Three Independent Presentations

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Impact of Codes on Building Performances
“Moisture Control”

2001 National Workshop on State Building Codes

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Oak Ridge National Laboratory

Presentation

- Whats New in Moisture Control ??
- What is Hygrothermal Analysis ?
- What are the needed Inputs (Material, Loads)
- What are design tools ?
- What are advanced tools ?
- Examples/Concluding Remarks

Whats New ???

- Better Understanding of how COMPLEX moisture transport and interlinkage
- Still do not have an accurate way of measuring moisture content
- Material properties are not available (Major Effort)
- Some misinformation is being cleared-up

Whats New ???

- MOISTURE is among the TOP three importance items for many many organizations (!) ASHRAE # 1, DOE # 3

- Models are now available that can do more than ever before (WUFI-ORNL/IBP)

- Public is becoming increasingly aware of Moisture Damage, MOLD and health implications (Higher level of Expectations)

Whats New ???

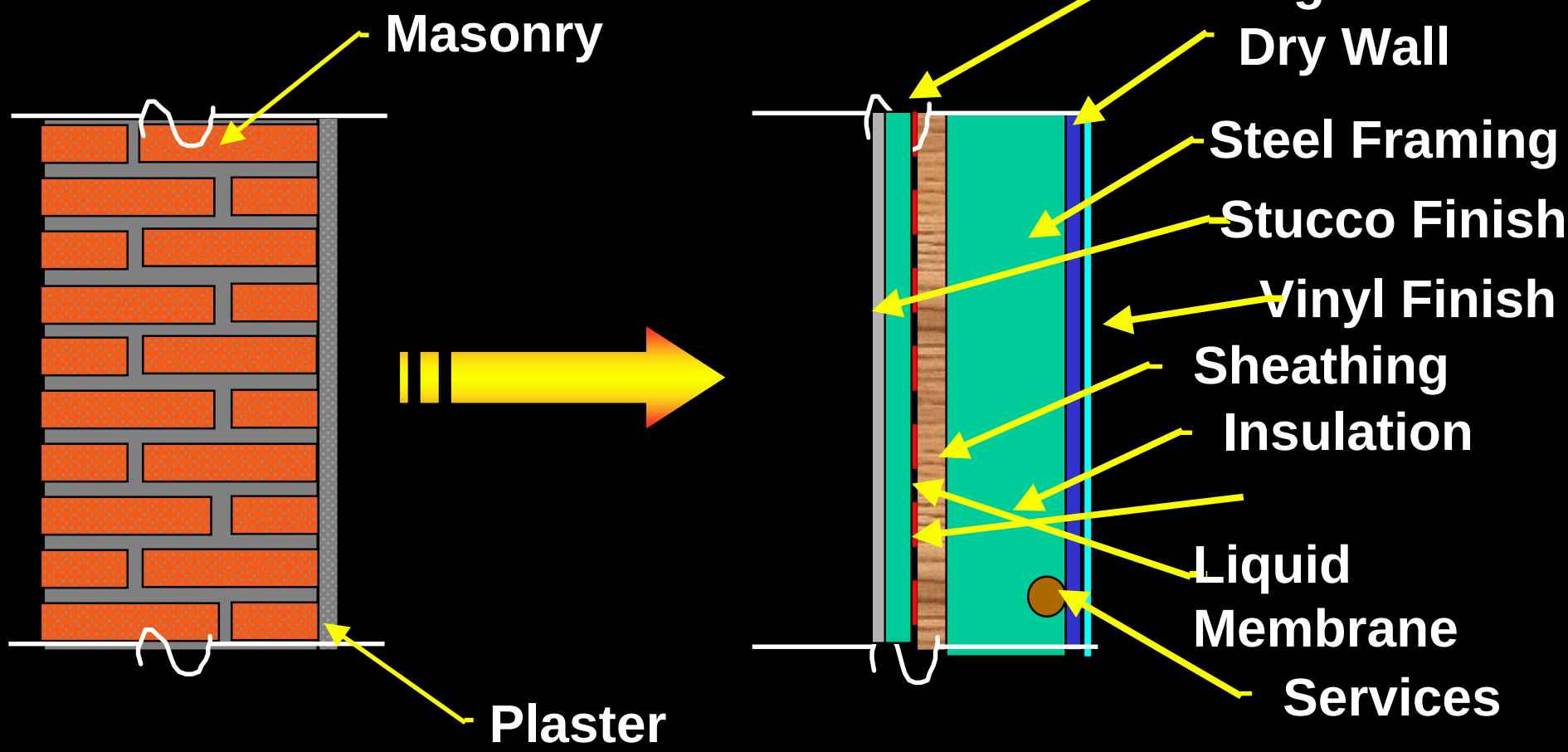
- BUILDING ENVELOPES will be DESIGNED for MOISTURE CONTROL for the first time
- MOISTURE is just becoming of major interest to lawyers
- ORNL/DOE the last 3 years is developing cutting edge moisture engineering competencies

Tim Padfield

Past Design Approach

Today’s Design Approach

BUILDING ENVELOPES ARE CHANGING



18th Century → 20th Century

Building Enclosure Functions

- **Basic Functions**
  - **Support**
  - **Control**
  - **Finish**
  - **Distribute (sometimes)**

Heat
Air
Vapor
Rain
Sound
Fire
Insects
Access

"Control Mass and Energy Flows"

Moisture Control

Moisture-related Problems

1. *Moisture* must be available
2. There must be a *route* or *path*
3. There must be a *force* to cause movement
4. The material must be *susceptible* to damage

Theory: eliminate *any one* for complete control

- Practice: control *as many as possible*

MOISTURE Problems

Moisture Problems: Who's to Blame?

- **Climate**
  - cold, wet, warm, rainy
- **Poor quality construction** :
  - rushed construction time
  - non-union or unskilled labor,
  - greedy developers
- **Material change**
  - OSB vs. plywood,
  - Tyvek vs. building paper,
  - Stuccos, more cement, more Joy
  - poorer quality windows
- **Assembly change**
  - increased R-value,
  - addition of poly
- Architectural style:
  - California style "Sausolito in a Swamp", exposed decks,
  - closed hand rails w/ no cap flashing,
  - cantilevered decks
  - no overhangs
- change from 3 to 4 storeys
  - more condos less houses

Who Pays for Moisture/Indoor Air Quality Problems ????

- **Architects, Insurance Companies**
- ***Building Material Manufacturers***
- ***Owner***

Change in Paradim

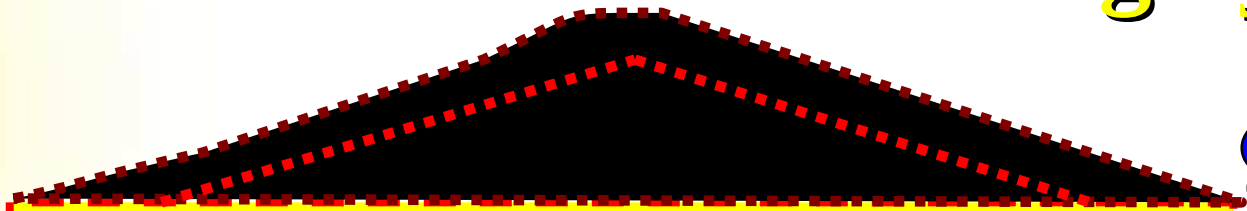
- Use MOISTURE Engineering Principles
- Use all loads (Not just Vapor, Diffusion)
- Radical Change Paradim:
  - Design Perfect Wall (OLD)
  - Design Real Wall (New)

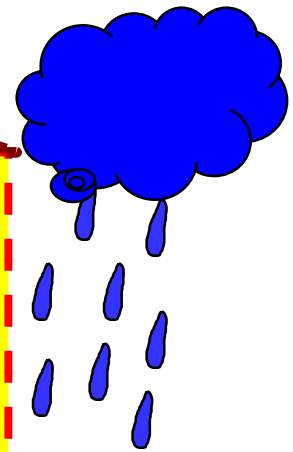
Water, Water Penetration, Air Flow, WDR, Material Property & Changes

Building Science Approach

- Define Physics
- Define Load Inputs
- Define Material Response
- Define Construction System & System

Moisture Control: Building System





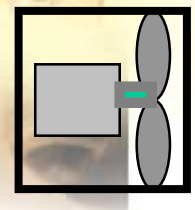
Moisture, Energy Production

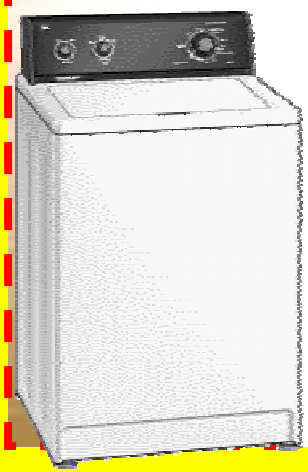
Energy +

Air +

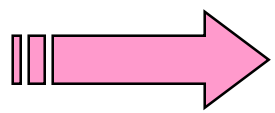
Moisture

HVAC

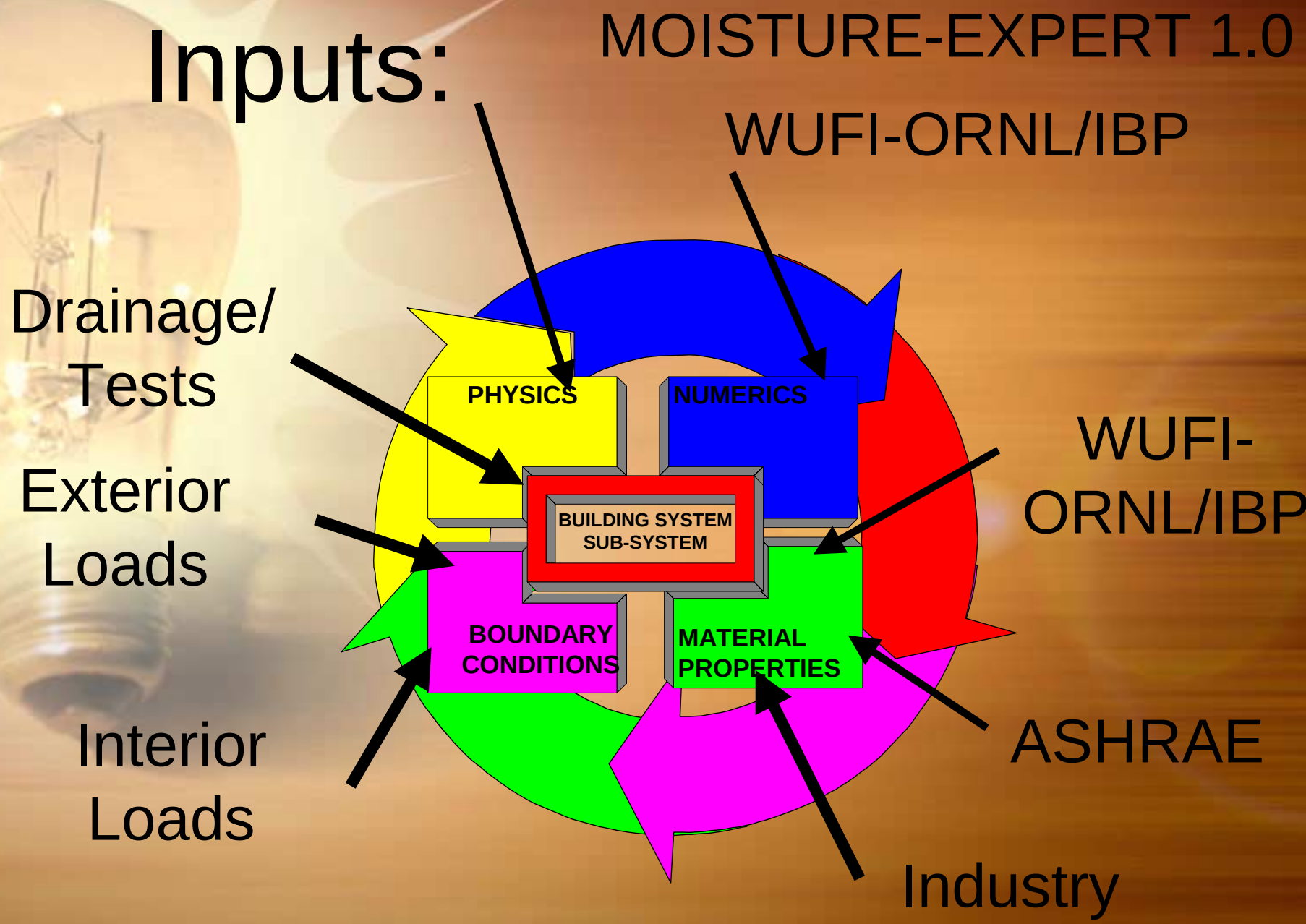




Out



Inputs:


MOISTURE-EXPERT 1.0
WUFI-ORNL/IBP
Drainage/ Tests
Exterior Loads
Interior Loads
WUFI-ORNL/IBP
ASHRAE
Industry
PHYSICS
NUMERICS
BUILDING SYSTEM SUB-SYSTEM
BOUNDARY CONDITIONS
MATERIAL PROPERTIES

Environmental Loads

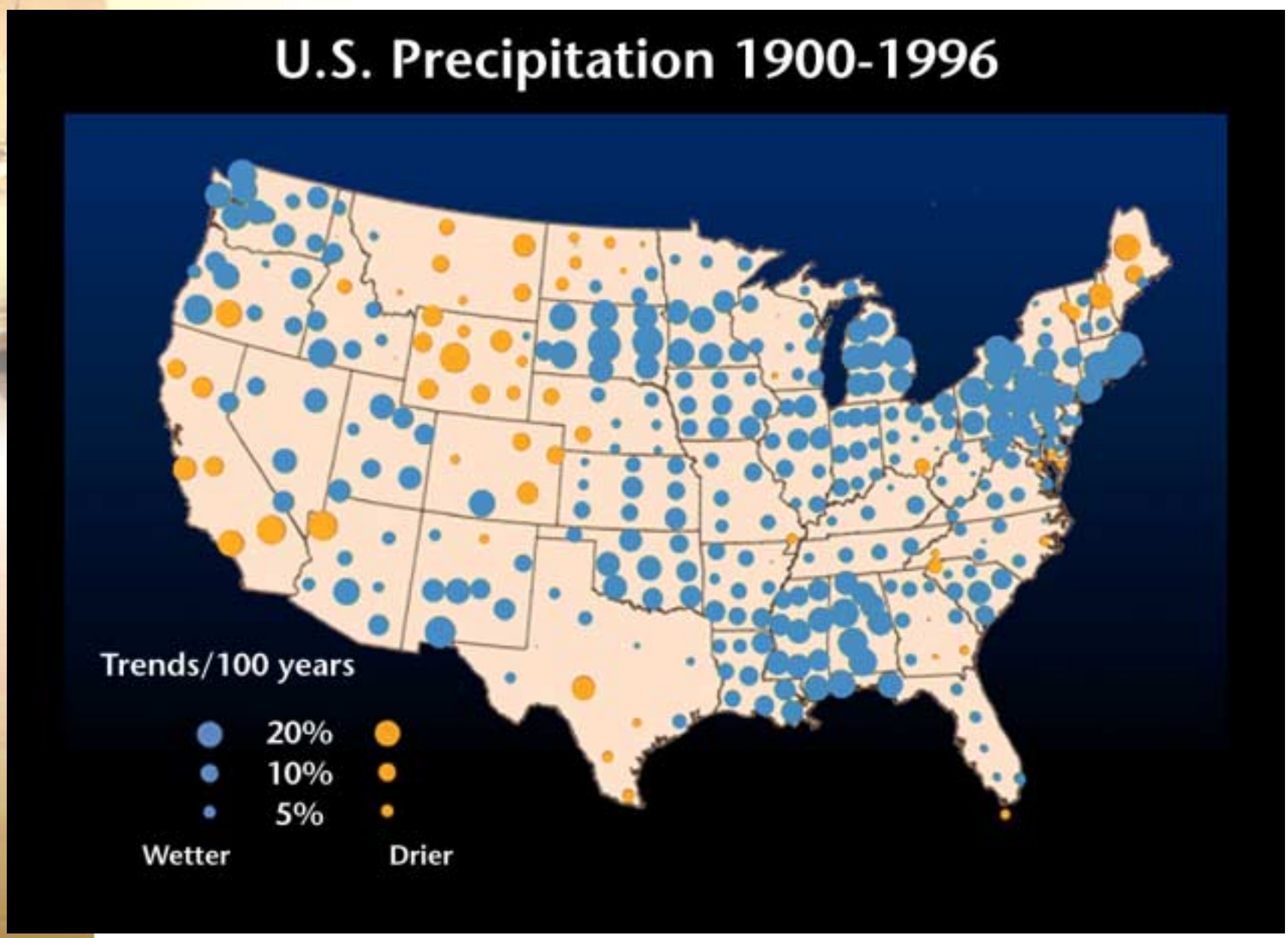
EXTERIOR

Orientation, Inclination, Temperature, Relative humidity, Direct, Diffuse, Reflective and Sky Radiation, Wind-Driven Rain, Wind Speed and Orientation, Cloud Index

INTERIOR

Temperature, RH, Stratification, Stack, Mechanical Pressurization, Moisture Production/ Supply Rates, Ventilation Rates

Climate Region: Rain



Interior Loads

- Inhabitants
- Processes
- Plants/Animals
- Pool/Fountains/Humidifier /Dehumidifiers
- Other Sources

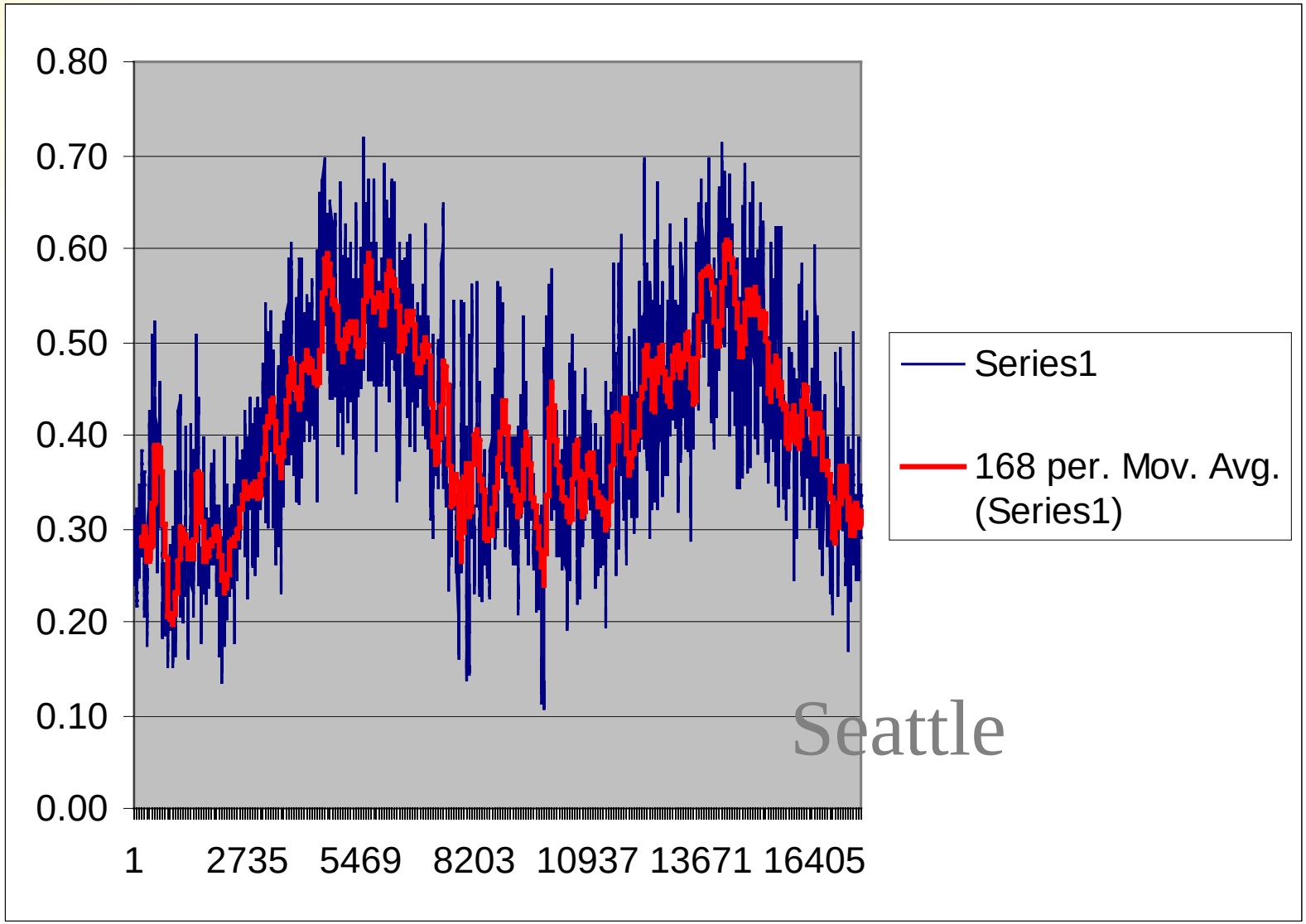
House Loads

- Define Interior Loads (IEA) (2 adults + 2 kids)
  - Human body (3.5 kg/day)
  - 20 Plants (0.5 kg/day)
  - Personal Hygiene (1.3 kg/day)
  - House cleaning (0.2 kg/day)
  - Washing up (0.4 kg/day)
  - Laundry (1.8 kg/day)
  - Cooking (0.9 kg/day)
  - Miscellaneous (0.2 kg/day)

TOTAL 8.5 kg/day (4 to 14 kg/day) (3.3 g/kg at 0.5ACH)

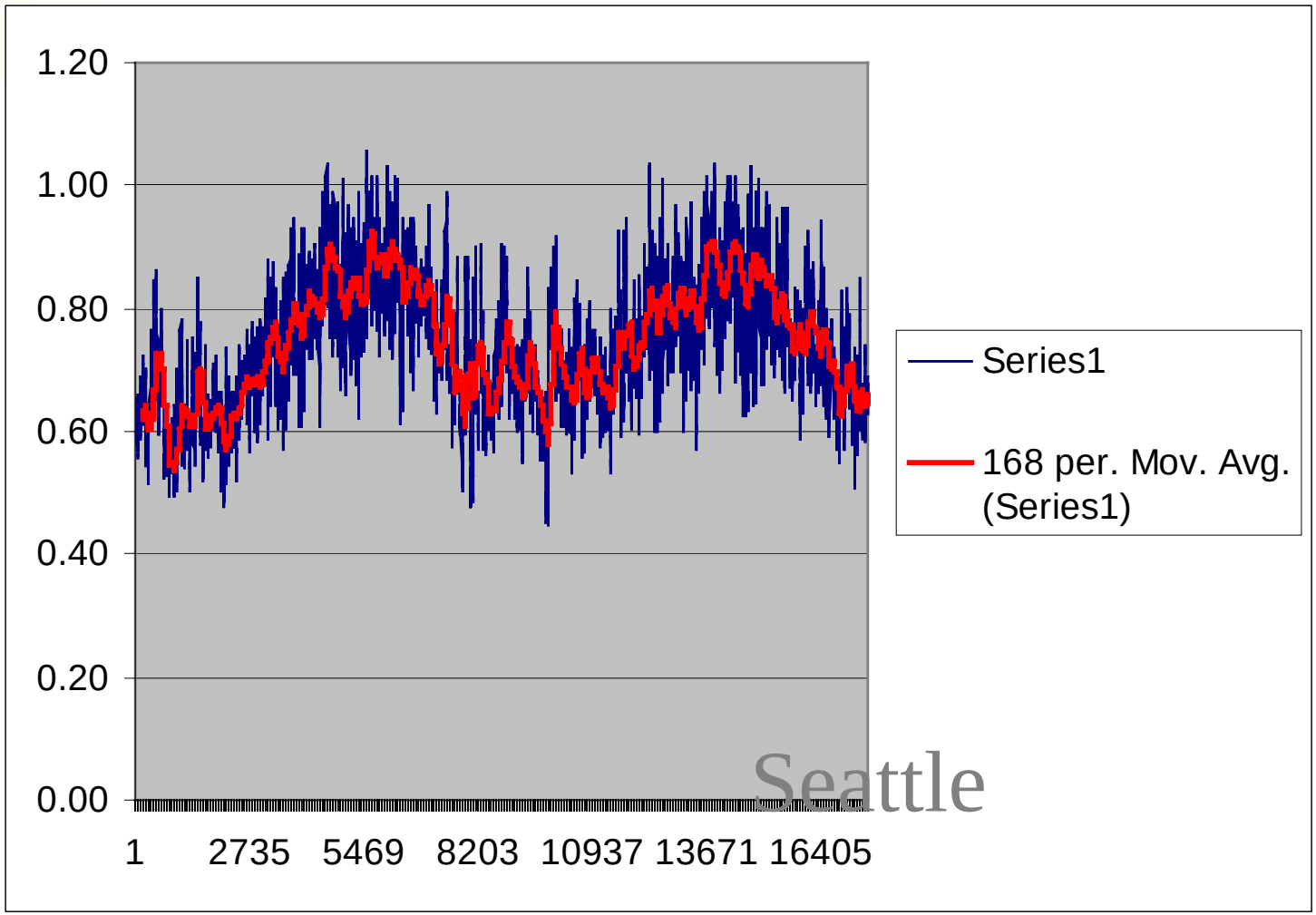
Effect of ACH + Moisture Production

T= 21 C, 10 kg/day, ACH=3, Area= 80 m^2

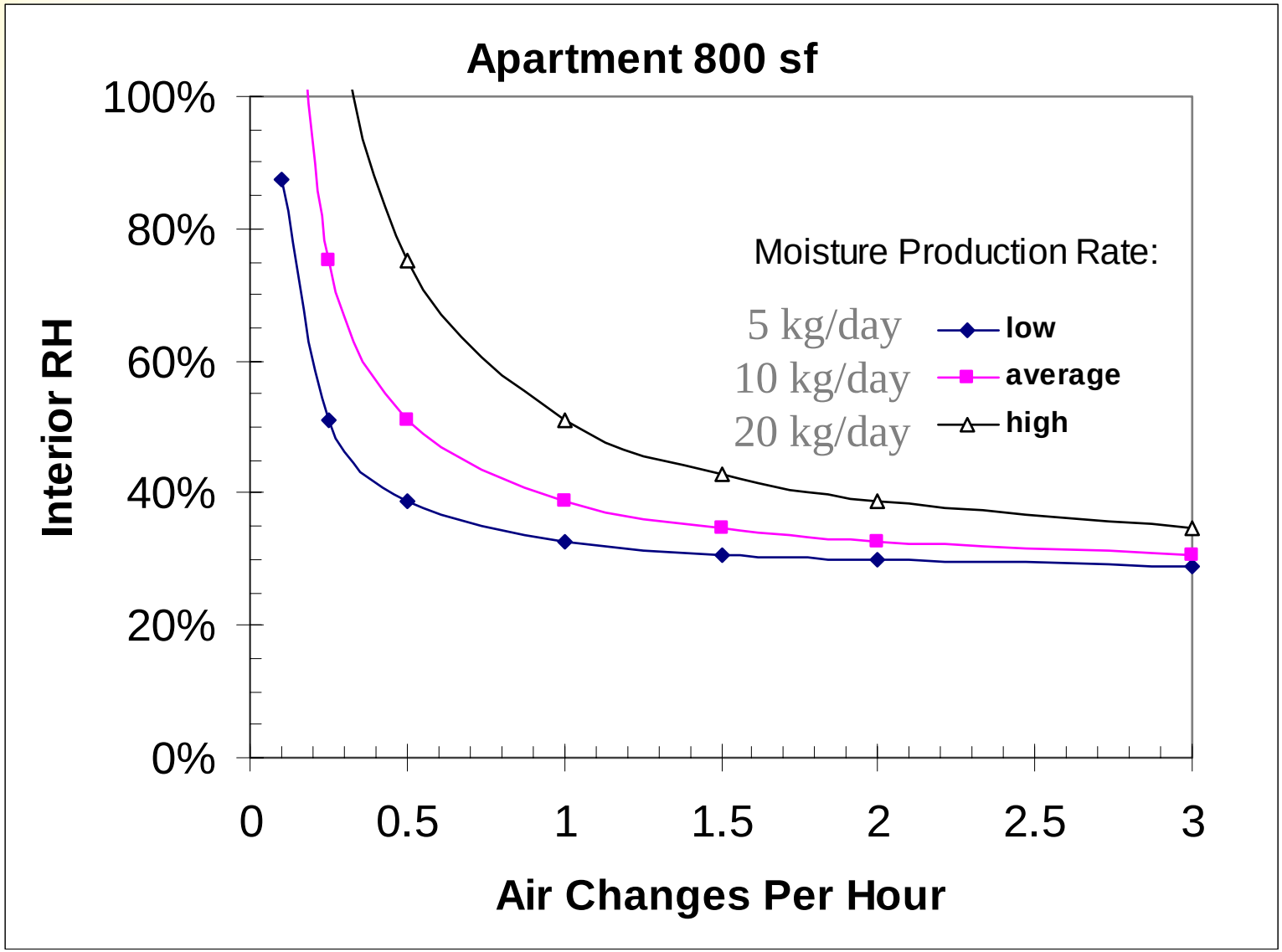


Effect of ACH + Moisture Production

T= 21 C, 10 kg/day, ACH=0.3, Area= 80 m^2



Text= 5 C, RH = 80 %


Apartment 800 sf
100%
80%
60%
40%
20%
0%
Interior RH
0
0.5
1
1.5
2
2.5
3
Air Changes Per Hour
Moisture Production Rate:
5 kg/day
10 kg/day
20 kg/day
low
average
high

Material Hygrothermal Response

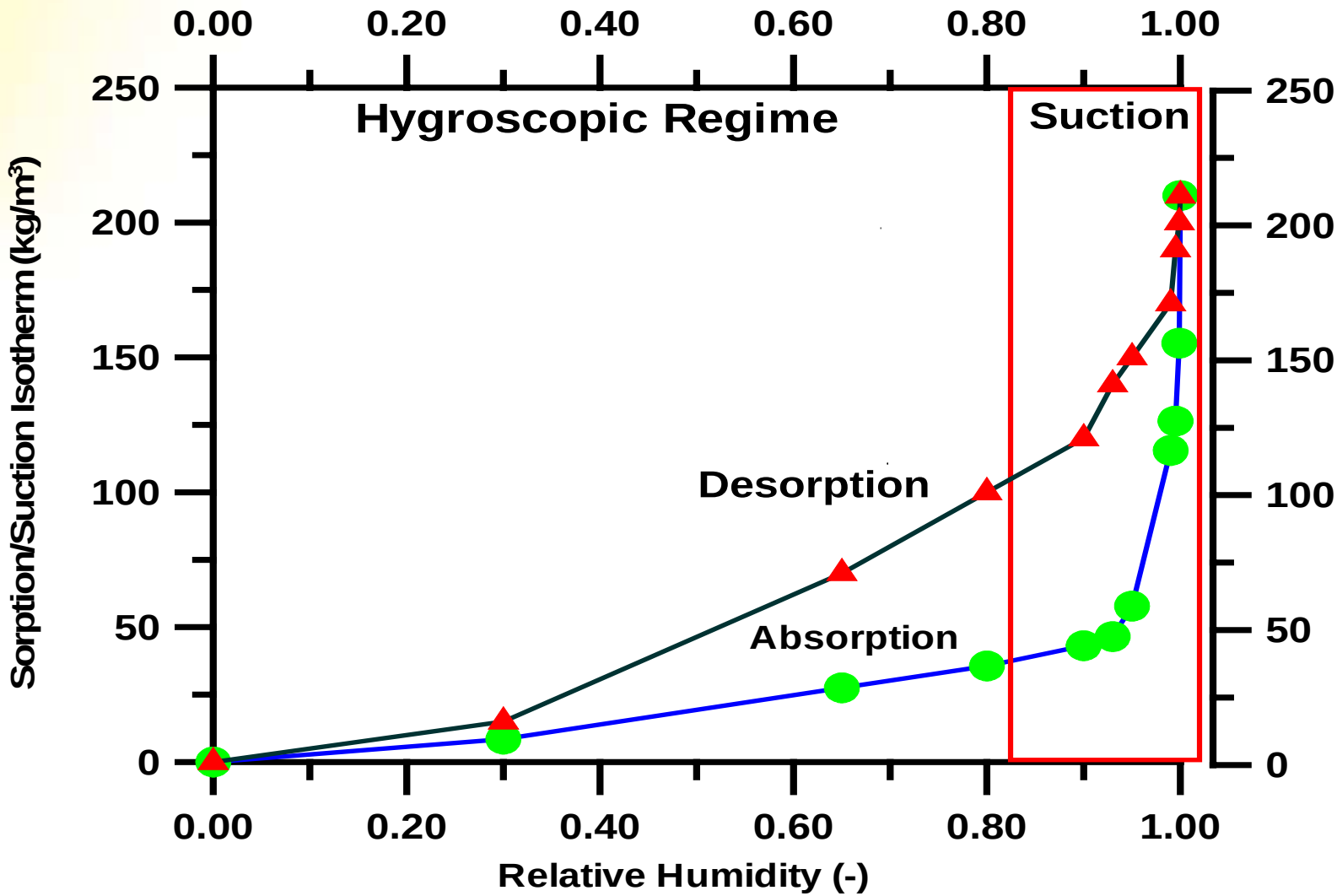
Material Properties

Material Hygrothermal Properties

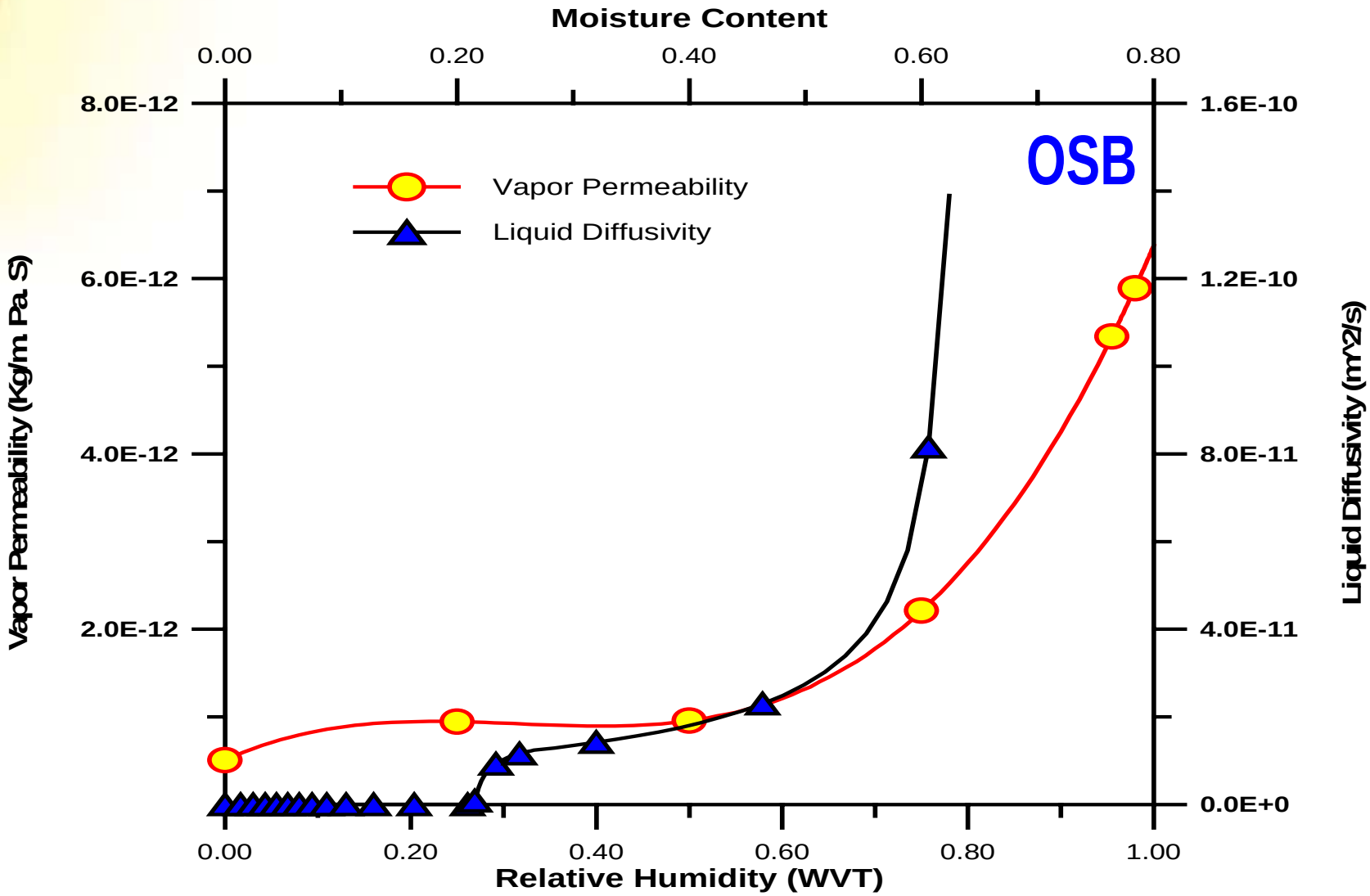
Materials can be characterized by:

- Sorption/Suction Isotherm (RH,U,T)
- Vapor Permeability (RH, T)
- Liquid Diffusivity (U, Process)
- Thermal Conductivity, (U,T), Heat Capacity (U), Density (U,T)

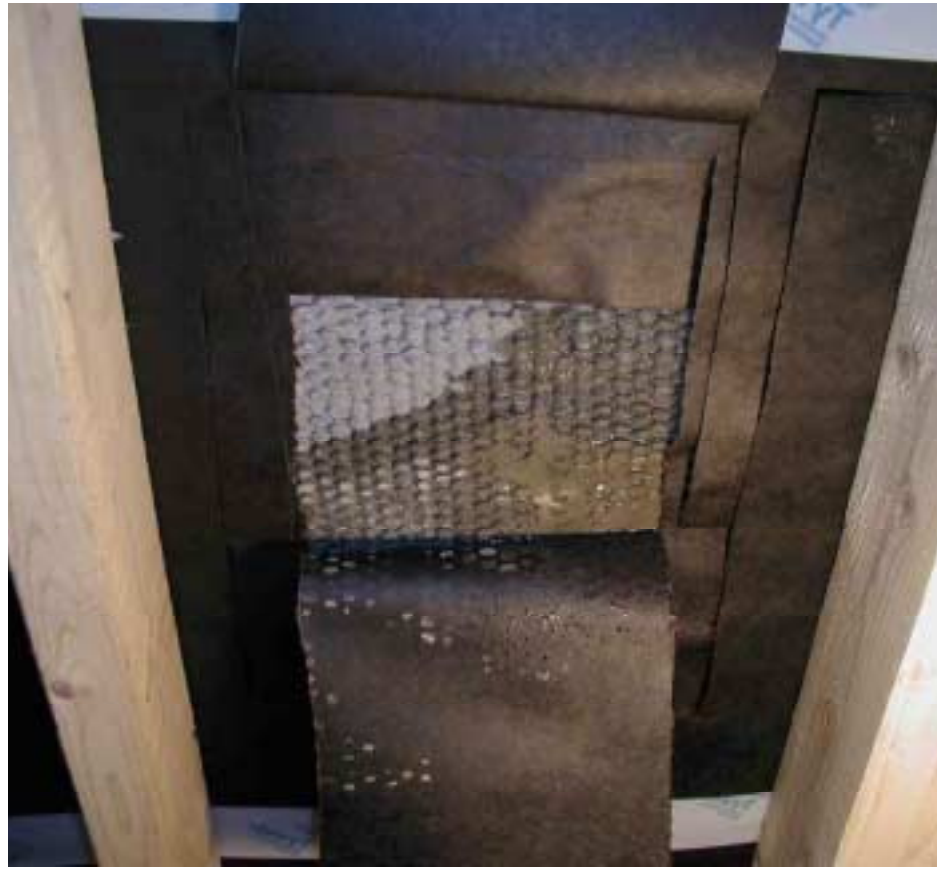
Sorption/Suction Isotherm (Baumberger Stone)



Vapor Permeability/Liquid Diffusivity



Building System Performance: Drainage Study



ORNL's New Advanced Model

MOISTURE-EXPERT

- **Integrates: Physics + Building System Effects + Climate**

MOISTURE-EXPERT v.1.0

- **2-D Capabilities**
- **Vapor Air Flow**
- **Vapor and Liquid Diffusion and WDR**
- **Solar and Sky Radiation**
- **Moisture-Thermal Sources and Sinks**
- **Dynamic Stack and HVAC Schedules**
- **Temperature Dependent Sorption Processes**

Application Case

- **Stucco Clad Wall System**
- **Investigate Hygrothermal Performance**
- **Introduce Drainage Sub-system**
- **Durability Performance**

Simulation Info

- **2- D Simulations**
- **Hourly Exterior and Interior Load Values**
- **Wind-Driven Rain**
- **Stucco simulations have been performed as a function of:**
  - **No air flow**
  - **No water Penetration**
  - **1% , 3 %, 5 % and 10 % Water Penetration**

1/8 in Acrylic Stucco

7/8 Cement Stucco

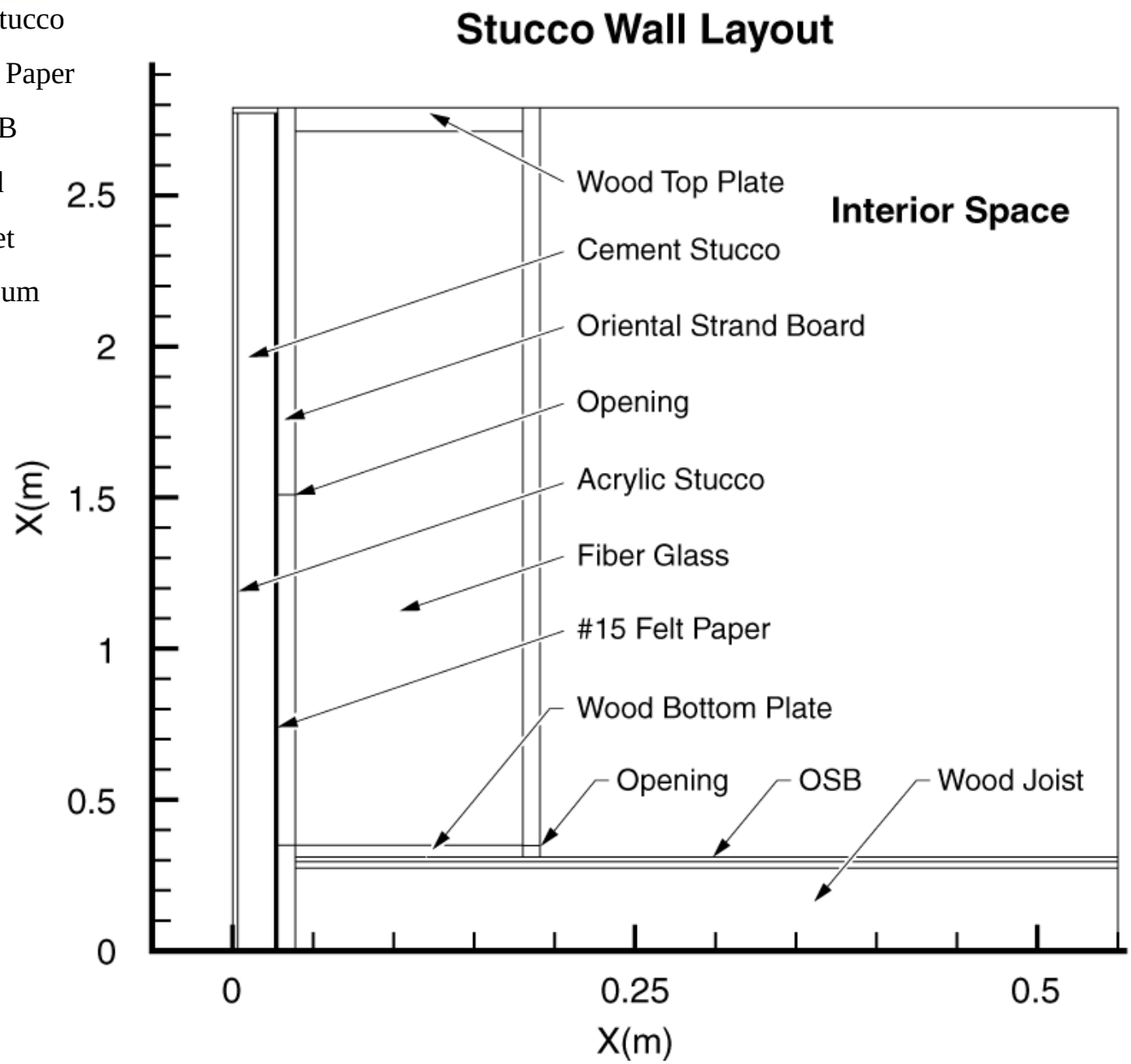
15 # Felt Bldg Paper

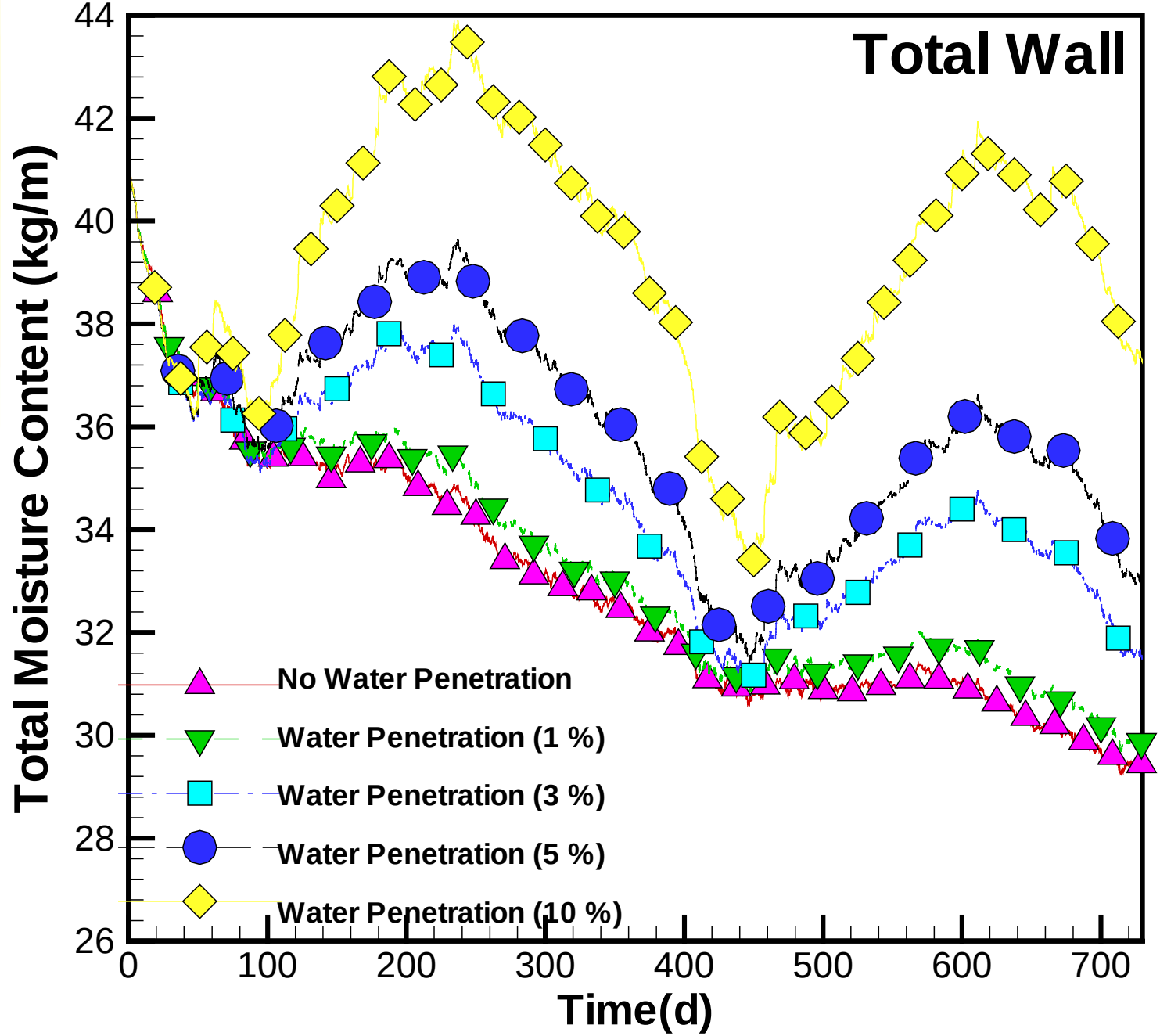
1/2 in OSB

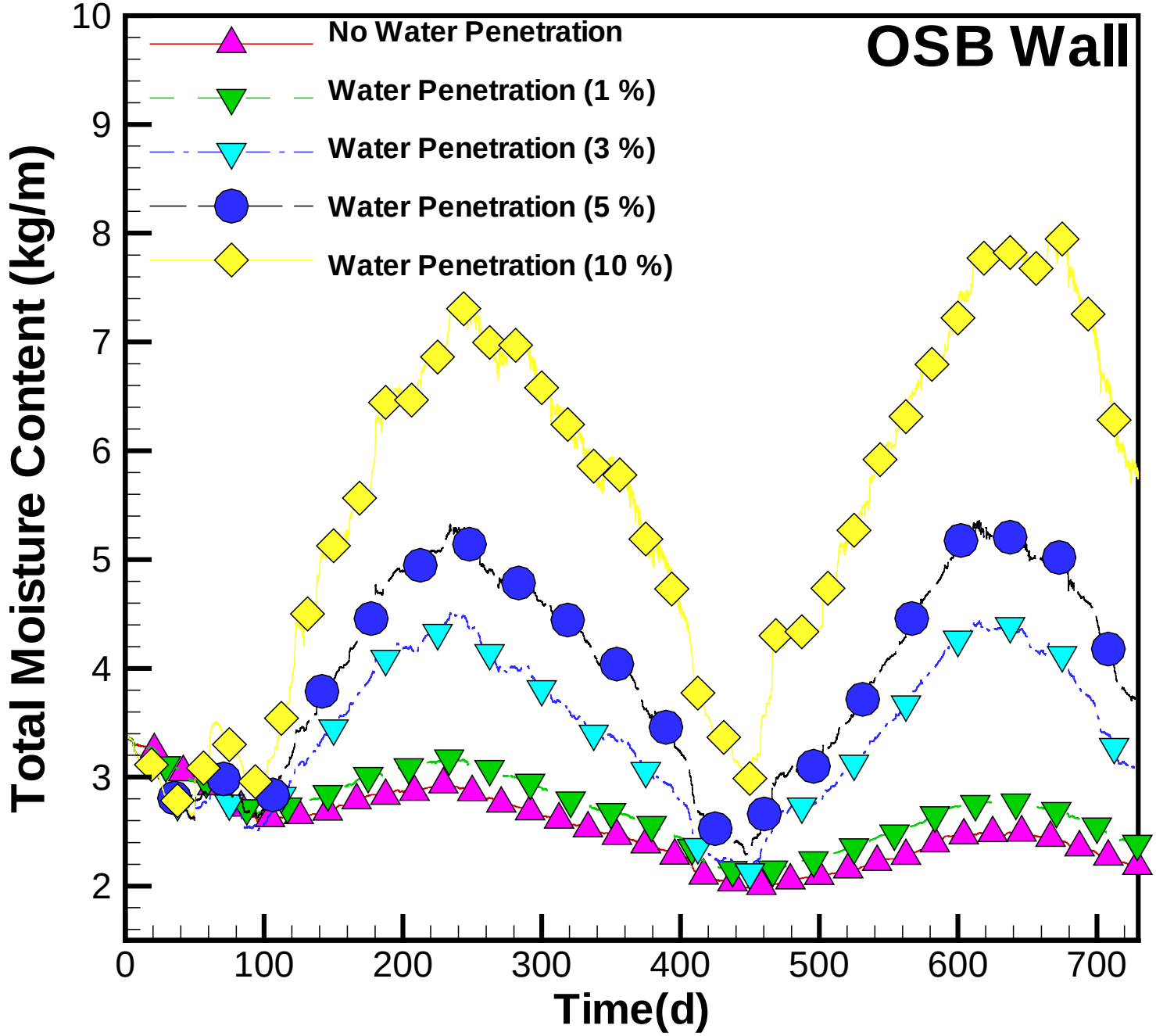
6 in Stud

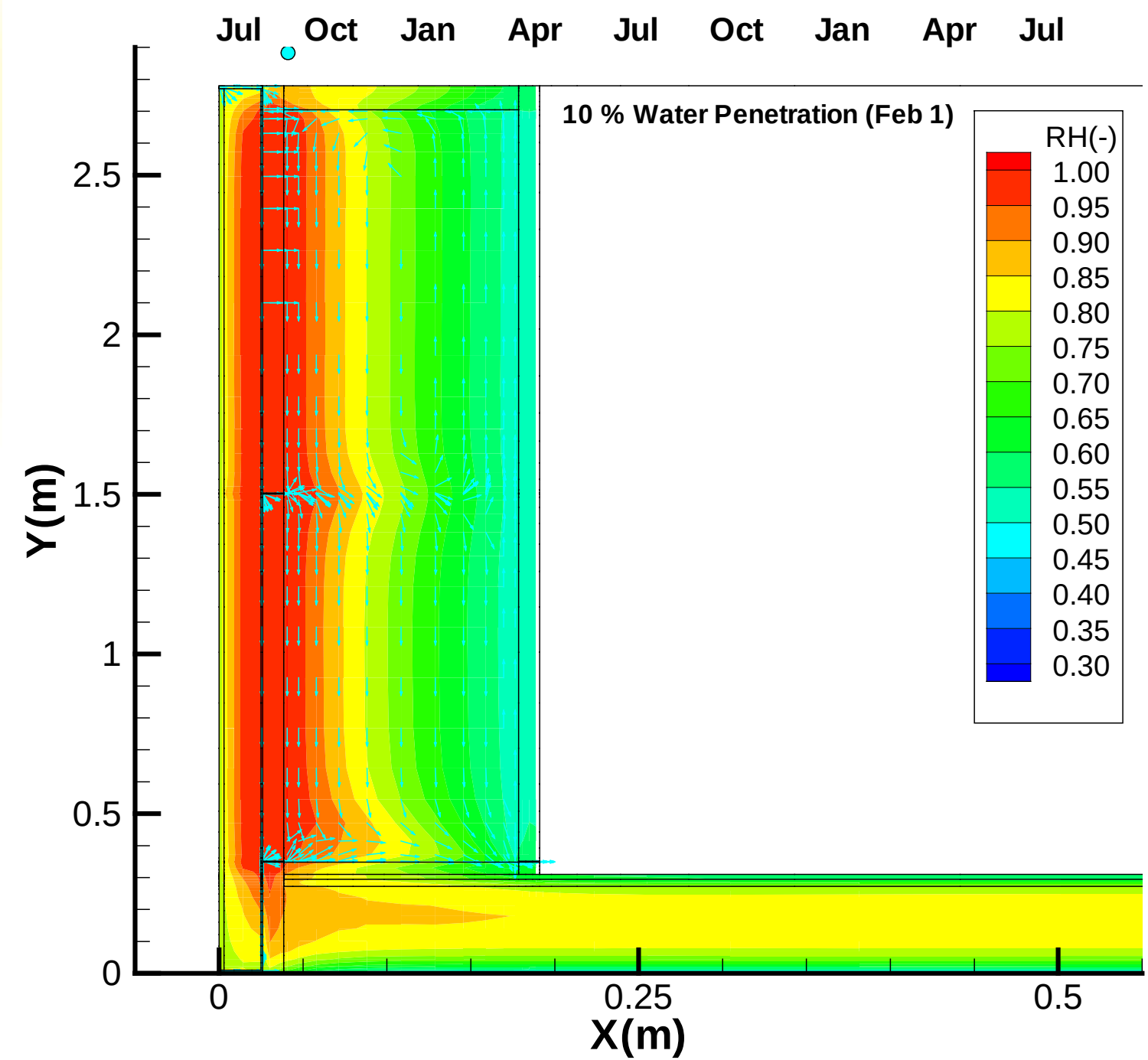
Poly Sheet

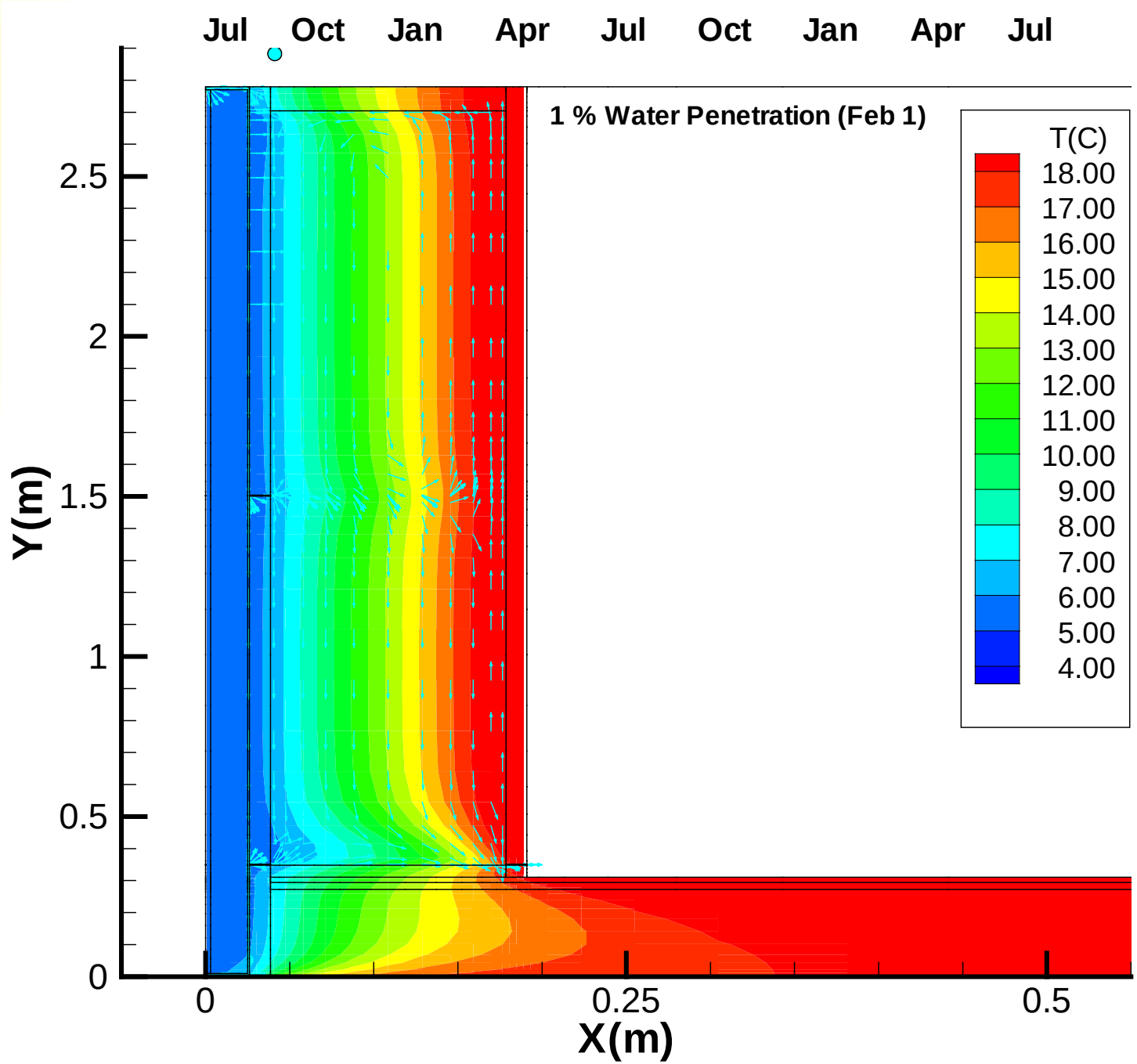
1/2 in Gypsum




Total Wall
Total Moisture Content (kg/m)
Time(d)
44
42
40
38
36
34
32
30
28
26
0
100
200
300
400
500
600
700
No Water Penetration
Water Penetration (1 %)
Water Penetration (3 %)
Water Penetration (5 %)
Water Penetration (10 %)


OSB Wall
No Water Penetration
Water Penetration (1 %)
Water Penetration (3 %)
Water Penetration (5 %)
Water Penetration (10 %)
Total Moisture Content (kg/m)
Time(d)
10
9
8
7
6
5
4
3
2
0
100
200
300
400
500
600
700


Jul
Oct
Jan
Apr
Jul
Oct
Jan
Apr
Jul
10 % Water Penetration (Feb 1)
RH(-)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
Y(m)
2.5
2
1.5
1
0.5
0
0
0.25
0.5
X(m)

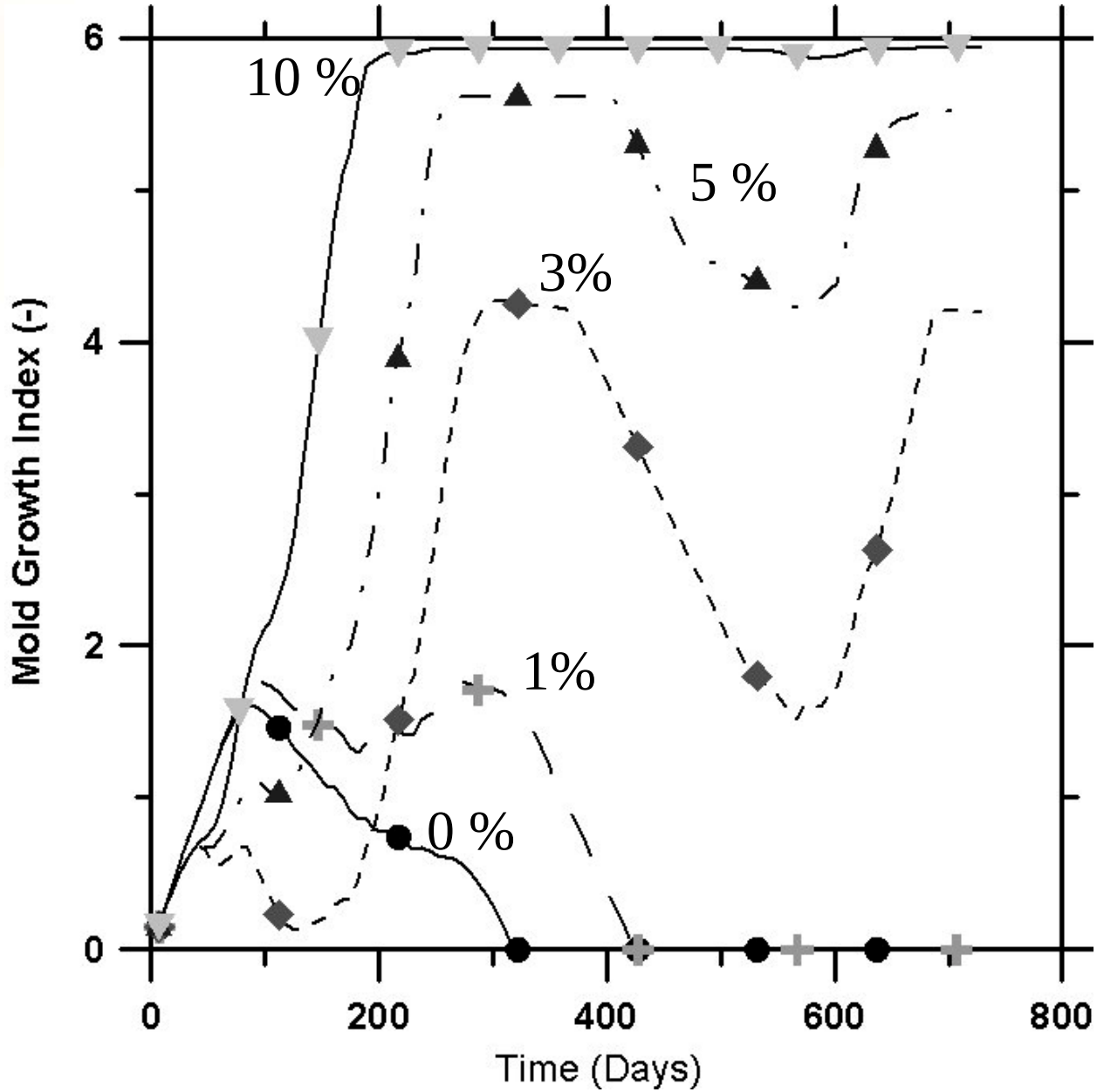

Jul
Oct
Jan
Apr
Jul
Oct
Jan
Apr
Jul
1 % Water Penetration (Feb 1)
T(C)
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
Y(m)
2.5
2
1.5
1
0.5
0
0
0.25
0.5
X(m)

Mold Growth Index

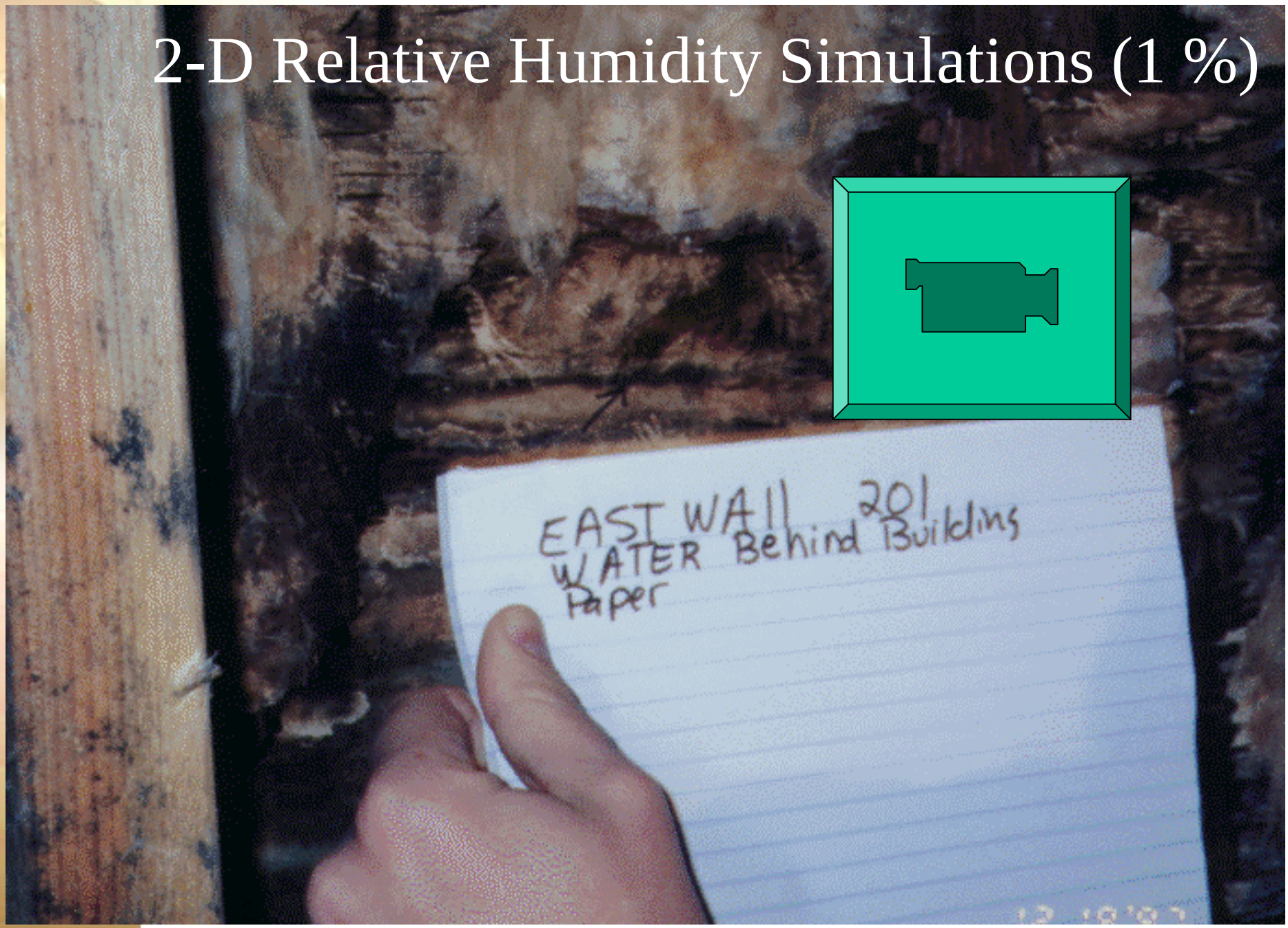
TABLE 1: :Mold Index Values and Description.

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%

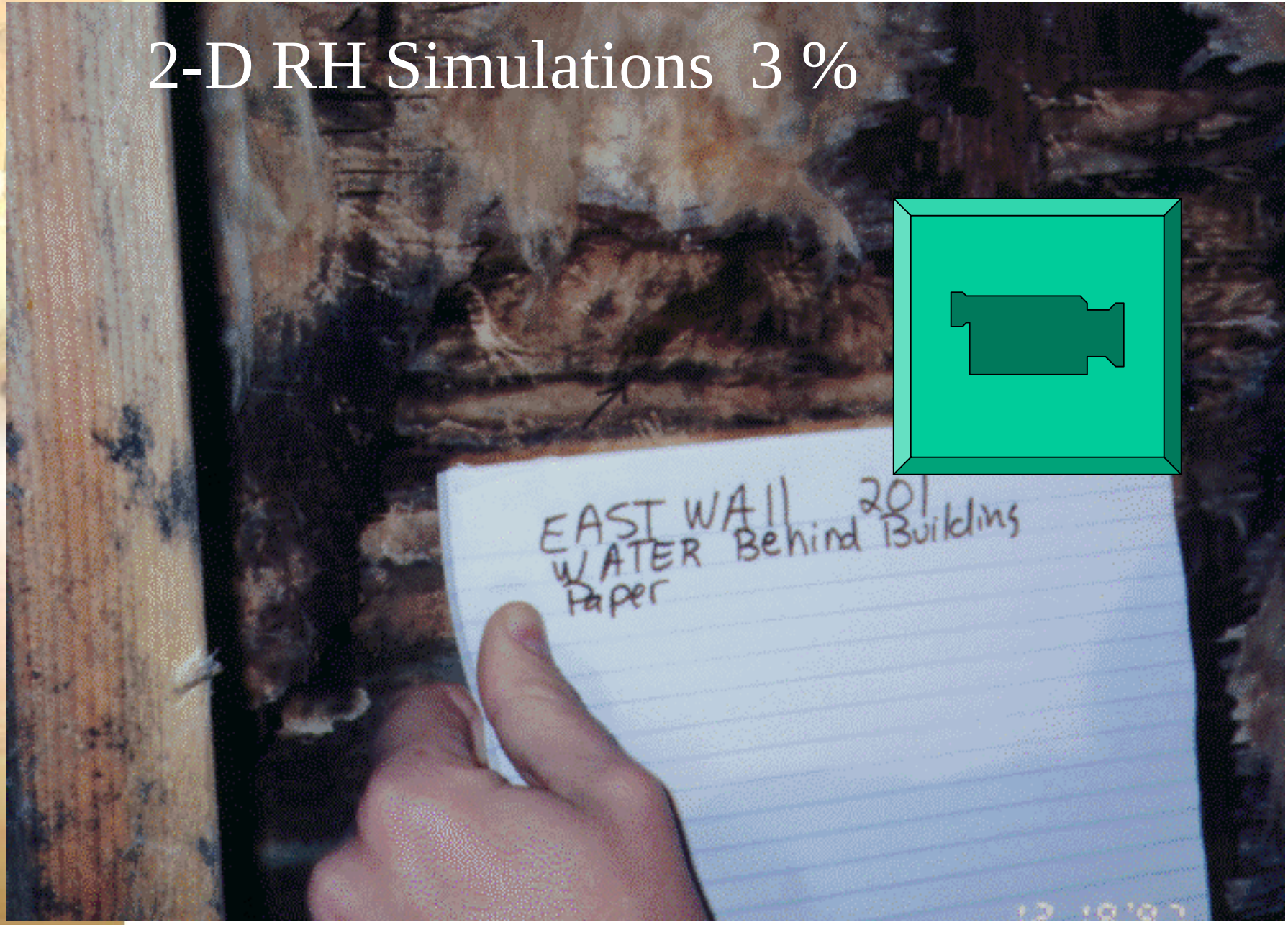
Engineering Assessment



2-D Relative Humidity Simulations (1 %)



2-D RH Simulations 3 %



ORNL's New Hygrothermal Design Tool

WUFI-ORNL/IBP

- **Never Re-invent the Wheel if you intent to go to the Moon (IBP)**
- **Use/Consult experts (Intended)**

Advanced Design Hygrothermal Tool

Jointly Developed:
ORNL & IBP

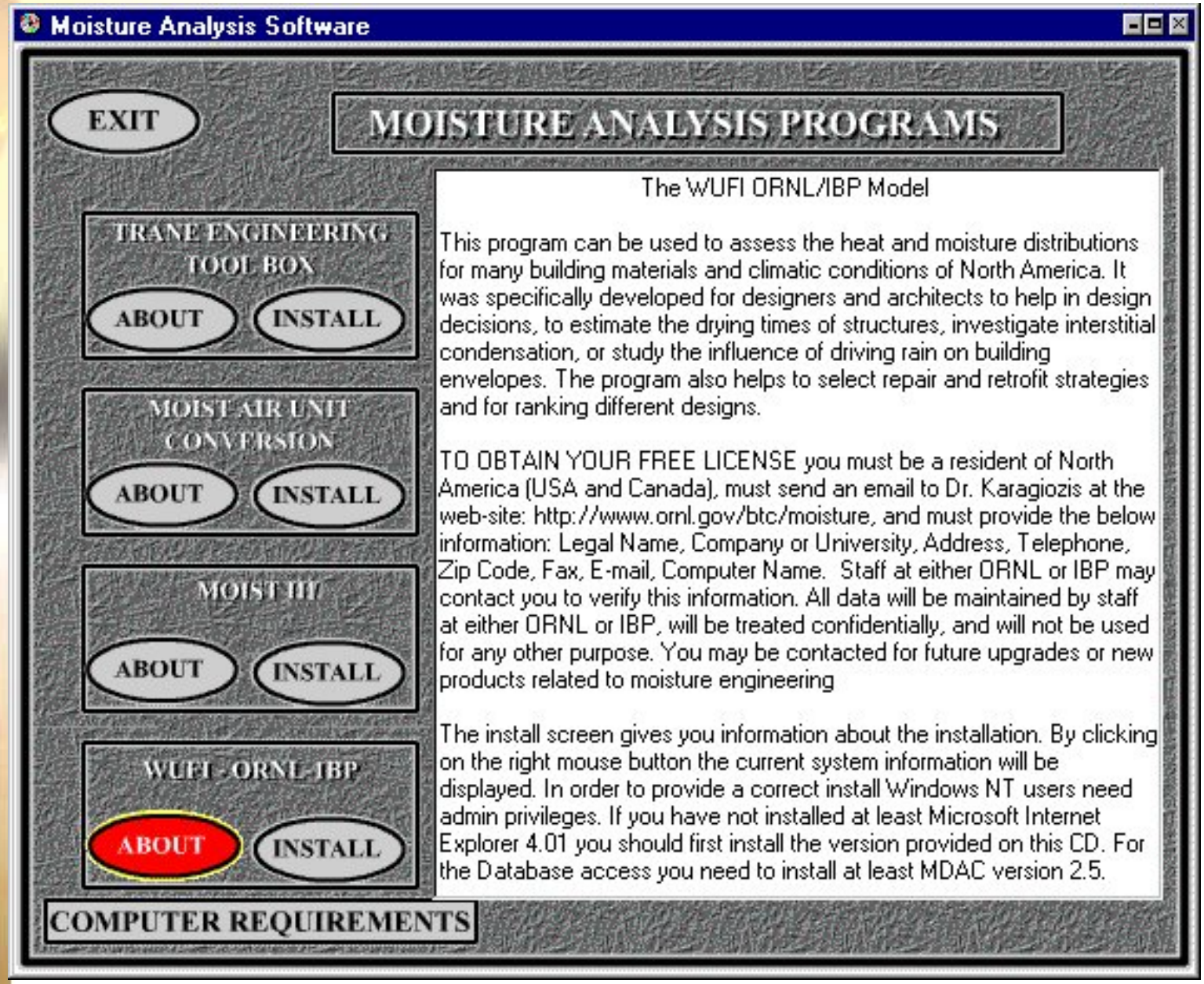
- Designed for Architects/ Engineers Excellent Educational
- Graphical User Interface
- ASTM MLN 40

Don’t Forget this Web Site

www.ornl.gov/btc/moisture

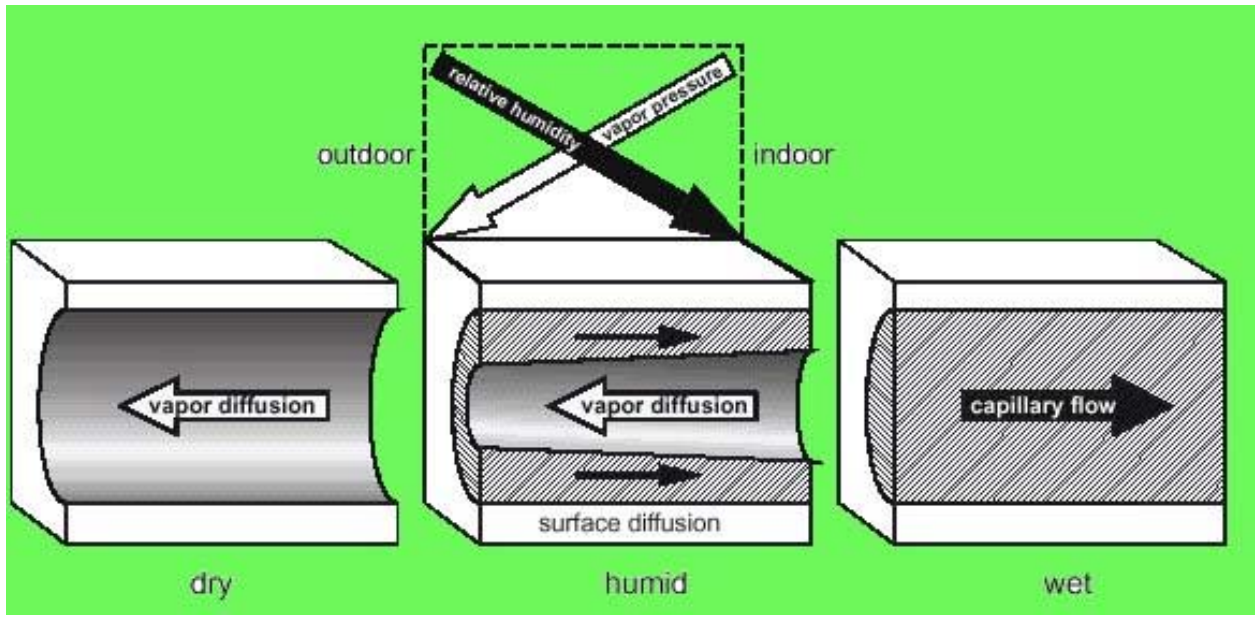
WUFI-ORNL/IBP

New ASTM Manual



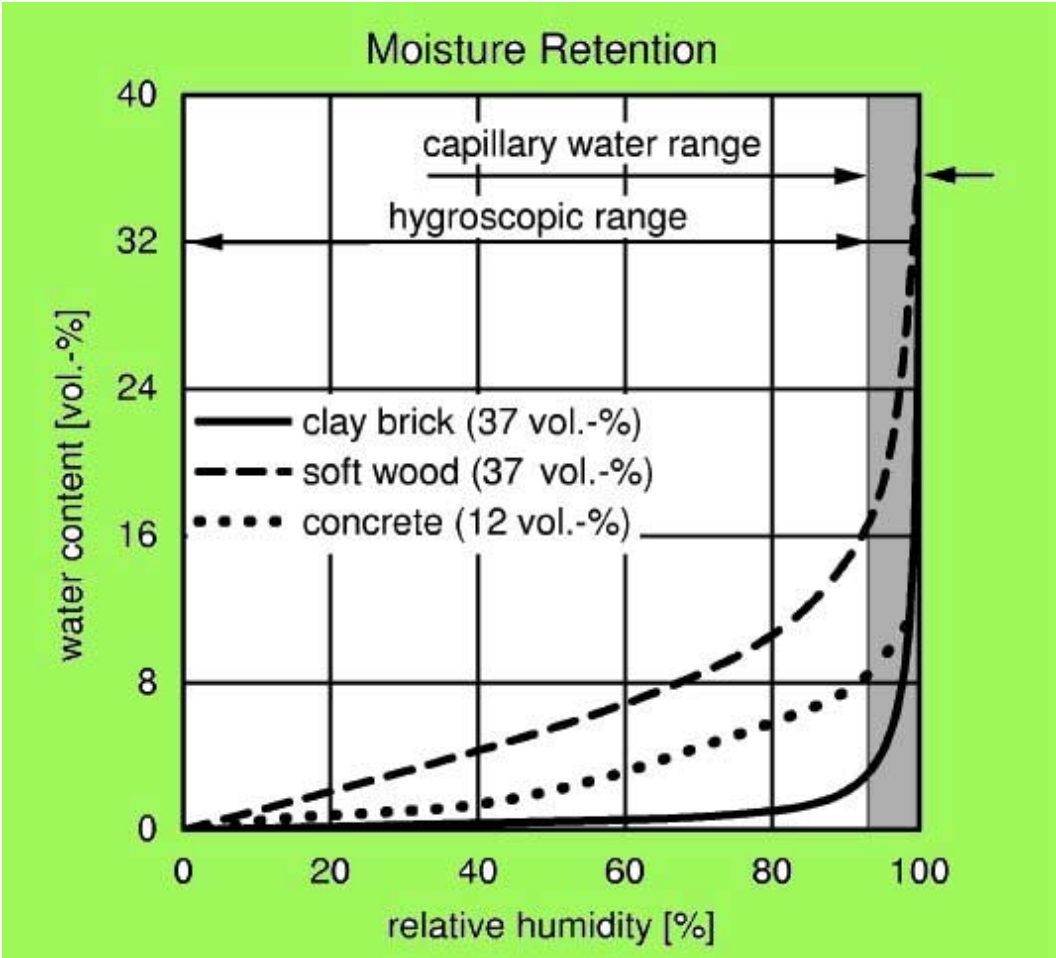
WUFI ORNL-IBP Incorporates:

- Vapor Diffusion
- Liquid Diffusion (Only Tool D_R, D_w)
- Wind-Driven Rain (Only Tool available)



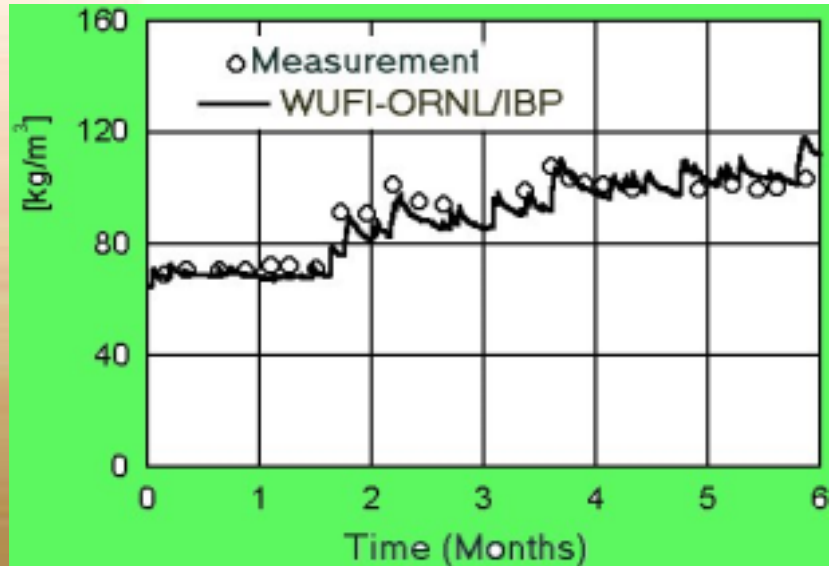
WUFI ORNL-IBP Incorporates:

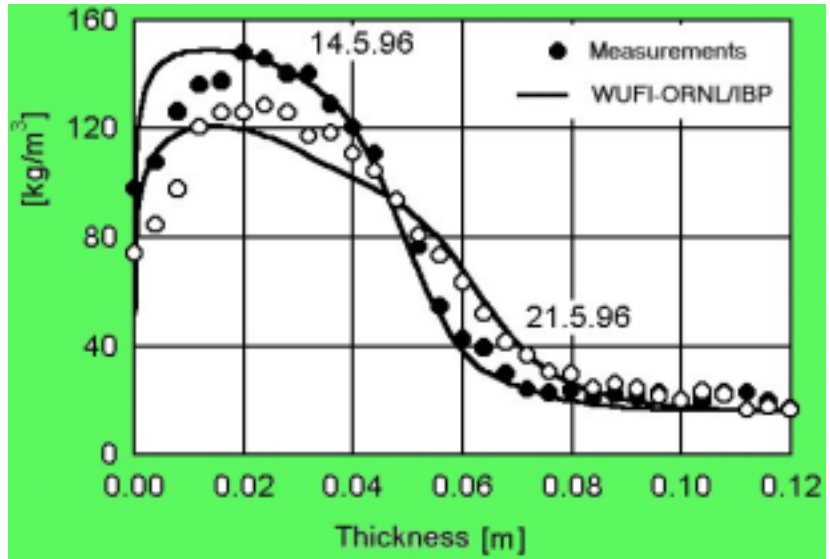
- Full Functional Hygrothermal Properties



WUFI ORNL-IBP Incorporates:

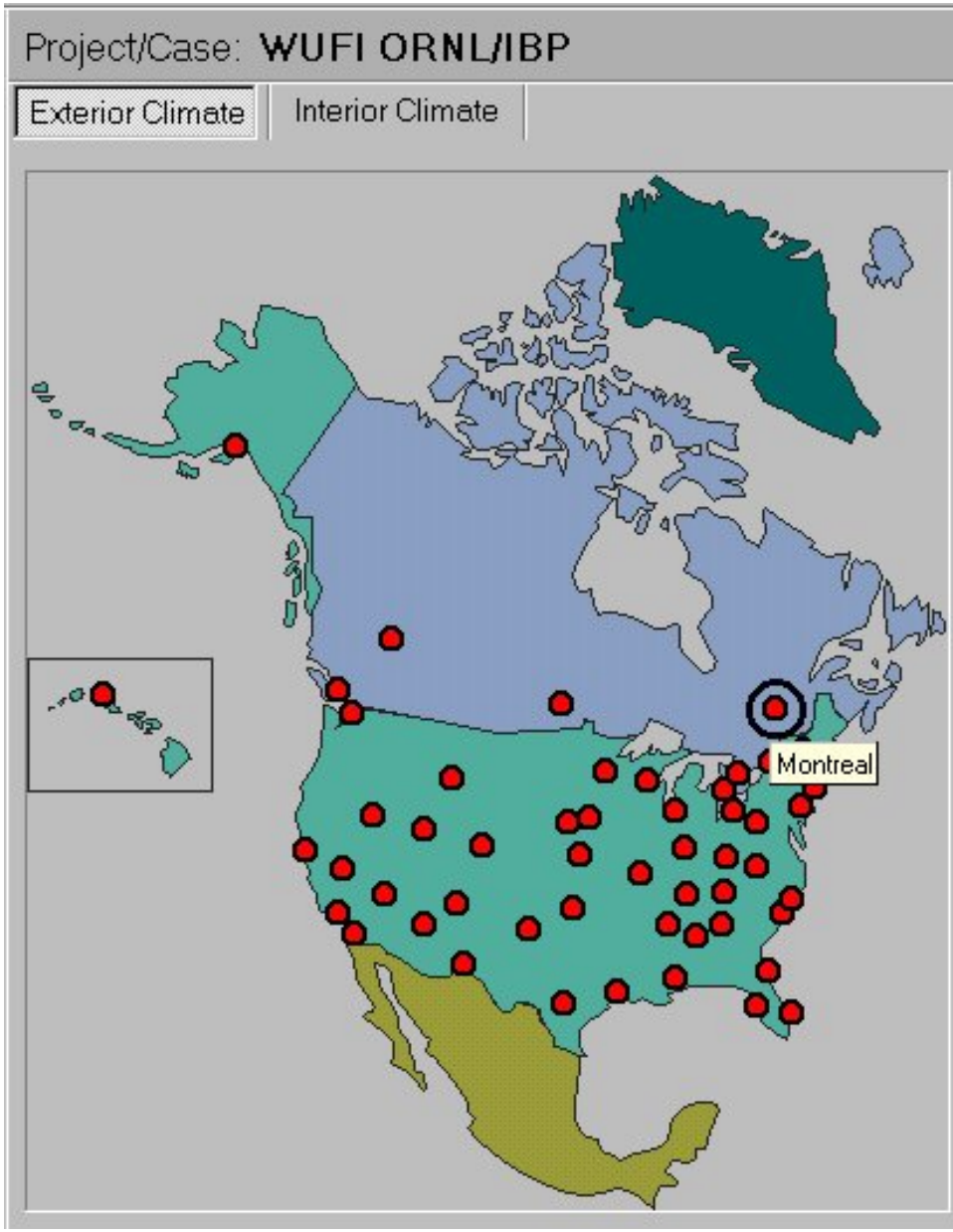
- Most Benchmarked Model





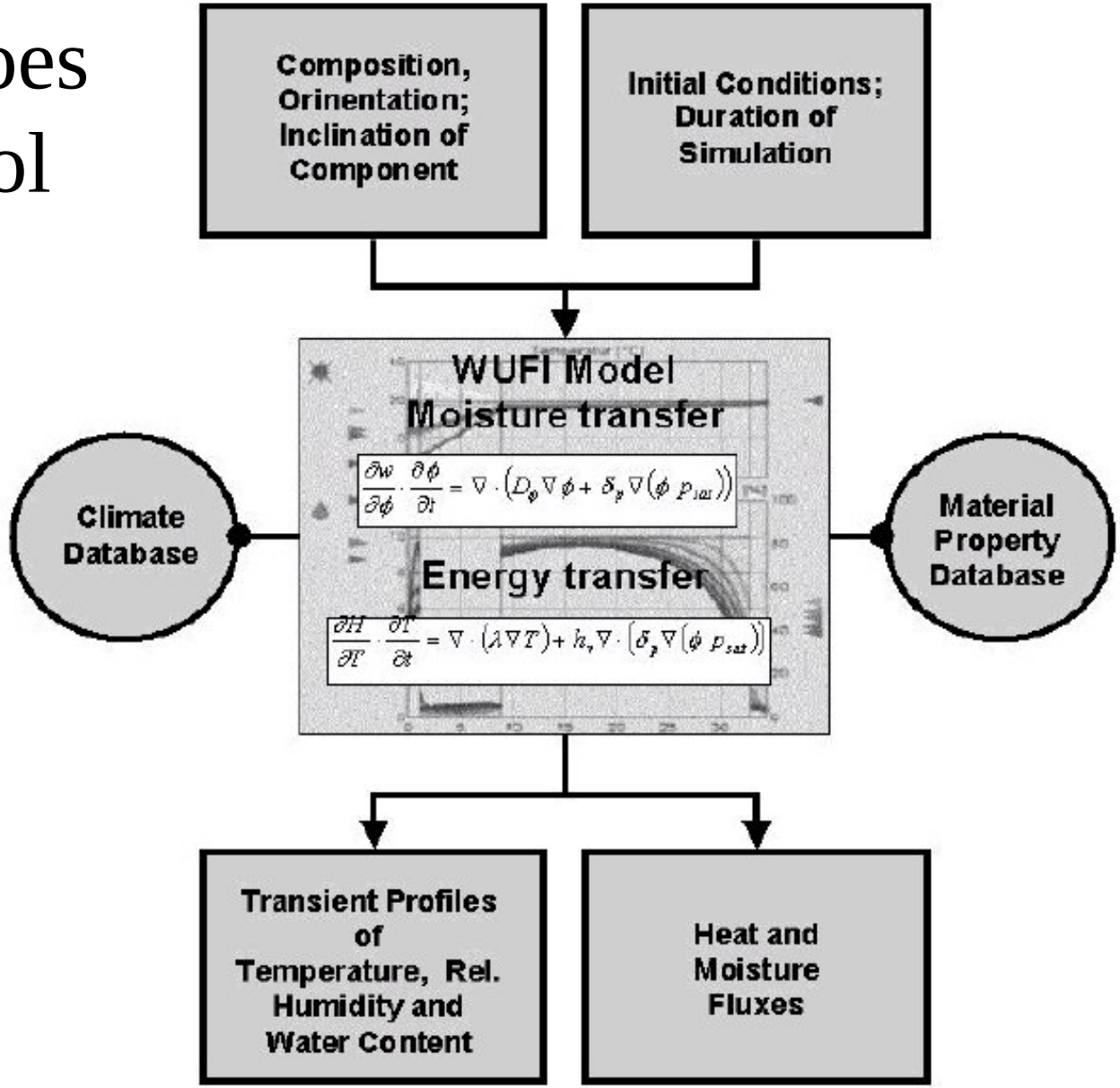
Weather Locations:

- 53 Locations for North America
- MDY (Moisture Design Years)



WUFI-ORNL/IBP

How does this Tool Work ?



Example Case:

Conventional Stucco

Mesh

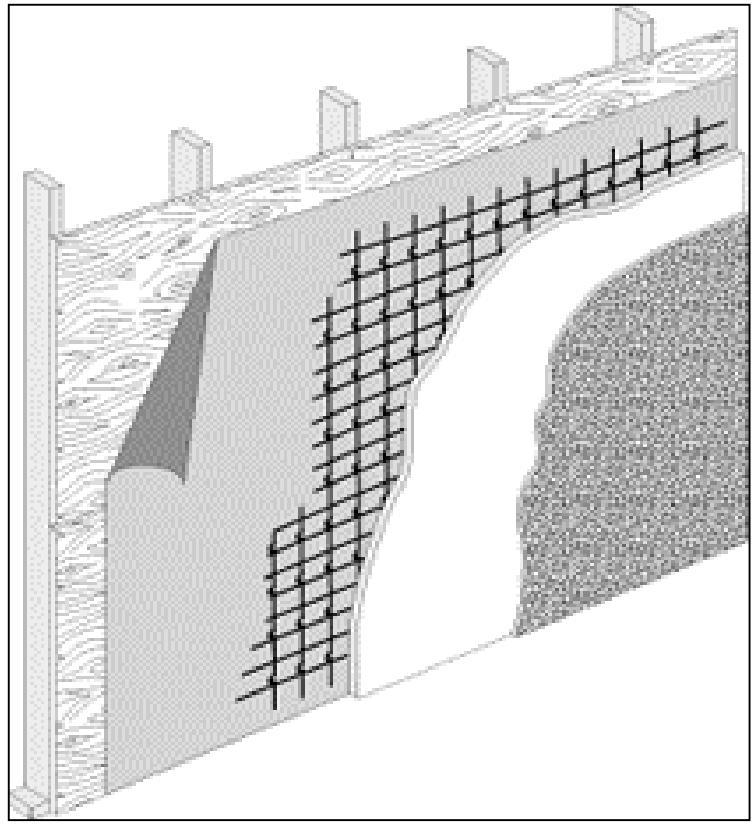
Building Paper

Sheathing (OSB or Plywood)

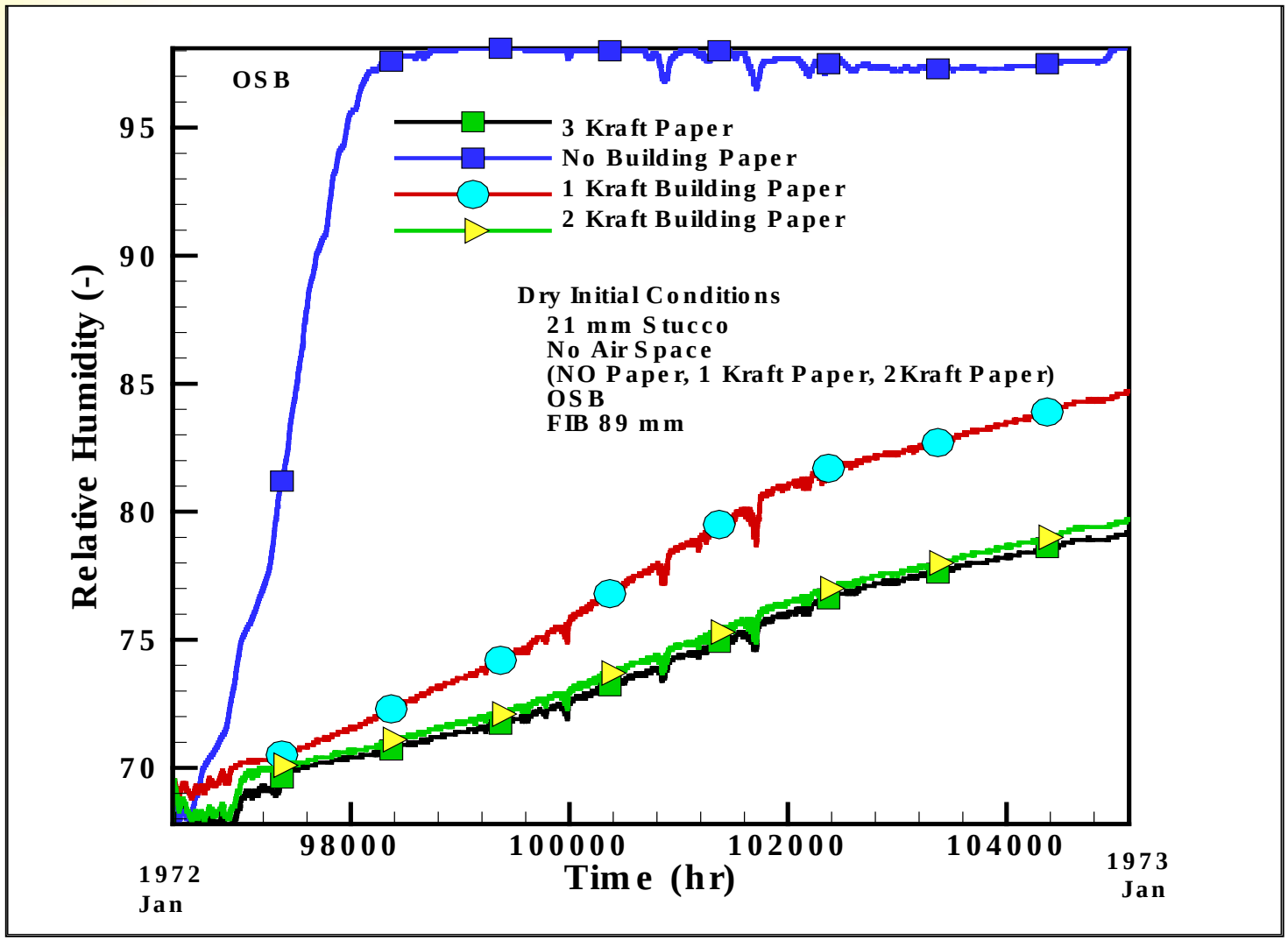
Insulation

Vapor Retarder

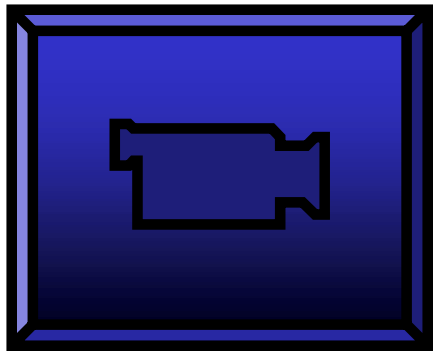
Drywall



Design Consideration of Exterior Weather Resistive Barrier



Let’s Take a Tour of WUFI-ORNL/IBP



WUFI-ORNL/IBP Limitations:

- Weather Data for Canadian Cities
- Material Properties & Sub-System Perf.
- Specific Inputs get Pro Version

Conclusions (Design Tools)

- Major changes in codes is expected the next 5 years

- A tool is now available for the first time WUFI-ORNL/IBP fully documented is available by ASTM MNL 40 (100 page User Manual)

- Material Properties will be upgraded by ORNL Expected to help better Understanding/designs

Conclusions Advanced Models

- Advanced Moisture Engineering was demonstrated

- New Moisture Engineering Approach SPC 160P

- Opportunity to customize material properties and sub-systems

And Don’t Forget : Don’t Use Fungi Impregnated Lumber