USING TOOLS TO PREDICT AND RESOLVE MOISTURE AND MOLD PROBLEMS IN BUILDING ENVELOPES

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WHY HYGROTHERMAL RESEARCH?

- “Moisture Damage Contributes to 90% of All Building and Building Material Failures” (ASHRAE)
- “Moisture Leading Cause of Building Problems Costing More Than $9 Billion Annually in U.S.” (ASTM)
- “Moisture Will Replace Asbestos as the Most Frequently Mentioned Topic in Building Litigation” (C. Gaal, NJ Investigation Commision Counsel)

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AUSTIN, June 27 - Mold is showing up in more homes and buildings in Texas than ever before. In many cases the mold is at toxic levels.

THOUSANDS OF PEOPLE have lost their homes, their health and even their life-savings because of mold. Many blame their losses on insurance companies that will not cover mold contamination.

Tuesday hundreds of homeowners told the state's insurance commissioner just that.

Mostly homeowners filled the auditorium, but insurance company representatives, contractors and consumer groups were also there. All of them pointed fingers at who they think is responsible for mold contamination and its effects.

Texas Insurance Commissioner Joe Montemayor set up the hearing of a request from Farmer's Insurance Company to exclude mold coverage altogether from home insurance policies.

The commissioner will make a decision regarding that request, but not before getting input from all sides.

"Possible results of micro toxin exposure can include effects on the vascular system, digestive system, respiratory system, nerve system and immune systems," Kay Soper with the Texas Department of Health said.

"I lost my home to stachybotris mold, but the bad thing is I almost lost my daughter," Homeowner Alda Brunson said.

"There are no state or federal statutes or regulations regarding molds in a home environment. There are no standards promulgated by the EPA. There are no standards promulgated by the Texas Department of Health," Tom Rogers with Farmer's Insurance said.

Currently home insurance policies in Texas only cover mold if it results from other damages like water leaks. The number of water damage claims resulting in mold contaminations have skyrocketed in Texas within the last two years.

No decision was made at the hearing.

98°
HIGH 100°
LOW 76°
MOSTLY SUNNY

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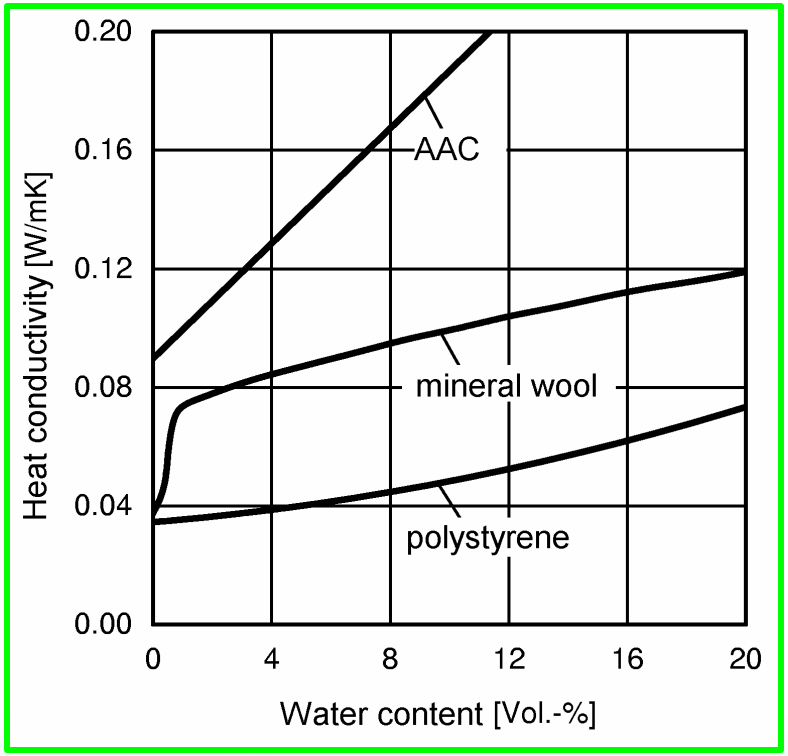
MOISTURE AND BUILDINGS

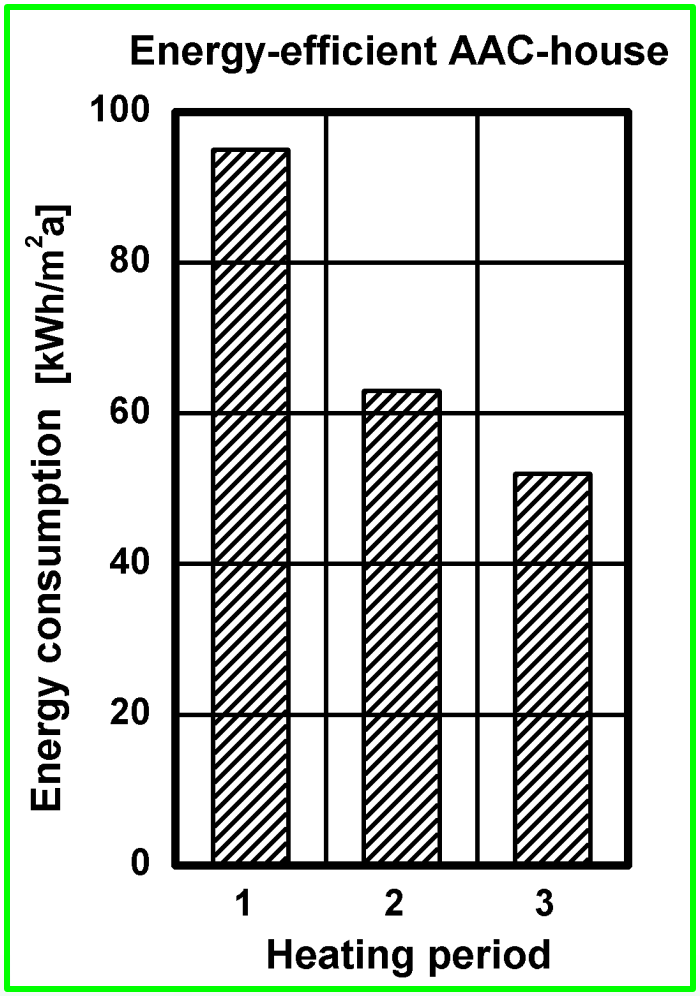
- Moisture Involved in Almost All Building Envelope Performance Problems
  - Energy Inefficiency
  - Mold (IAQ)
  - Corrosion
  - Wood Rot
  - Termites
  - Staining

MOISTURE EFFECTS

Increase in Heat Transmission

- Influence on Thermal Conductivity
- Latent Heat Effects





MOISTURE EFFECTS

Visual Degradation

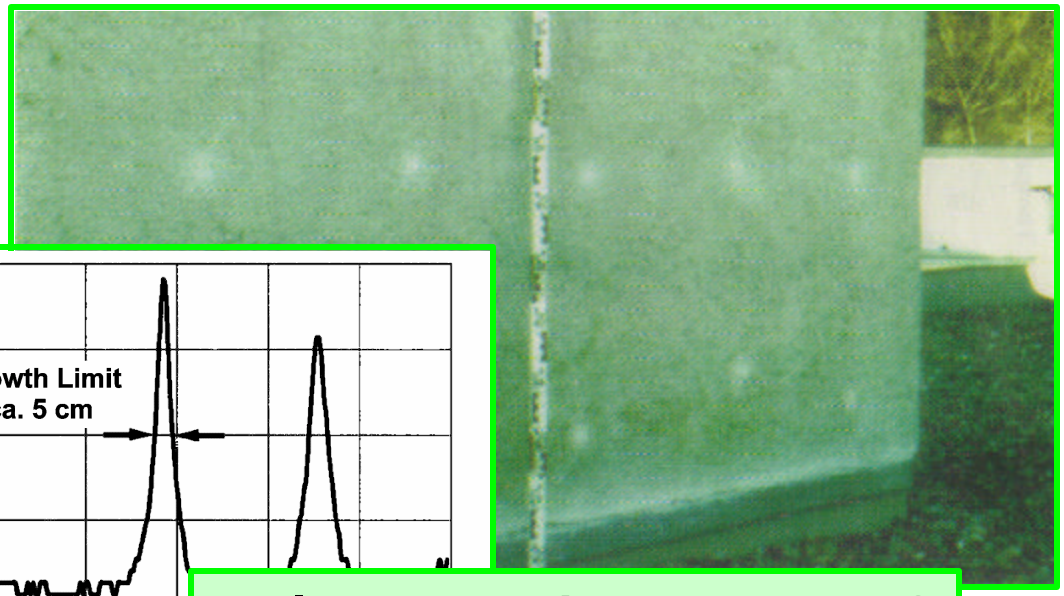
- Soiling and Staining

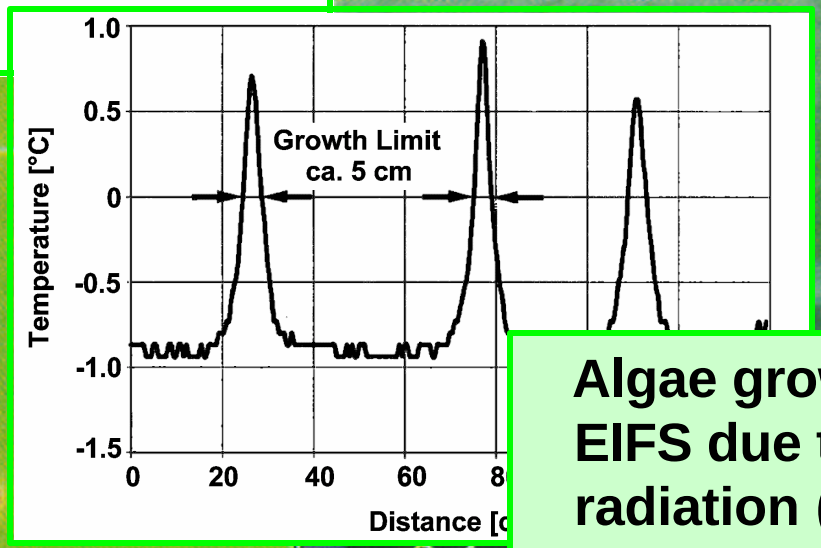
Outlining of the concrete structure beneath the plaster in a church due to differences in hygrothermal surface conditions (fogging)

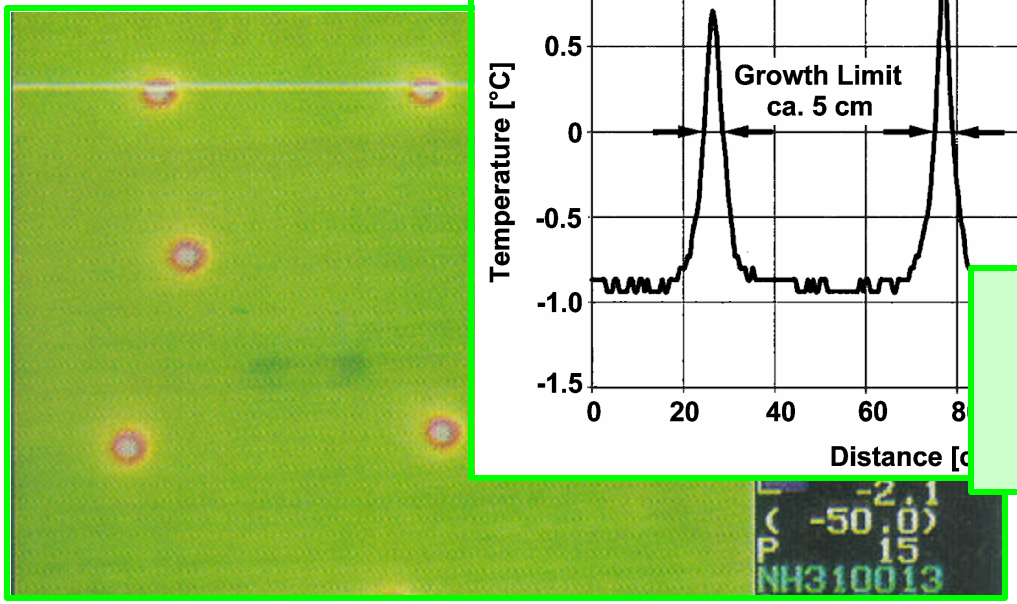
MOISTURE EFFECTS

Visual Degradation

- Soiling and Staining
- Microbial Growth







Algae growth on stucco of EIFS due to night time sky radiation (overcooling)

MOISTURE EFFECTS

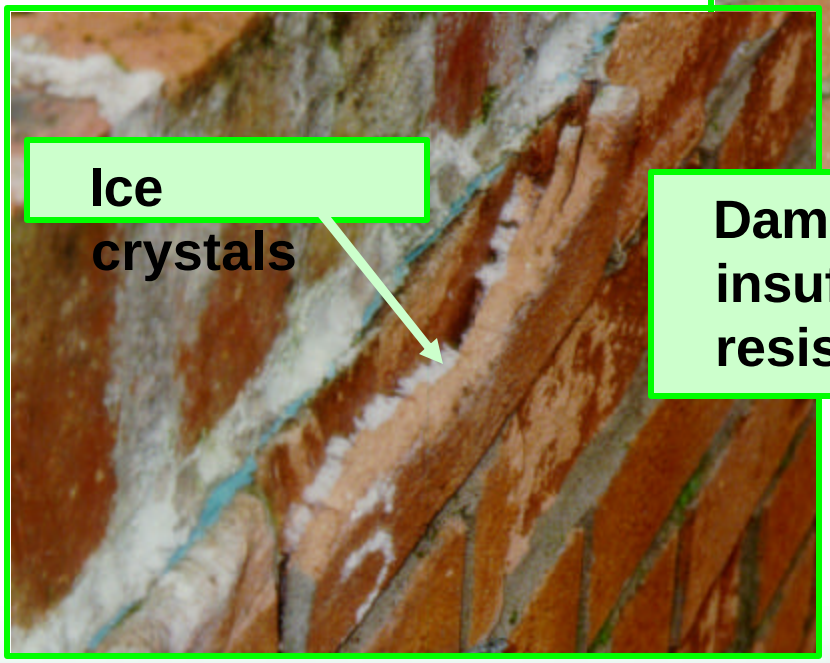
Visual Degradation

- Soiling and Staining
- Microbial Growth
- Salt Efflorescence

Lime efflorescence from mortar joints in brick veneer

Damage Caused by Elevated Water Content

- Freezing

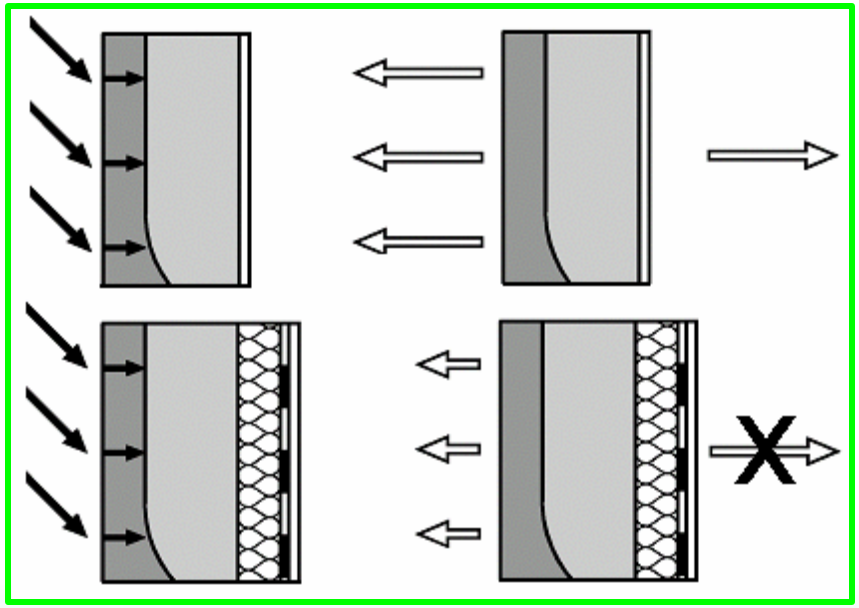


Damage due to insufficient frost resistance

Damage Caused by Elevated Water Content

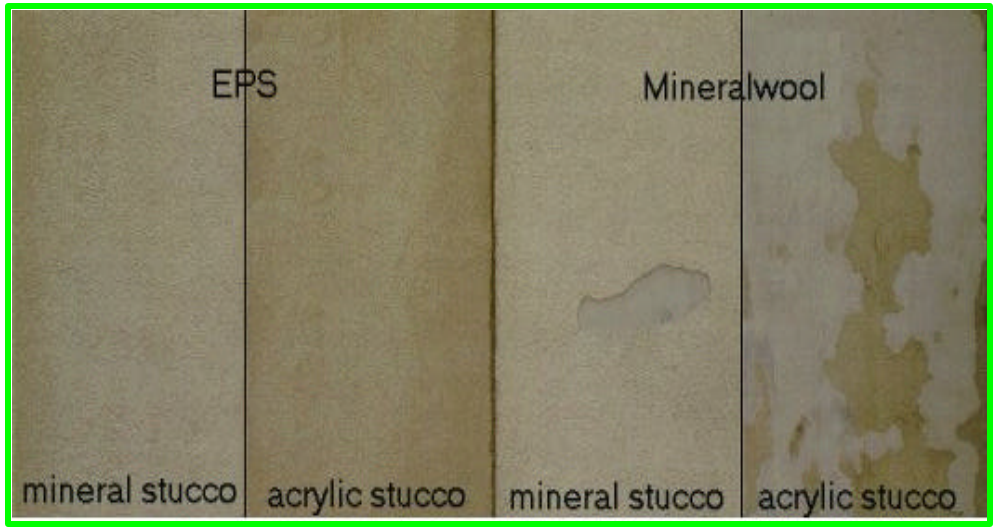
- **Freezing**

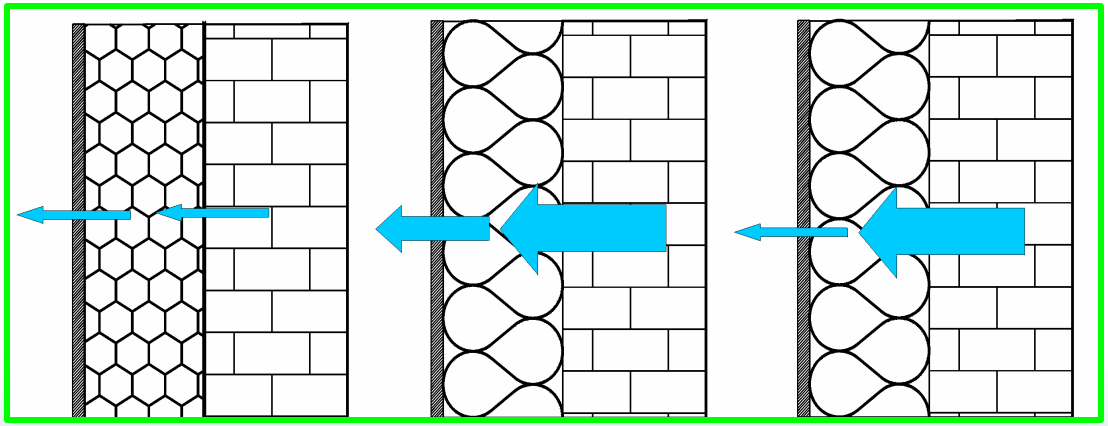
Frost damage at stucco facade after applying interior insulation



Damage Caused by Elevated Water Content

- **Freezing**



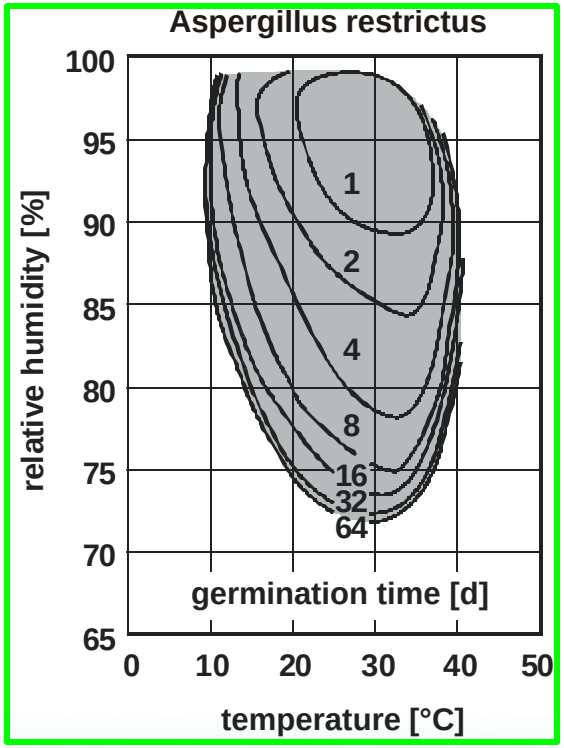


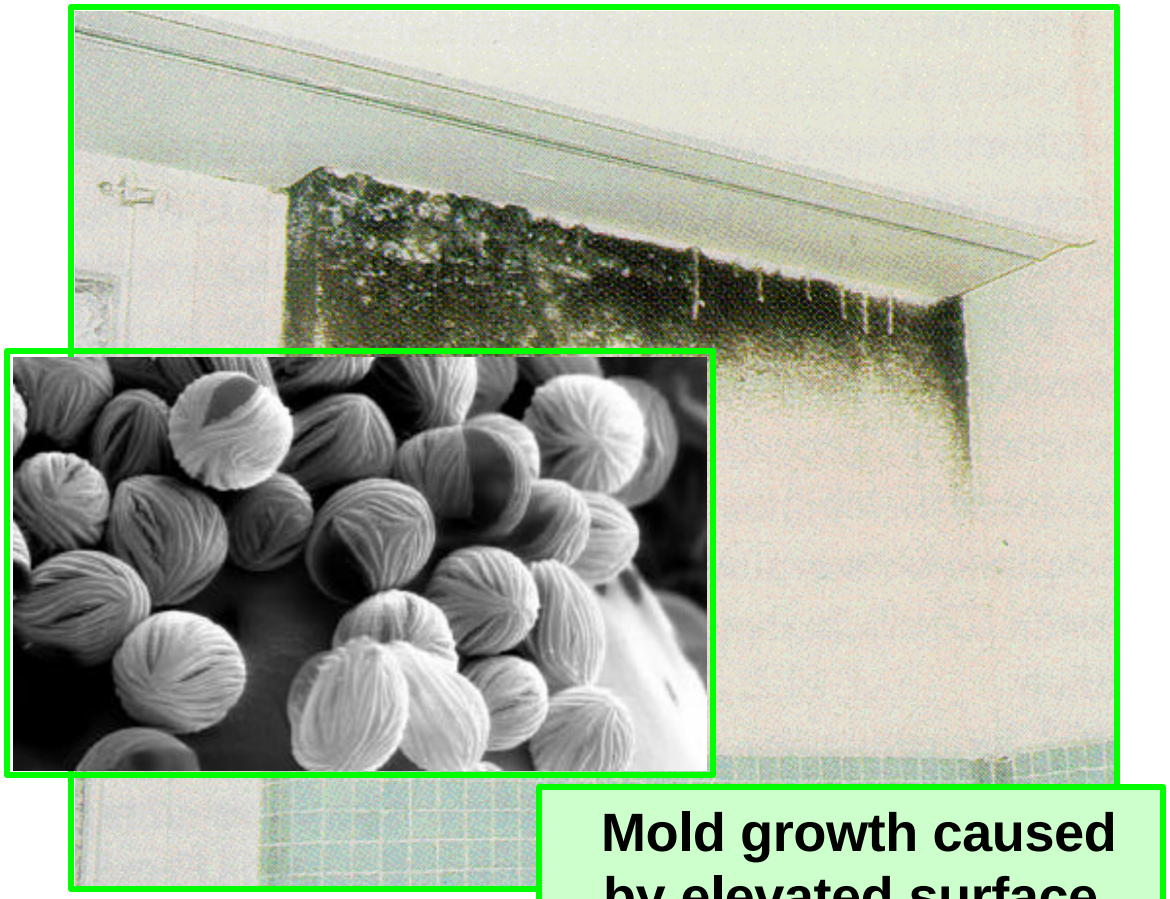
Frost damage to EIFS on moist masonry

MOISTURE EFFECTS

Health Aspects

- Air Quality





Mold growth caused by elevated surface humidity

MOISTURE EFFECTS

Health Aspects

- Air Quality

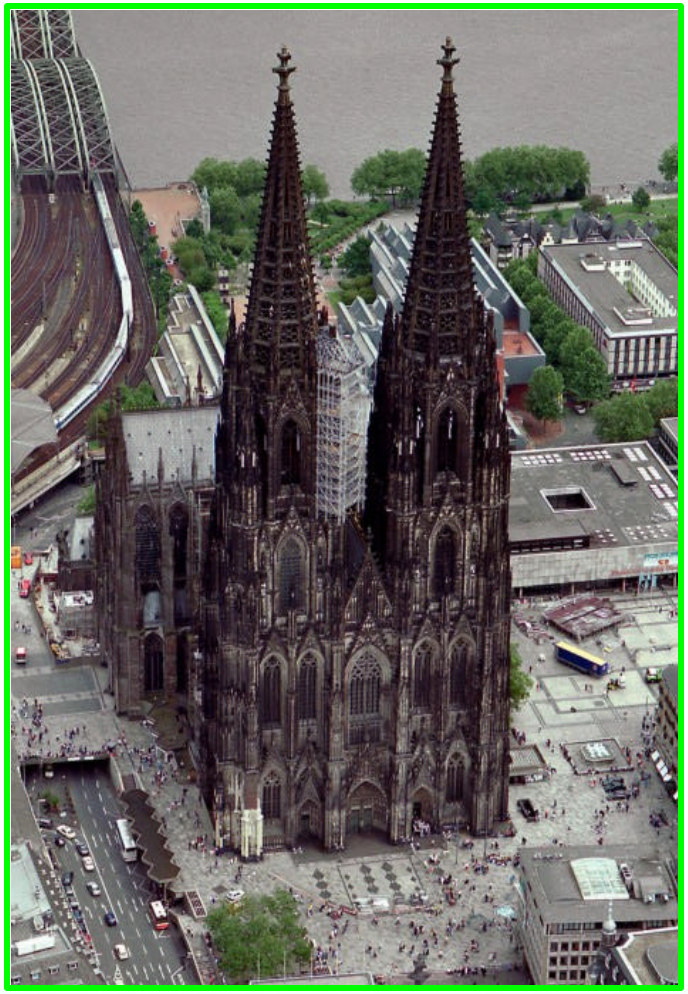
Microbial growth behind vinyl wall paper (Florida)

Ref.: Joe Lstiburek

MOISTURE ASSESSMENT

In-Situ Examination

- **Unique Situation; Generalization Usually Not Possible**
- **Wide Variation of Influences**



MOISTURE ASSESSMENT

Field and Lab Tests

- **Realistic, but Expensive**

MOISTURE ASSESSMENT

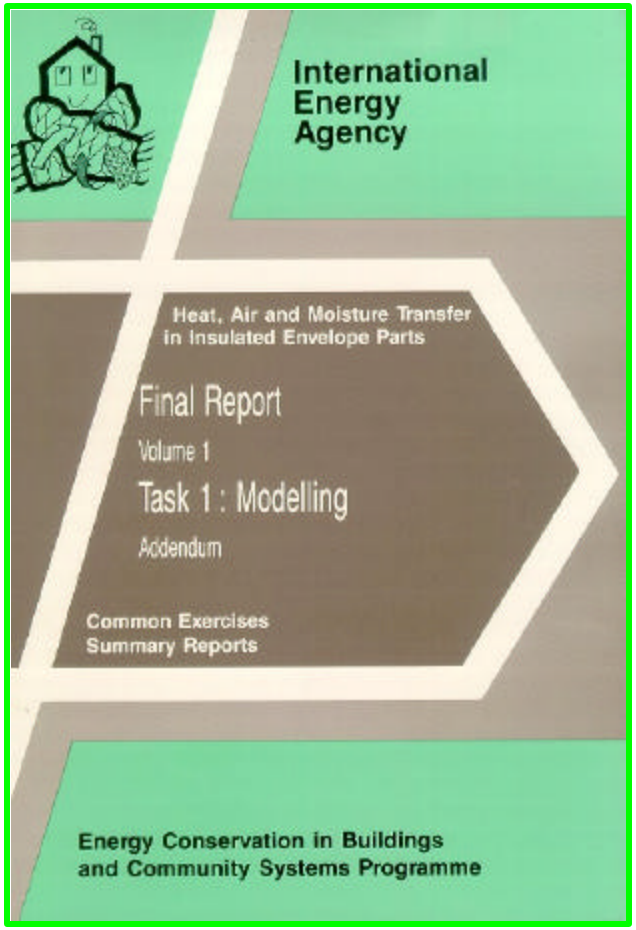
Field and Lab Tests

- Comparability (Boundary Conditions Difficult to Define)
- Limited Transferability to Different Climates

IBP outdoor test site in German Alps

Andre's Beach in Hawaii

HYGROTHERMAL MODELS



Type	Transport Phenomena	Steady state	Transient	Number of Models
1	- Heat conduction - Vapor diffusion	X X		3
2	- Heat conduction - Vapor diffusion - simplified capillary flow	X X X		2
3	- Heat transport - Vapor diffusion		X X	1
4	- Heat transport - Vapor diffusion - Liquid transport		X X X	17
5	- Heat transport - Convection	X	 X	3
6	- Heat transport - Vapor diffusion - Convection	X X X		2
7	- Heat transport - Vapor diffusion - Convection	X X	 X	1
8	- Heat transport - Vapor diffusion - Convection		X X X	4
9	- Heat transport - Vapor diffusion - Liquid transport - Convection		X X X X	4

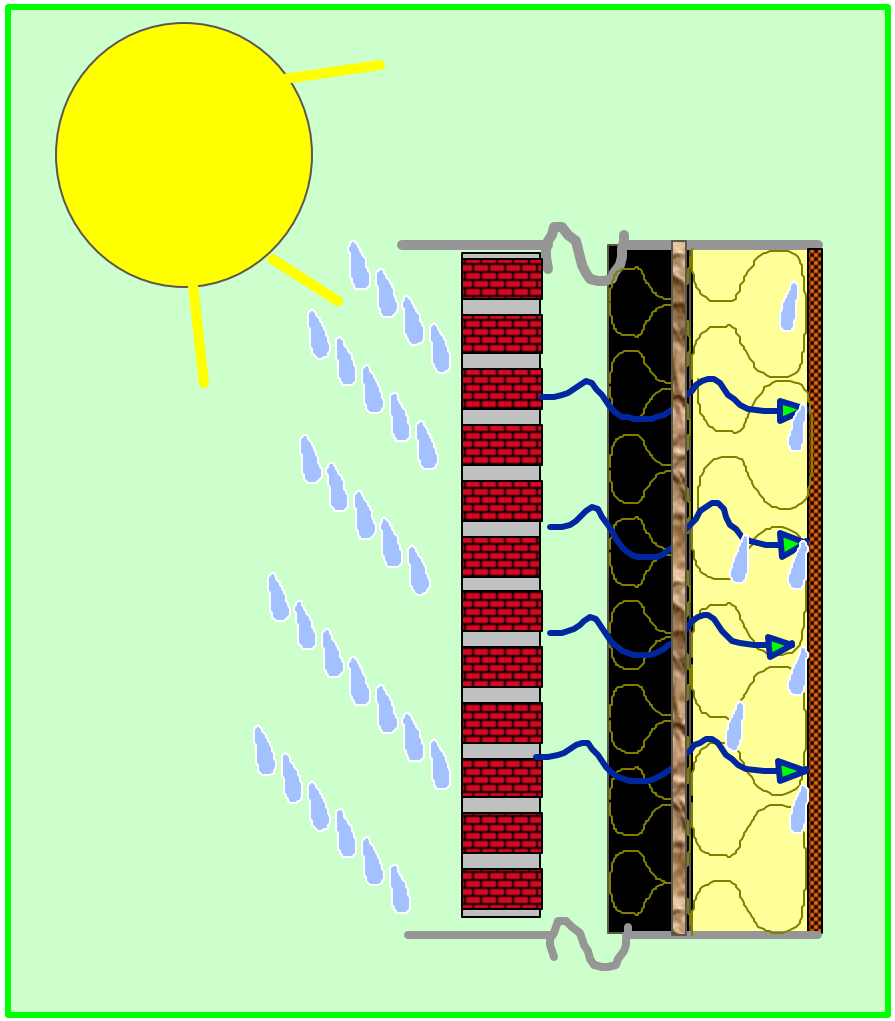
IEA Annex 24 - 14 countries - 37 models

Limitations of Models

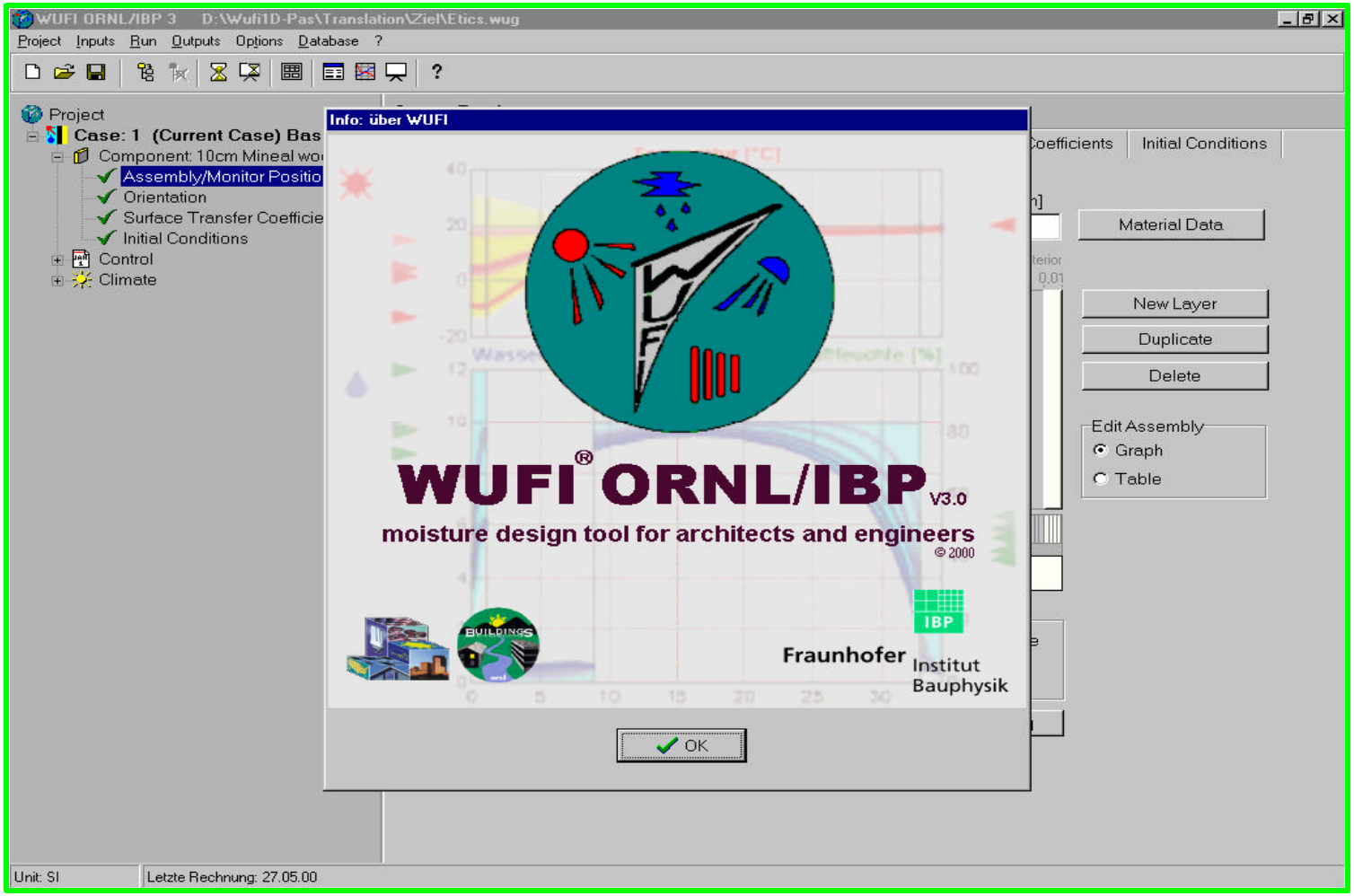
Every model has limitations. The user must be aware of what the model can and cannot do.

- Multi-Dimensional Structures
- Special Transport Phenomena (e.g. Convection)

SIMULATING IDEAL VS. REAL SYSTEMS



HYGROTHERMAL MODEL AVAILABLE



www.ornl.gov/btc/moisture

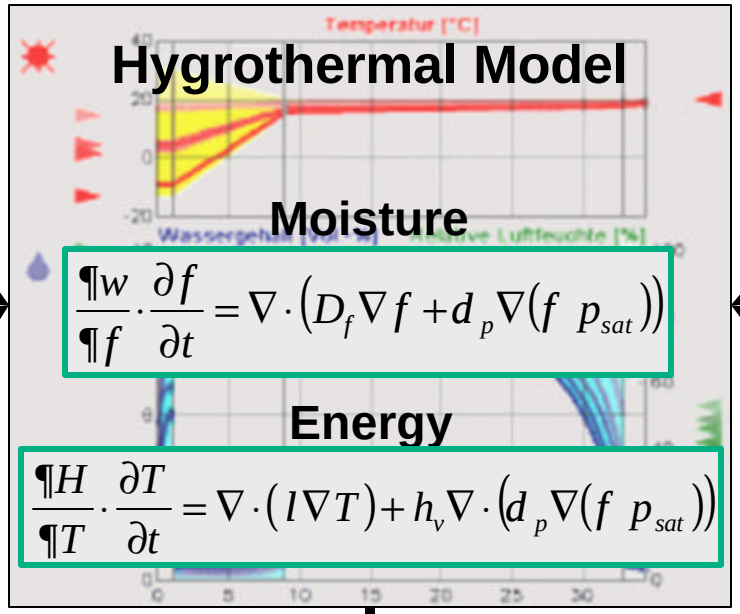
WUFI ORNL-IBP

Construction

Material Properties

Climate

Boundary Conditions



Hygrothermal Model

Moisture

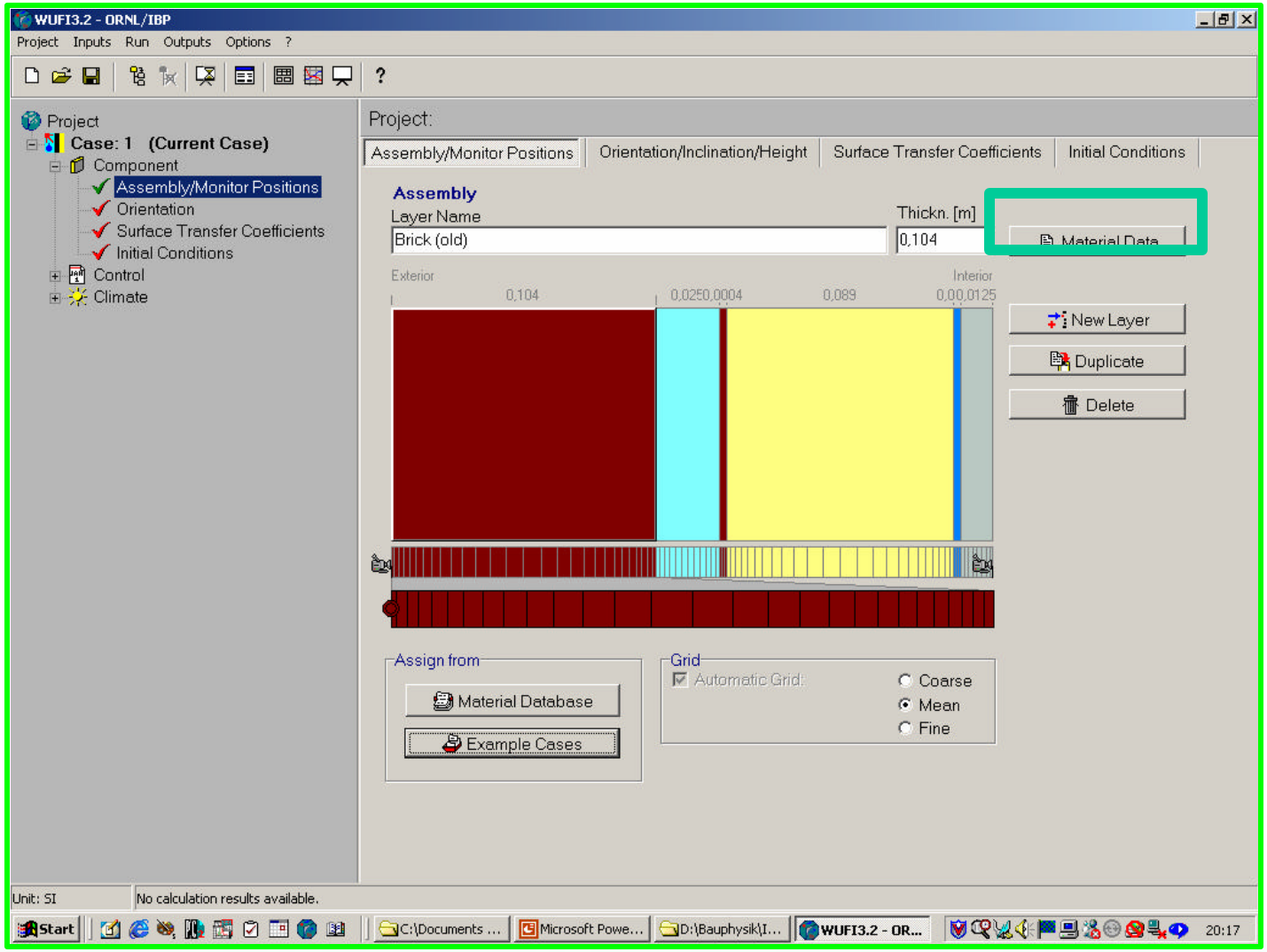
$$\frac{\partial w}{\partial f}\cdot\frac{\partial f}{\partial t}=\nabla\cdot\left(D_f\nabla f+d_p\nabla\left(f\ p_{sat}\right)\right)$$

Energy

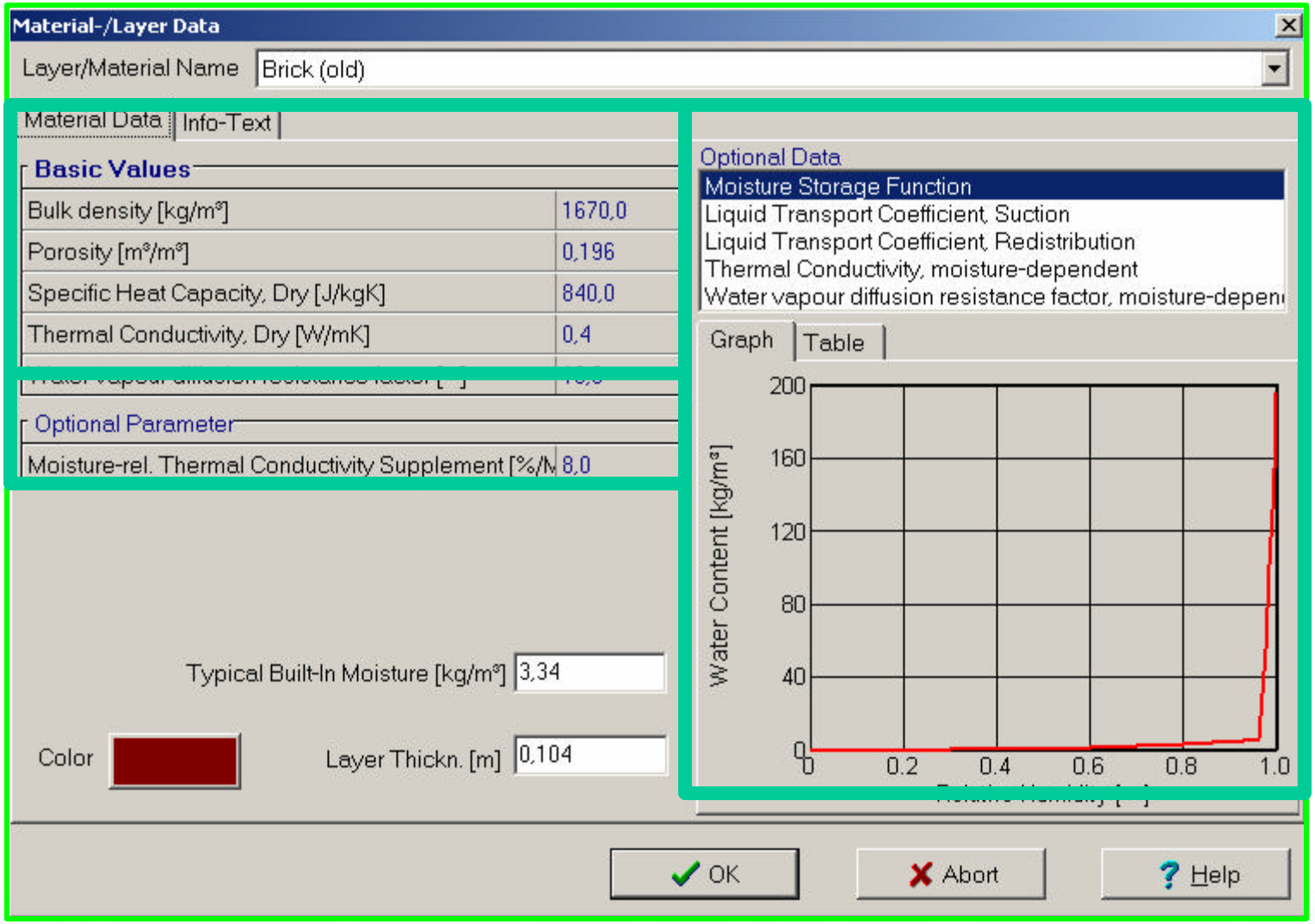
$$\frac{\partial H}{\partial T}\cdot\frac{\partial T}{\partial t}=\nabla\cdot\left(l\nabla T\right)+h_v\nabla\cdot\left(d_p\nabla\left(f\ p_{sat}\right)\right)$$

Temperature Field
Moisture Field
Heat Fluxes
Moisture Fluxes

WUFI ORNL/IBP SYSTEM DEFINITION

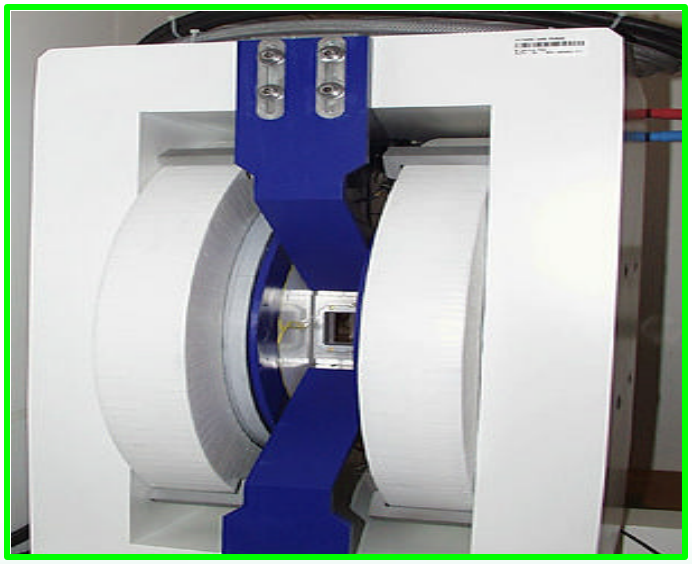


WUFI ORNL/IBP MATERIAL PROPERTIES



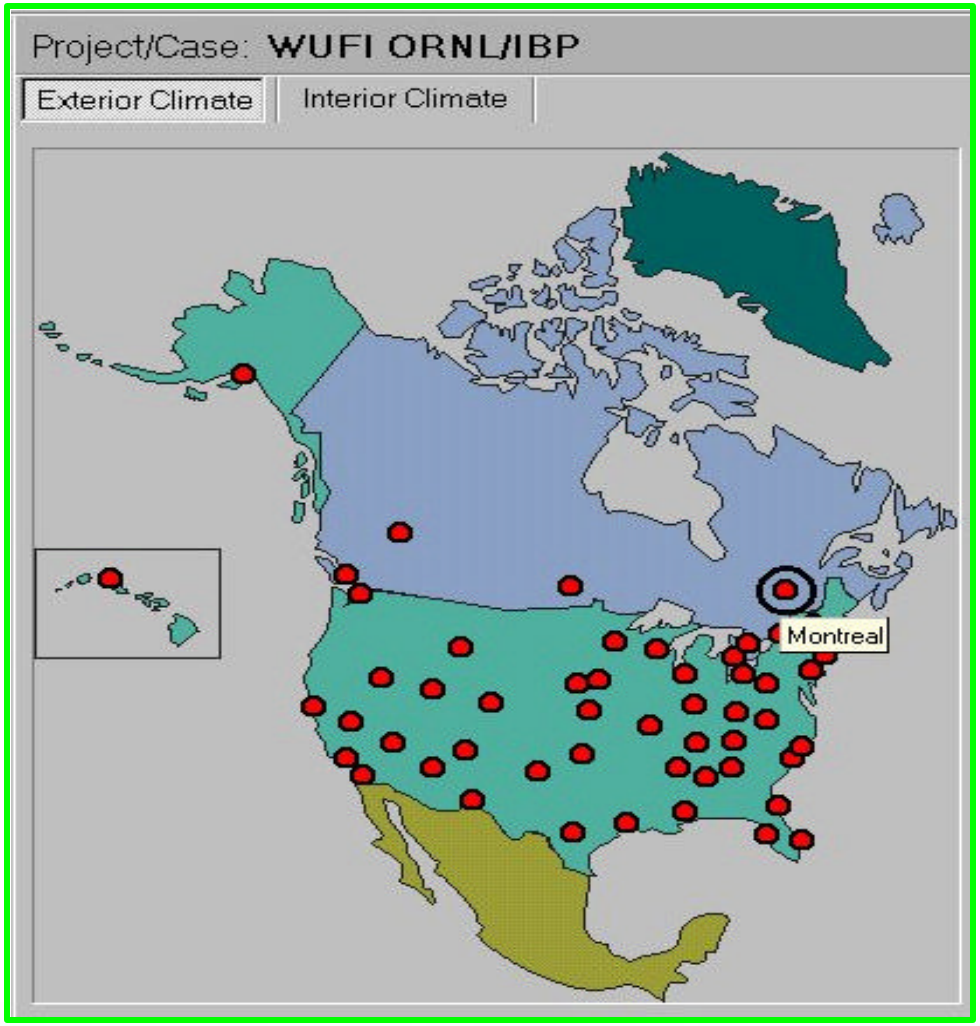
MATERIAL PROPERTY REQUIREMENTS

- Density
- Porosity
- Heat Capacity
- Thermal Conductivity
- Sorption Moisture Content
- Suction Moisture Content
- Water Vapor Permeability
- Liquid Diffusivity

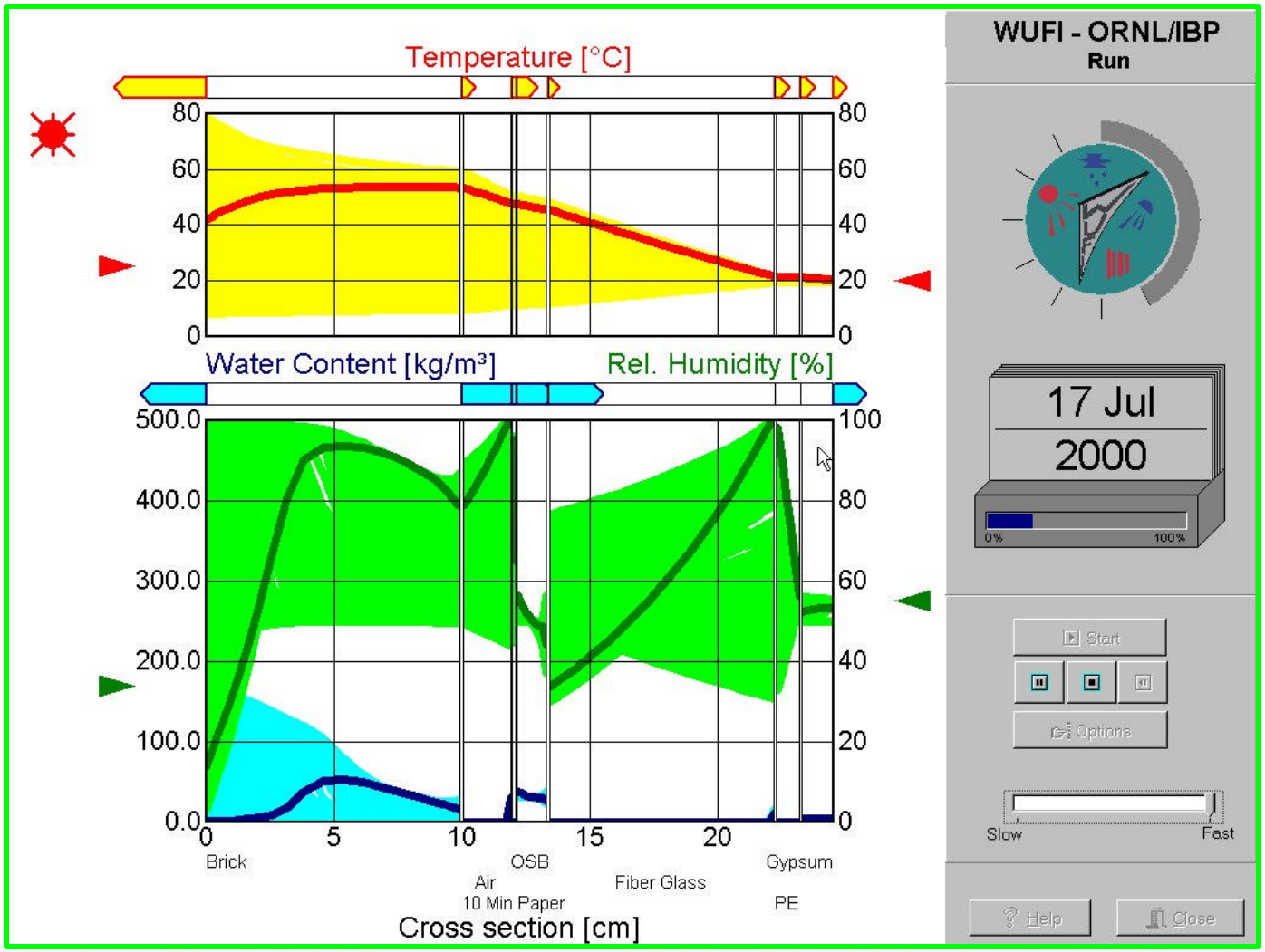


WUFI ORNL-IBP CLIMATE SPECIFIER

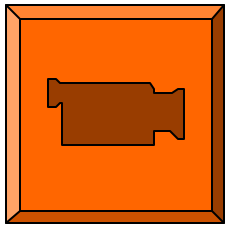
- 53 Weather Locations for North America
- Moisture Design Years



WUFI OUTPUT SCREEN

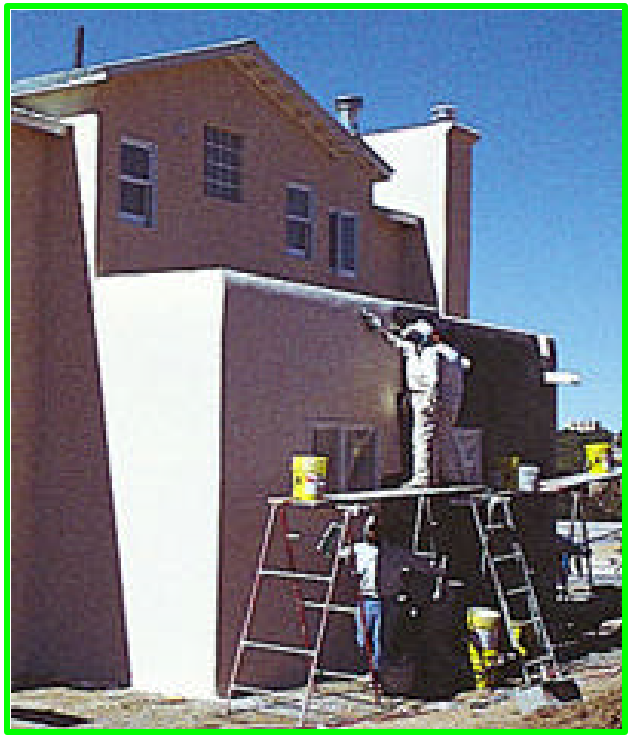


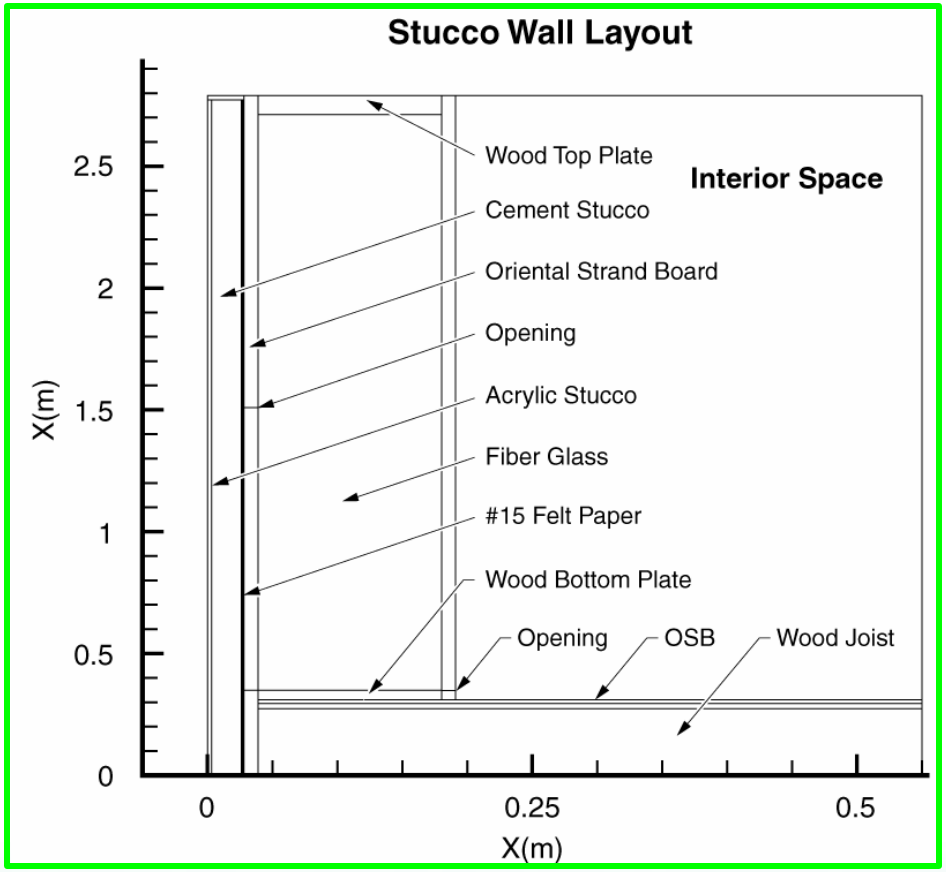
TOUR OF WUFI ORNL-IBP



AN EXAMPLE

Wall Moisture Performance to Water Leakage

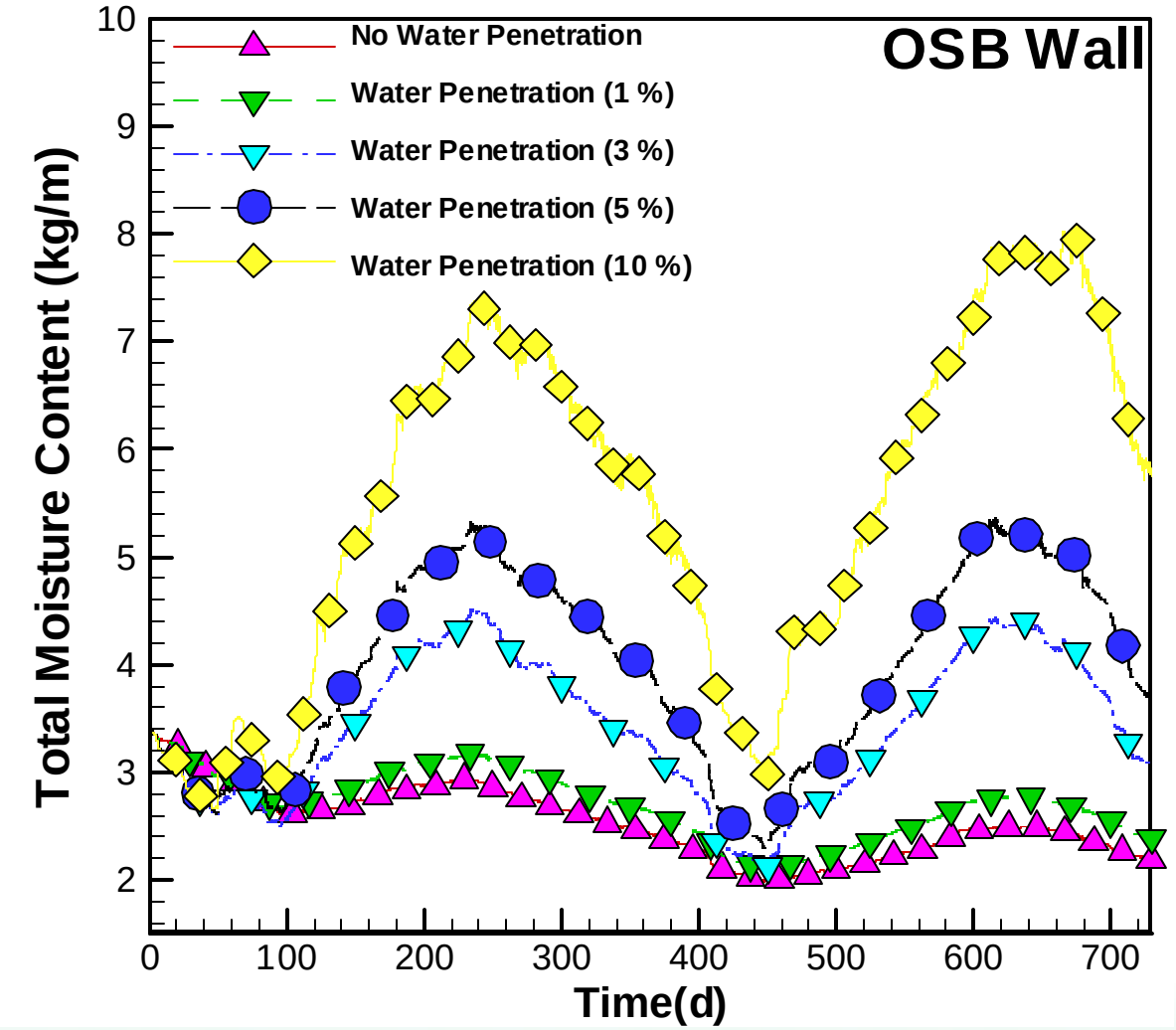




1: Effect of Water Penetration

2: Definition of Damage

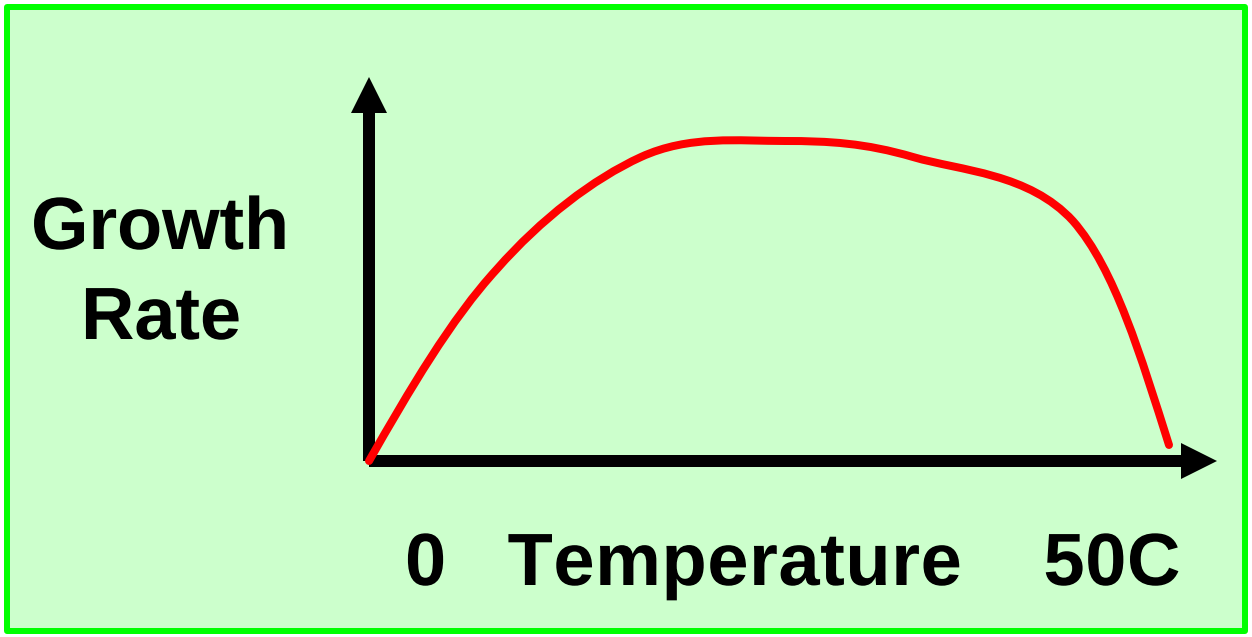
AN EXAMPLE



Look at Sensitive Element of Construction

MOLD GROWTH ON SURFACES

- Surface Humidity > 80% RH
- Temperature 5 - 50°C (40 - 120°F)



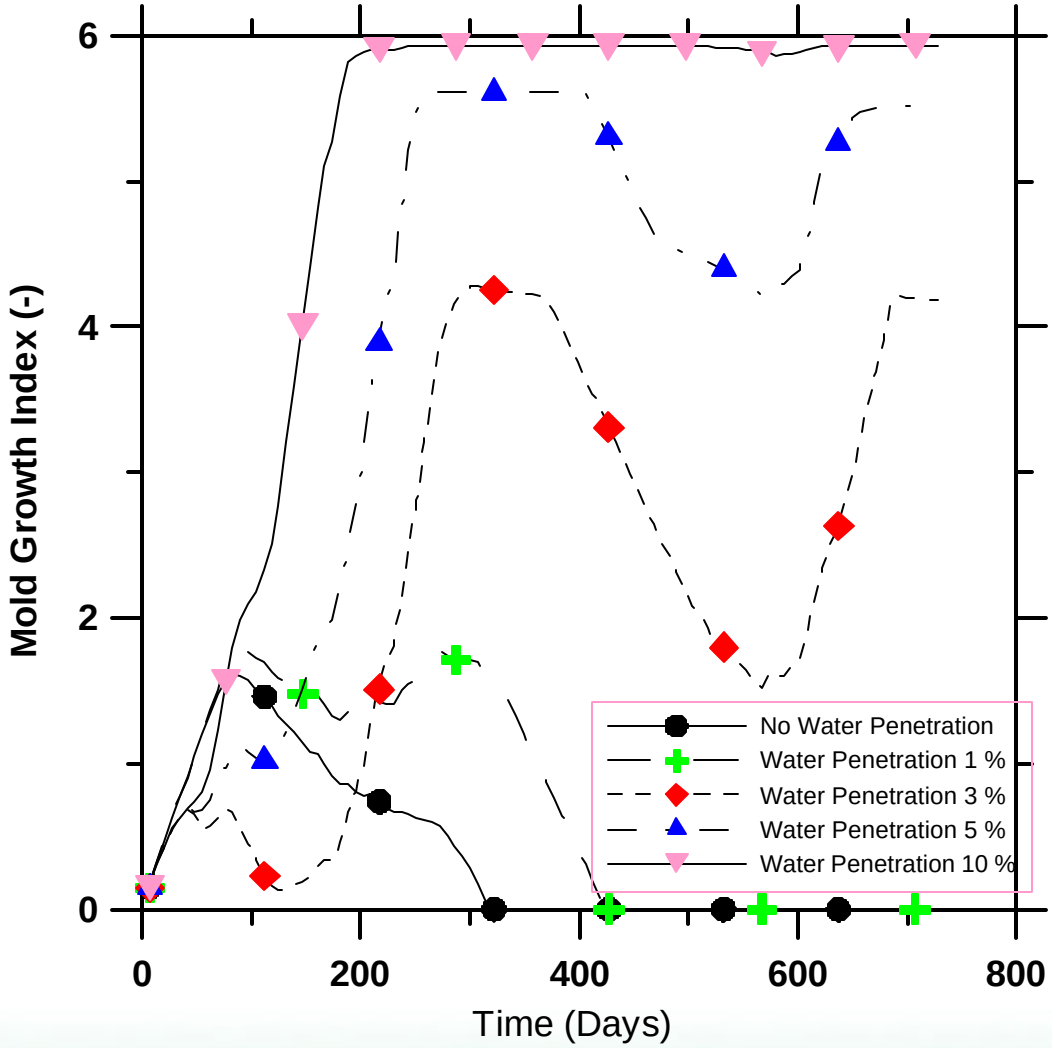
- Food Source (Cellulose, Soap, Wood, Oil)

MOLD GROWTH INDEX

TABLE 1: Mold Index Values and Description.

Index	Descriptive meaning
0	No growth
1	Some growth detected only with microscope
2	Moderate growth detected with microscope
3	Some growth detected visually
4	Visually detected coverage more than 10%
5	Visually detected coverage more than 50%
6	Visually detected coverage 100%

MOLD GROWTH INDEX



CLOSING SUMMARY

- DOE-Developed Tools Are Available to Address Today's Building Envelope Issues
- Efforts Underway to:
  - Increase Their Power
  - Educate Building Professionals About Their Availability and Use