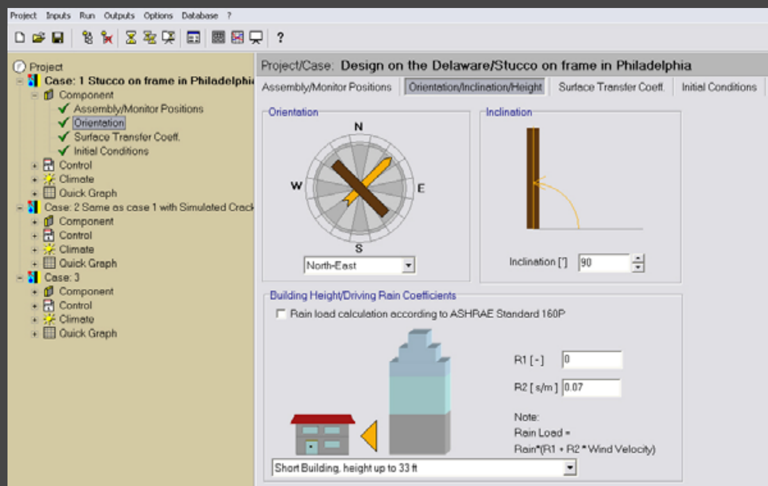
WUFI Case Development

Assembly



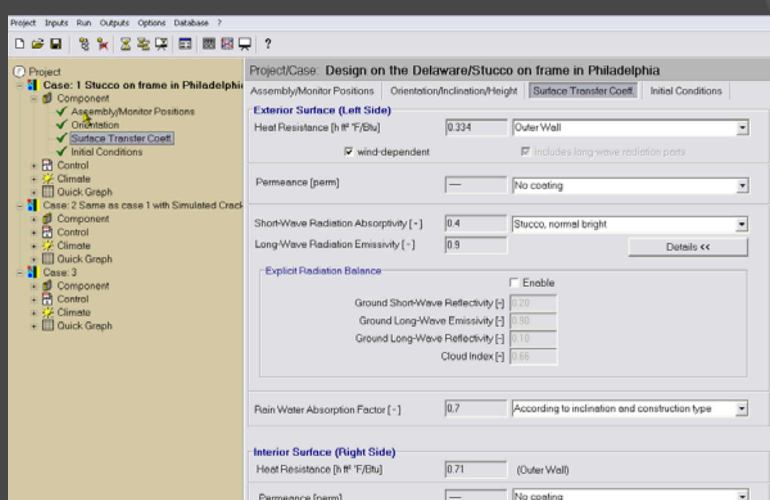
WUFI Case Development

Orientation



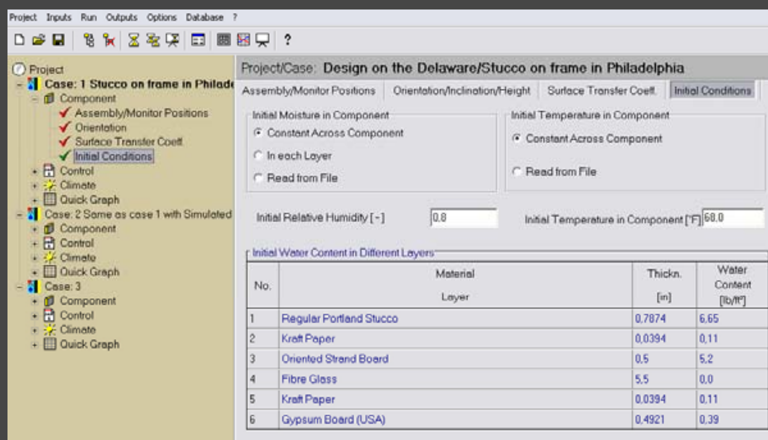
WUFI Case Development

Surface Transfer Coefficients



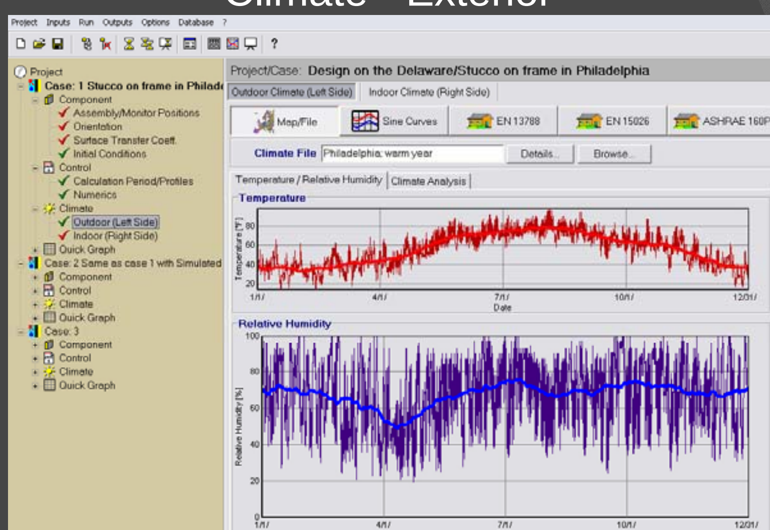
WUFI Case Development

Initial Conditions



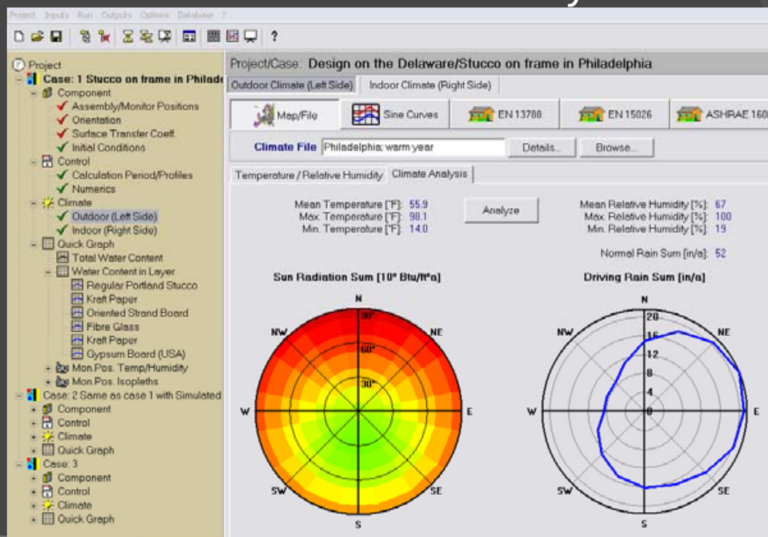
WUFI Case Development

Climate - Exterior



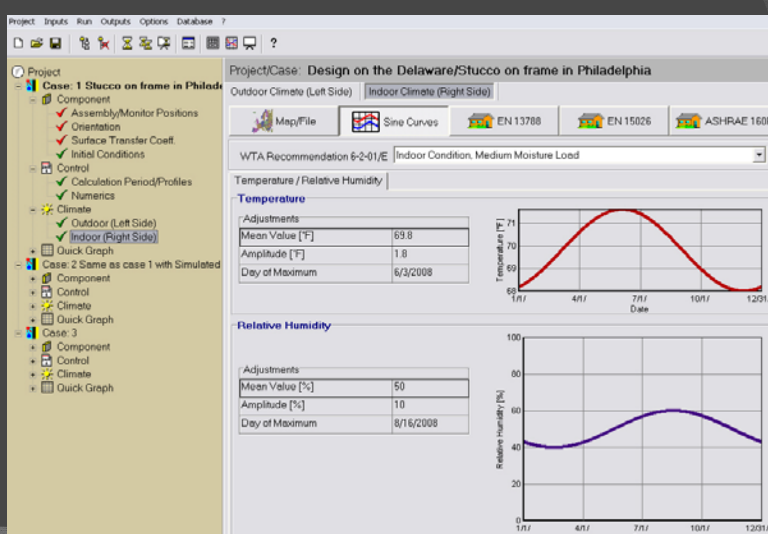
WUFI Case Development

Climate – Exterior Analysis

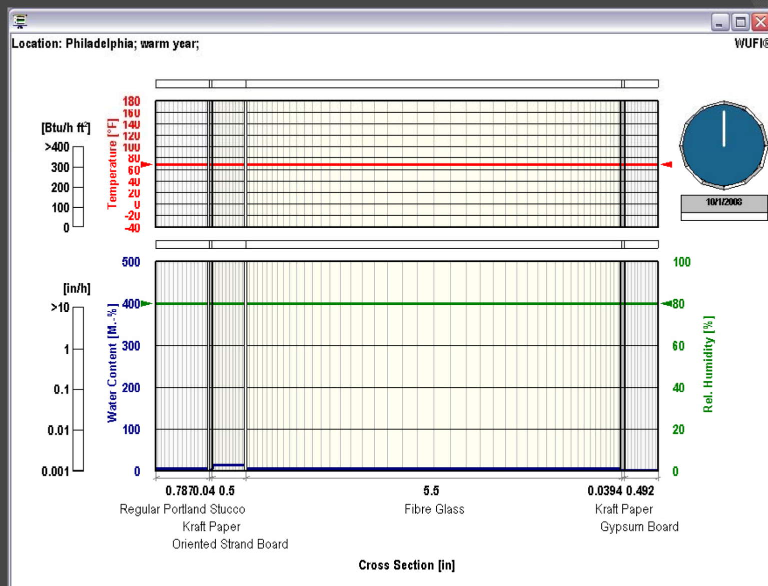


WUFI Case Development

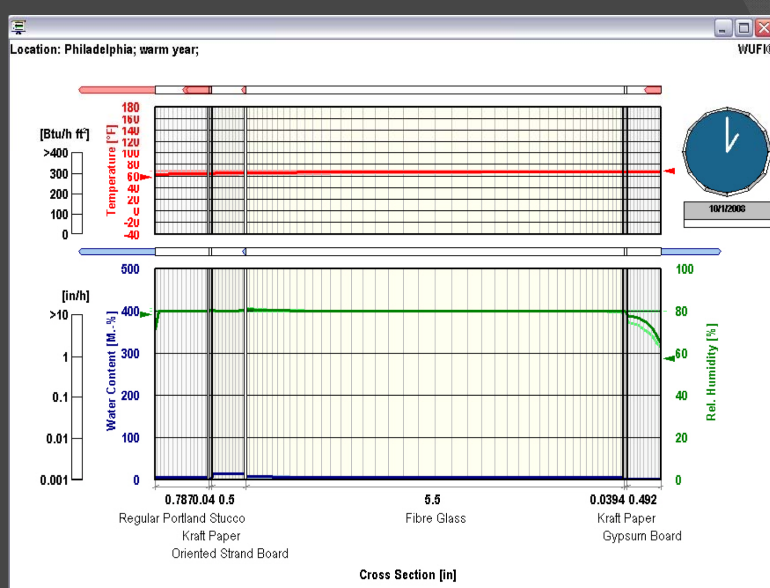
Climate - Interior



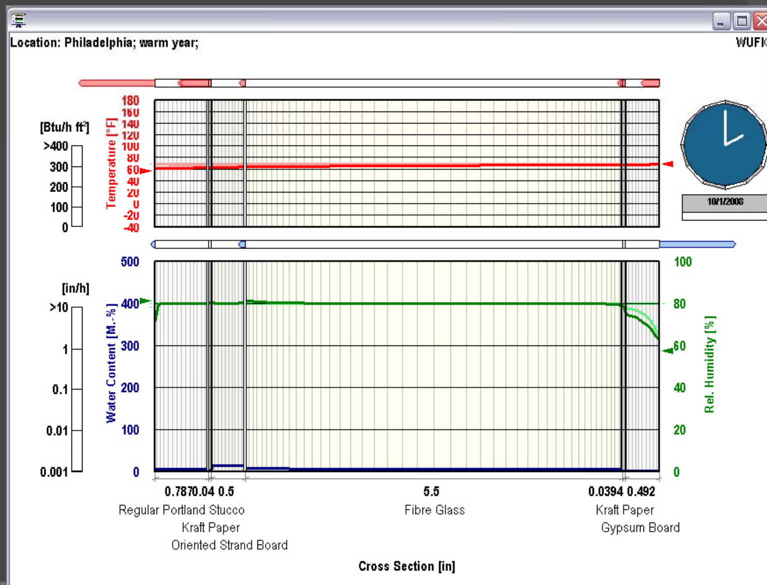
WUFI Output - Start



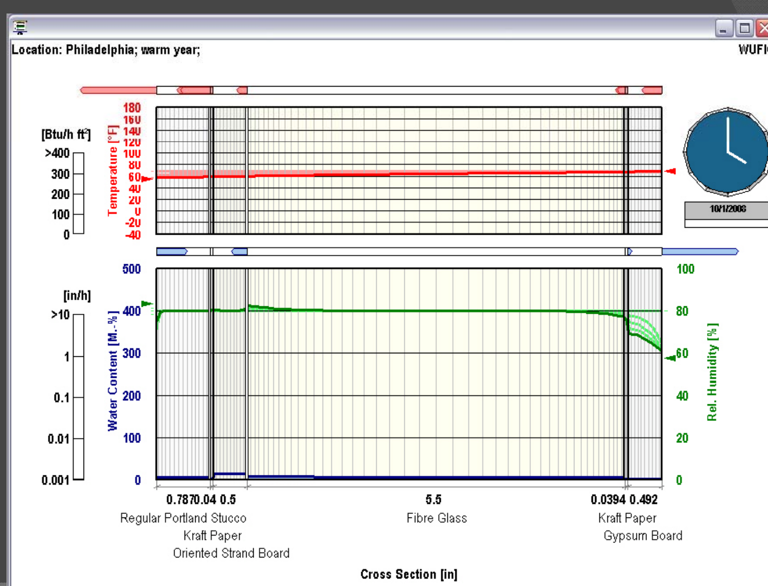
WUFI Output - + 1 hour



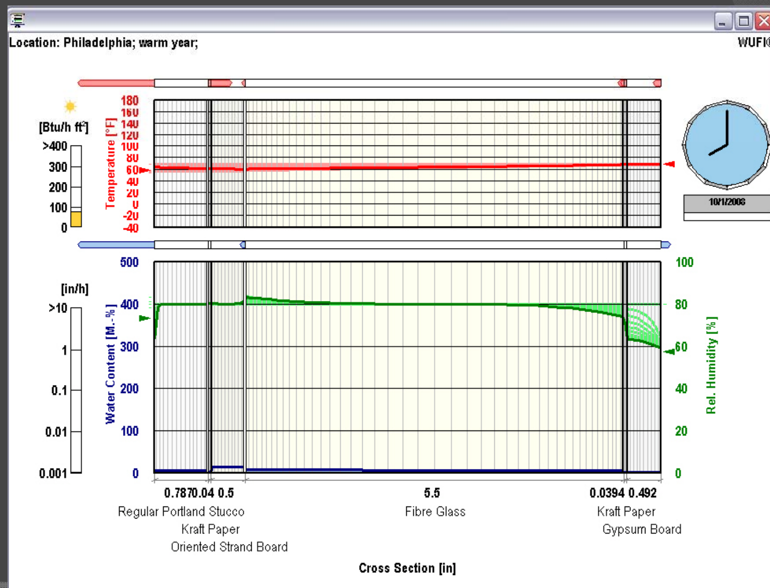
WUFI Output + 2 hour



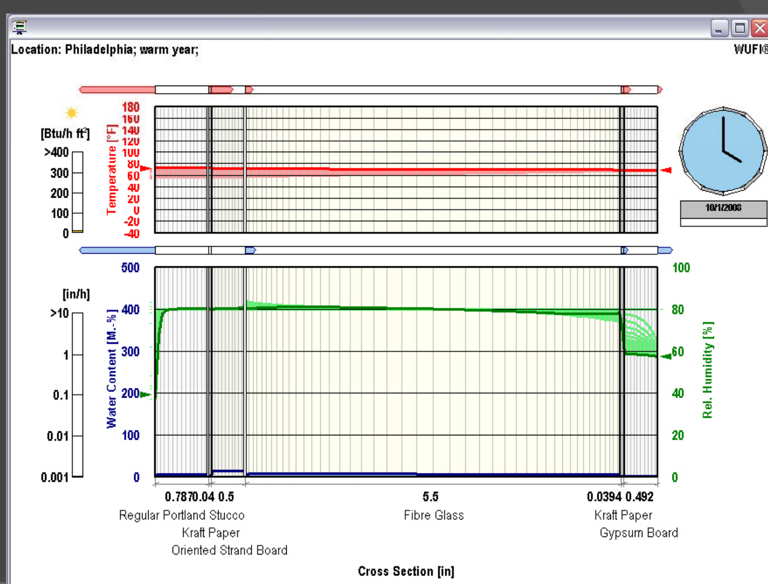
WUFI Output + 4 hour



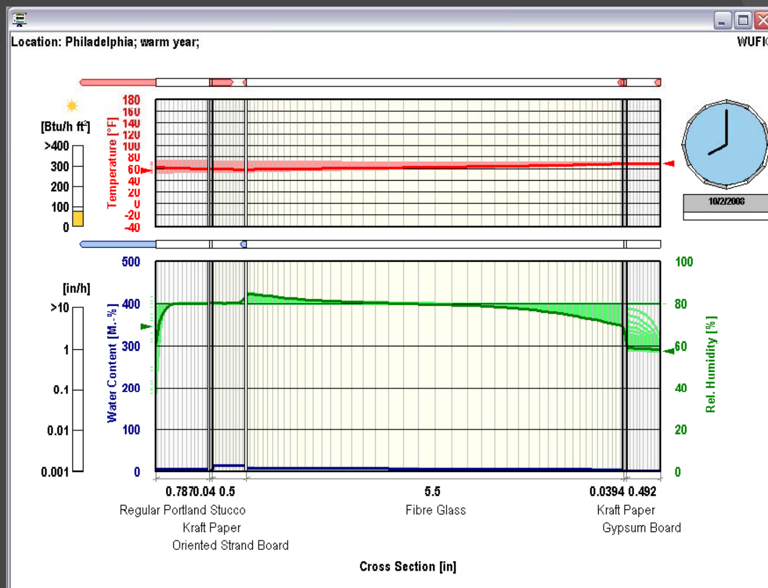
WUFI Output + 8 hour



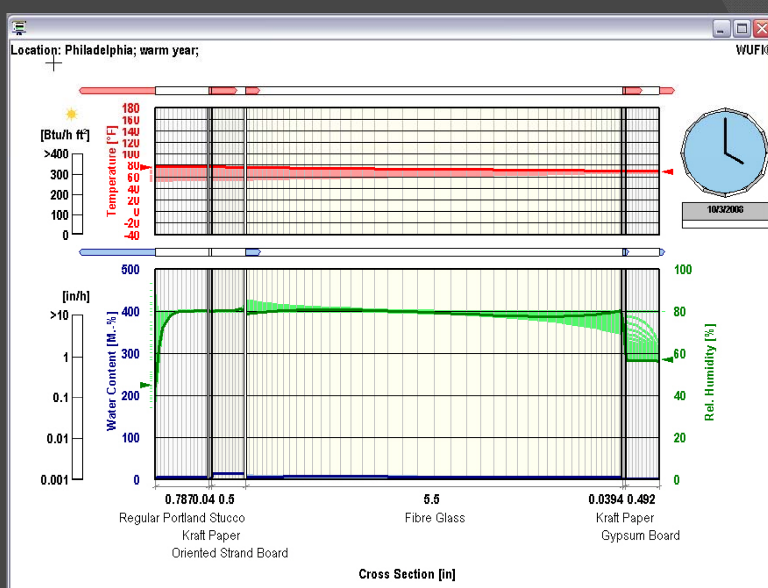
WUFI Output + 16 hour



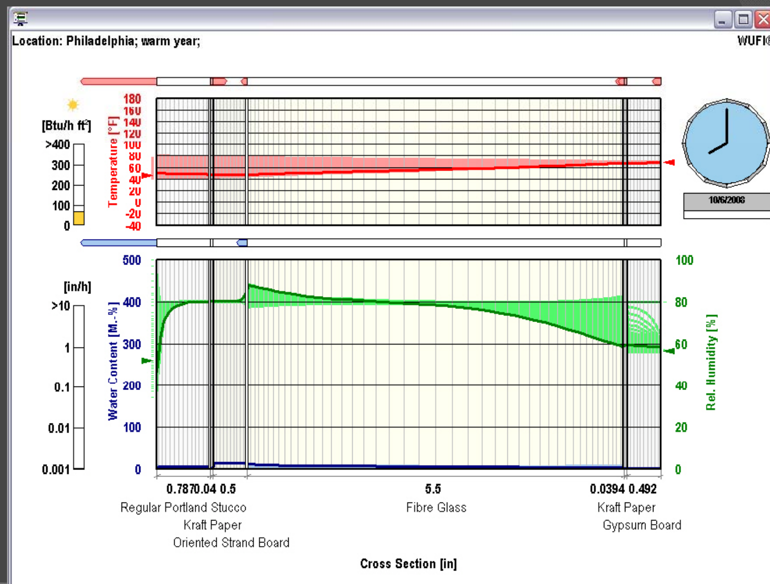
WUFI Output + 32 hour



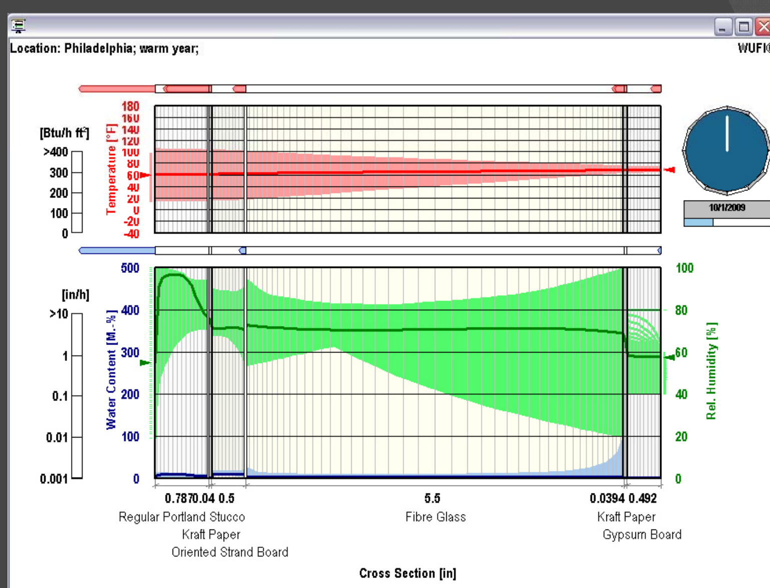
WUFI Output + 64 hour



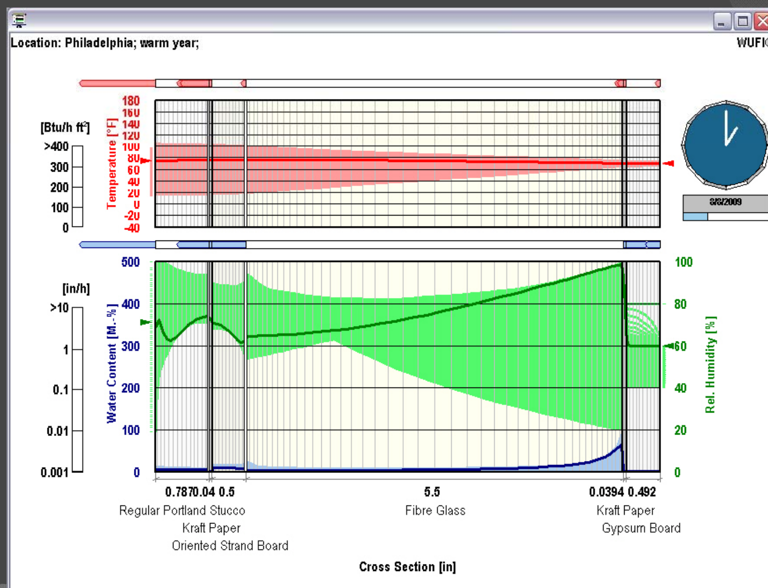
WUFI Output + 6 days



WUFI Output + 1 Year



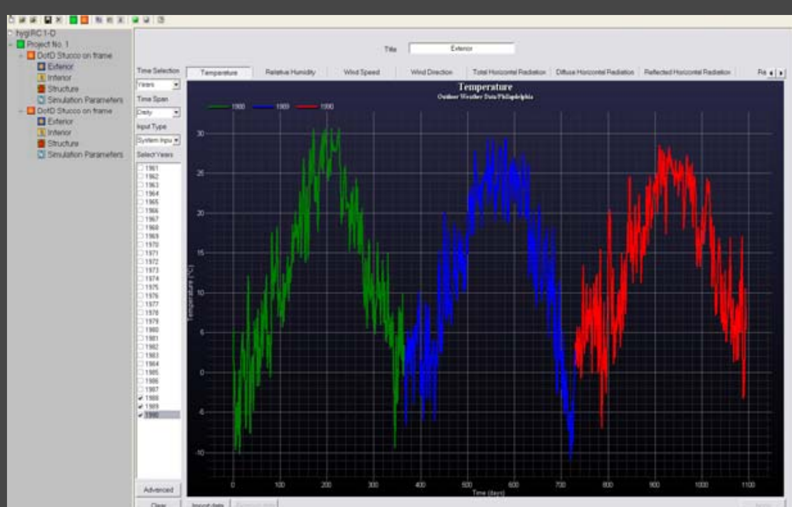
WUFI Output + 10 months



What is *hyg*IRC-1D?

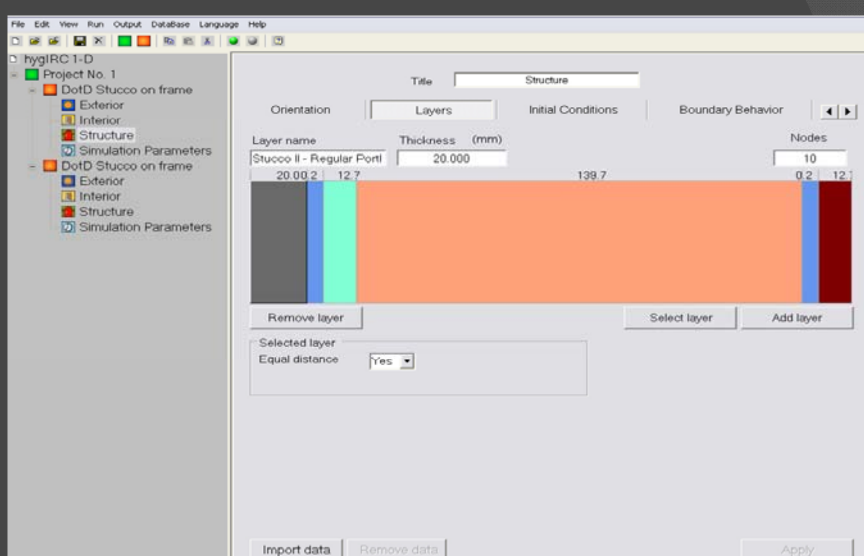
- an advanced one-dimensional hygrothermal modeling tool developed by the Institute for Research (IRC) at the National Research Council in Canada
- used to assess hygrothermal conditions in the envelope components of a wide range of building systems
- user – friendly and comes with a series of five (5) tutorials in *wmv* file format that can be viewed in streaming video or downloaded for later viewing. Each tutorial runs from 30 – 45 minutes in length.
- versatile and can analyze residential as well as high rise building envelopes
- contains a climate data base for the past 30-40 years of hourly weather data for 19 Canadian and 6 US cities; a materials database of 80 common construction materials as measured at the IRC; and a benchmarked *hyg*IRC solver

Exterior Weather Data

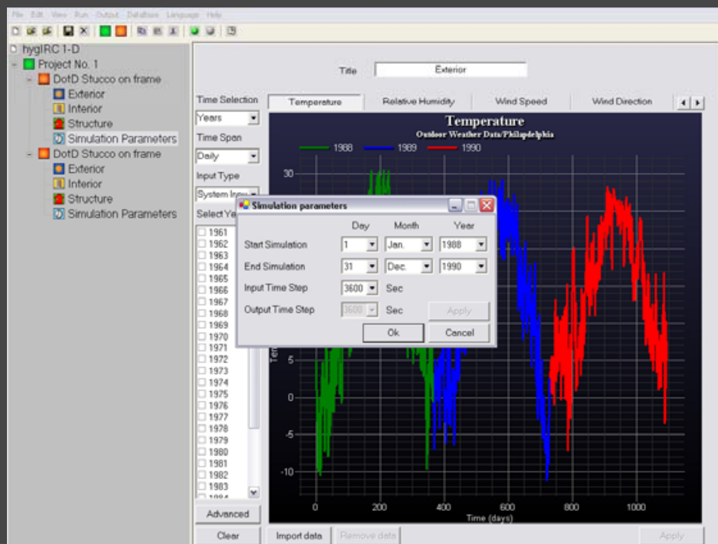


Interior Design Conditions

Envelope Structure

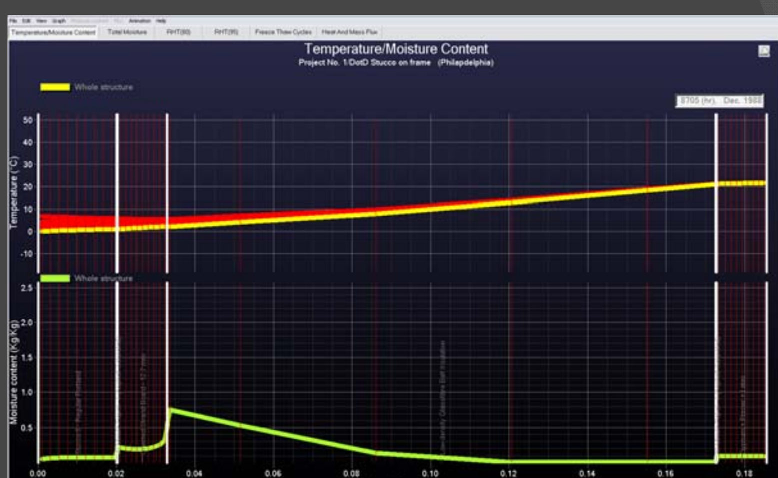


Simulation Parameters for Analysis



Analysis Output:

Temperature & Moisture Content



Total Moisture Content

Case Study:

Side of an EIFS Chimney

Case Study:
Side of an EIFS Chimney

Detail where water is concentrated

Half of highlighted area will drain past this detail

WUFI shows failure of OSB layer with only slight increase in moisture load

Case Study:
Side of an EIFS Chimney

Actual condition behind the EIFS

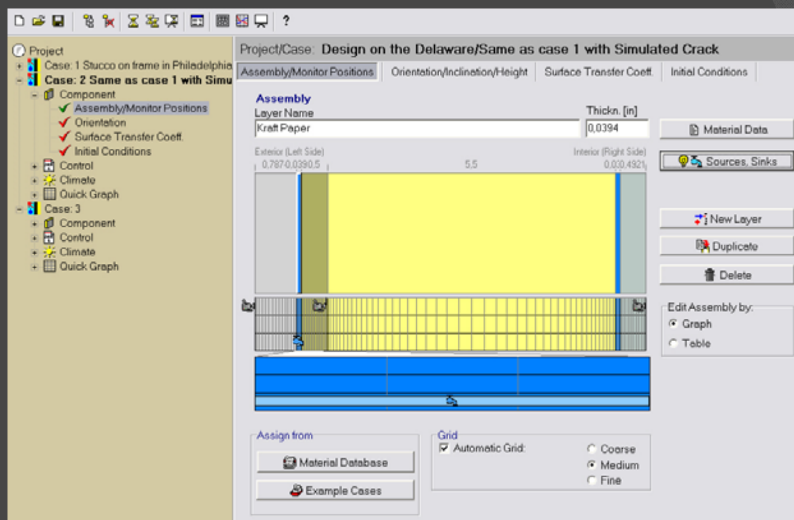
Case Study: Side of an EIFS Chimney

- Isn't something similar happening at lower window corners?

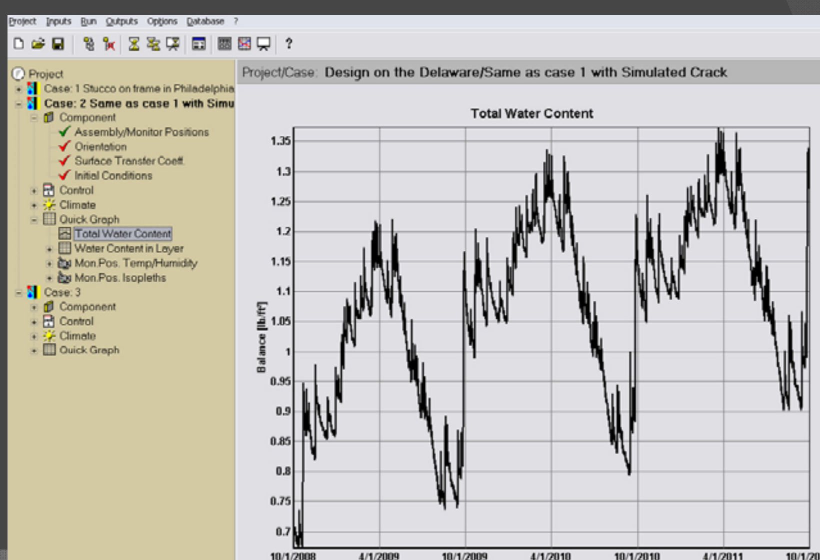
Case Study: Side of an EIFS Chimney

- Glazing of any size collects wind driven rain
- Hydrology demands a time delay before run off reaches bottom of window
- Bottom of window will be wetter longer than rest of wall
- This may be as big an explanation for problems at window sill corners as leaky windows

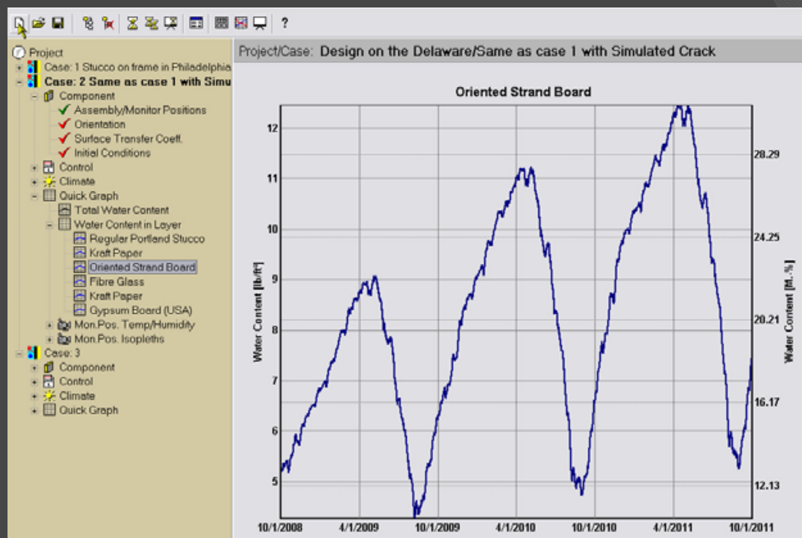
Case Study: Simulated Crack in Stucco



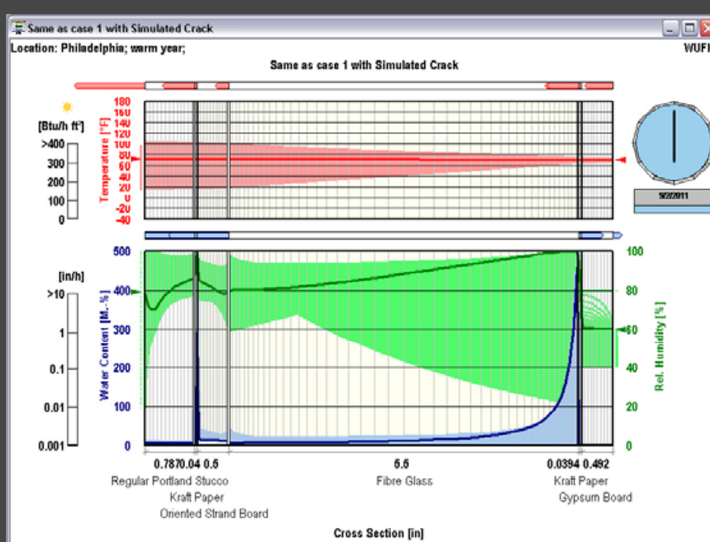
Case Study: Simulated Crack in Stucco



Case Study:
Simulated Crack in Stucco



Case Study:
Simulated Crack in Stucco



Current Pennsylvania Law

- The Pennsylvania Supreme Court recently added the Keystone State to the growing list of states that have suggested the economic loss doctrine is a viable theory of law, but then proceeds to find that the negligent misrepresentation exception is a viable means to avoid the doctrine. The opinion was handed down on January 19, 2005, in the case of *Bilt-Rite Contractors, Inc. v. The Architectural Studio*, 866 A.2d 270 (Pa. 2005).

Bilt-Rite v. TAS

- The Pennsylvania Supreme Court's opinion acknowledged that prior case law had held that a contractor cannot prevail against an architect for economic damages suffered as a result of negligence in drafting specification, absent privity of contract between the contractor and the architect
- The court noted that *tort law*, unlike *contract law*, was not generally intended to compensate parties for losses suffered as a result of a breach of duties, which are assumed only by agreement. To recover in tort there must be a *breach of duty of care* imposed by law and a resulting injury.

Bilt-Rite v. TAS

- This case was before the court as a matter of first impression. The court identified the issue before it as whether a building contractor may maintain a negligent misrepresentation claim against an architect for alleged misrepresentations in the architect's plan for a public construction contract where there is no privity of contract between the architect and the contractor, but the contractor reasonably relied on the misrepresentations in submitting its winning bid, and consequently suffered purely economic damages, as a result of that reliance.