Tampere University
Finish Building Physics
Symposium 2015

Future of environmental control in buildings is based on the study of its history

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The history of environmental control in buildings

"That men do not learn very much from the lessons of history is the most important of all the lessons that History has to teach"

Aldous Huxley 1894-1963

English novelist and critic

Challenge: explain the future

by answering 10 questions about the history of environmental control in buildings

In the first 5 Q/A we show that the building physics does not lead but follows the construction practice

Q1 (1930's building science is born from the social needs)

What were the first two steps in the history of the North American building physics?

History of environmental control of wood frame walls -1-

Air barrier

U of Minnesota

1929-1932

Wind washing

Building paper

Weather barrier: wind, rain penetration, + heat loss reduction

Environmental control of wood frame walls -2-

Thermal insulation

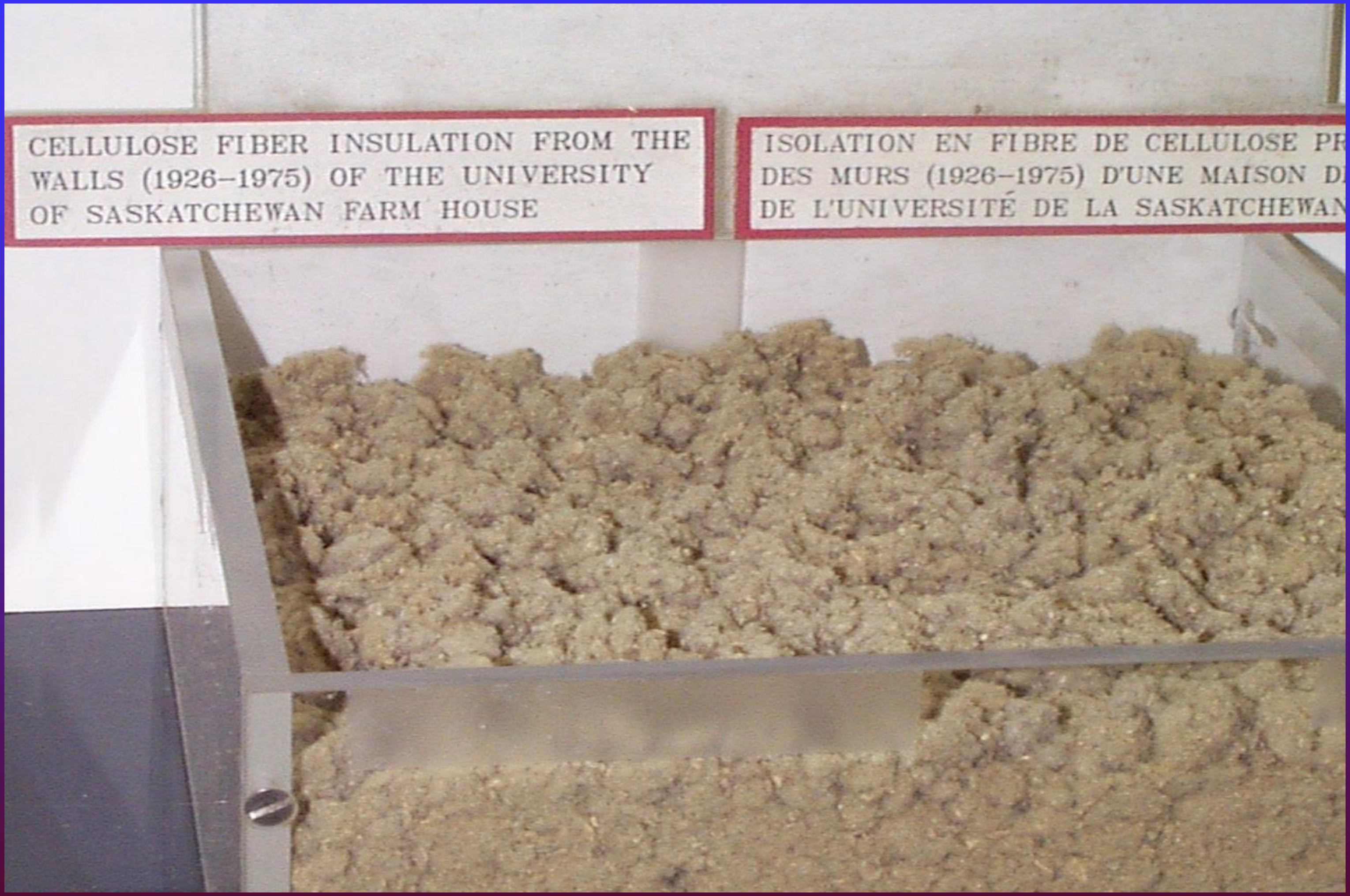
U. of Saskatchewan 1926 - 1929

Cold climate insulation

Cellulose fibre insulation

Thermal barrier: indoor comfort, heat loss reduction, reduced durability

Cellulose fiber insulation (since 1919) wall retrofit 1926, demolished 1975



Beginning of thermal upgrade, cellulose fiber insulation applied in1926

Q2

What happened when thermal insulation was placed inside the frame of cavity?

Environmental control of wood frame walls -3-

U. of Wisconsin

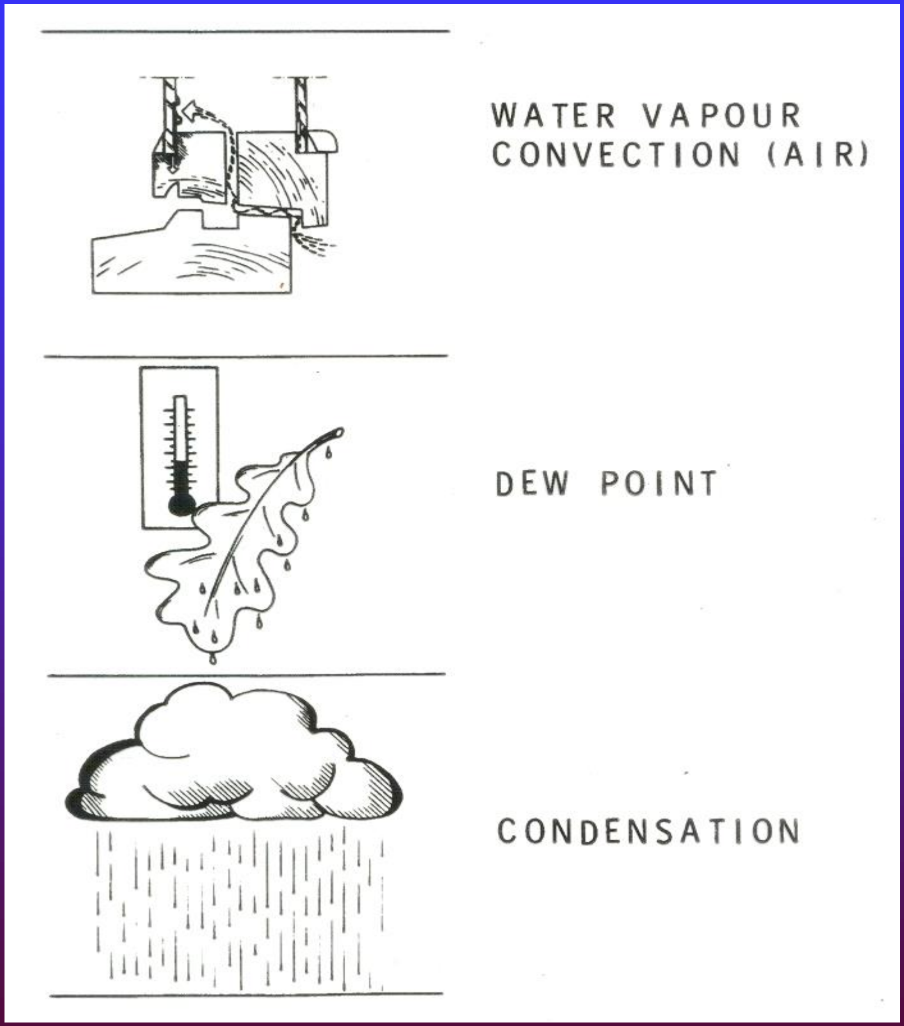
1934 - 1936

insulation lowered and condensation inside the wall

dew point took place

water vapor barrier to increase wall durability

Moisture in air: definitions

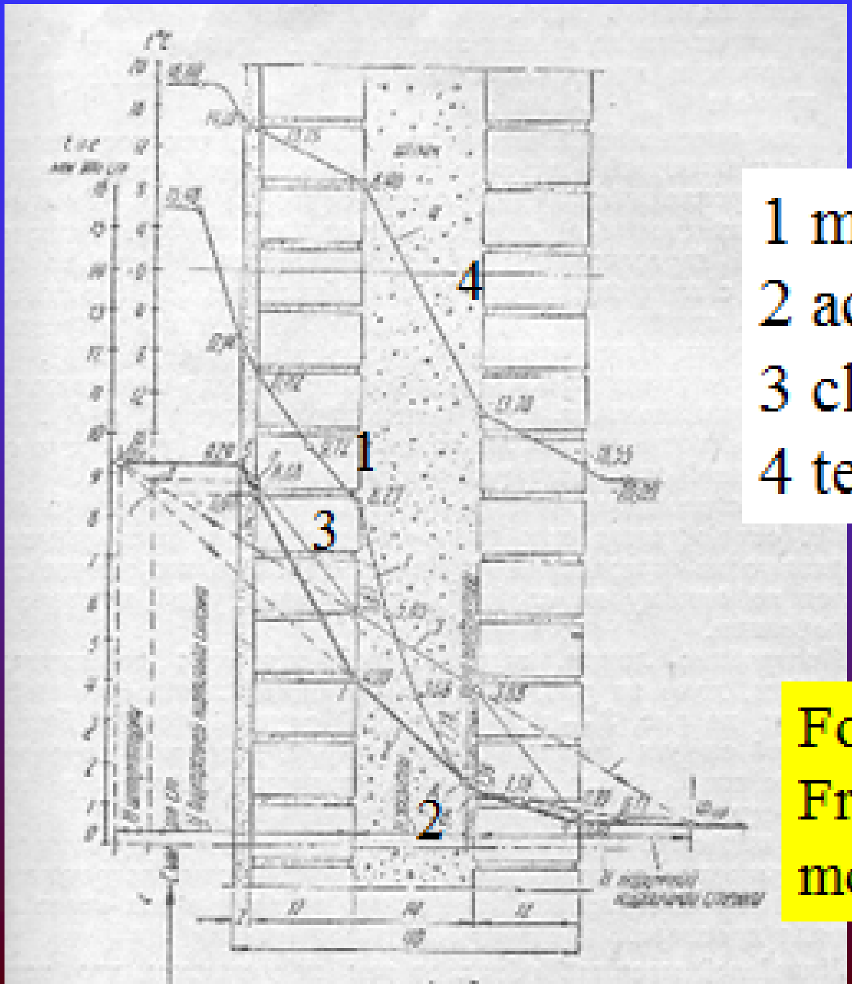


Papers published on condensation and diffusion of water vapor from 1938 to 1958

- Rowley et al (1938, 1938a, Rowley, 1939)
- Babbitt (1939) developed the theory of water vapor diffusion and condensation
- Hechler et al (1942), Teesdale (1943) and Joy et al (1948) provided information on material properties (1 perm = 57 ng/m^2Pa
- Fokin, 1953; Uszkow, 1955; Franchuk, 1958 presented models for calulating moisture movement

Knowledge about WV condensation since1938, but no action until 1958

F.W. Uszkow: Method to calculate moisture content in parts of the building enclosure, Moscow, 1955



1 max partial pressure
2 actual partial pressure
3 clay brick sorption
4 temperature curve

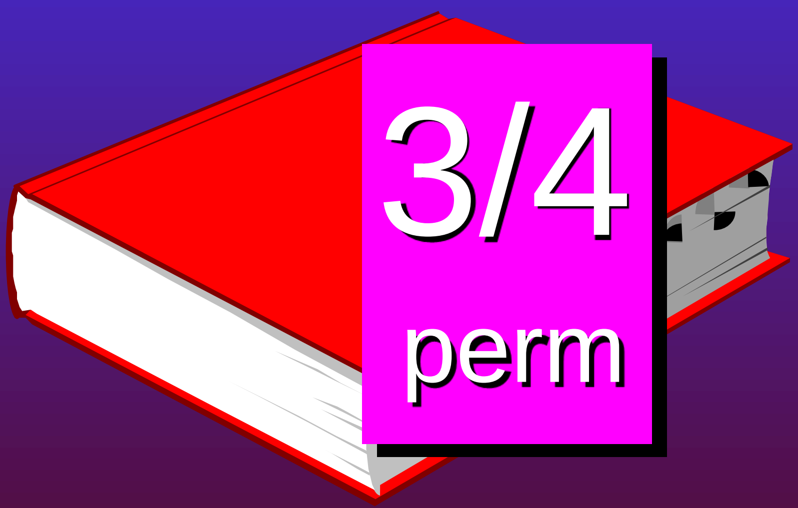
Fokin,1953; Uszkow, 1955 Franchuk,1958: etc know more about)

Q3

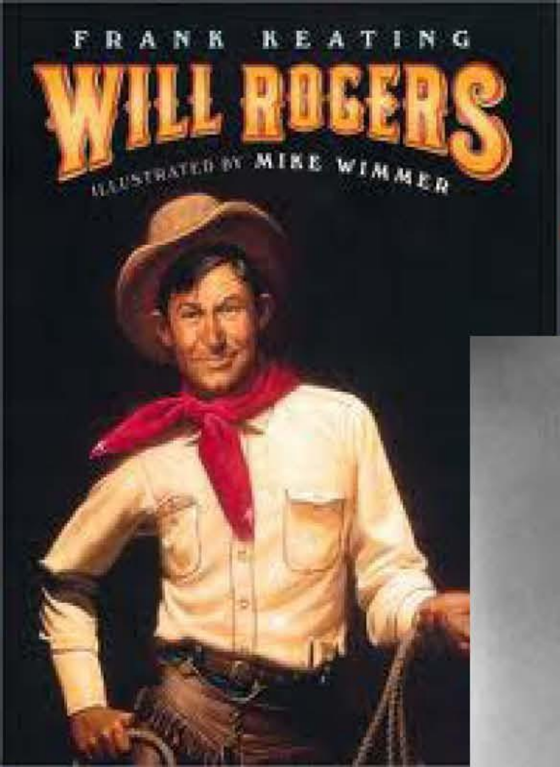
What happened when the moisture problems became more frequent in wood frame walls in middle of 1950's in the US?

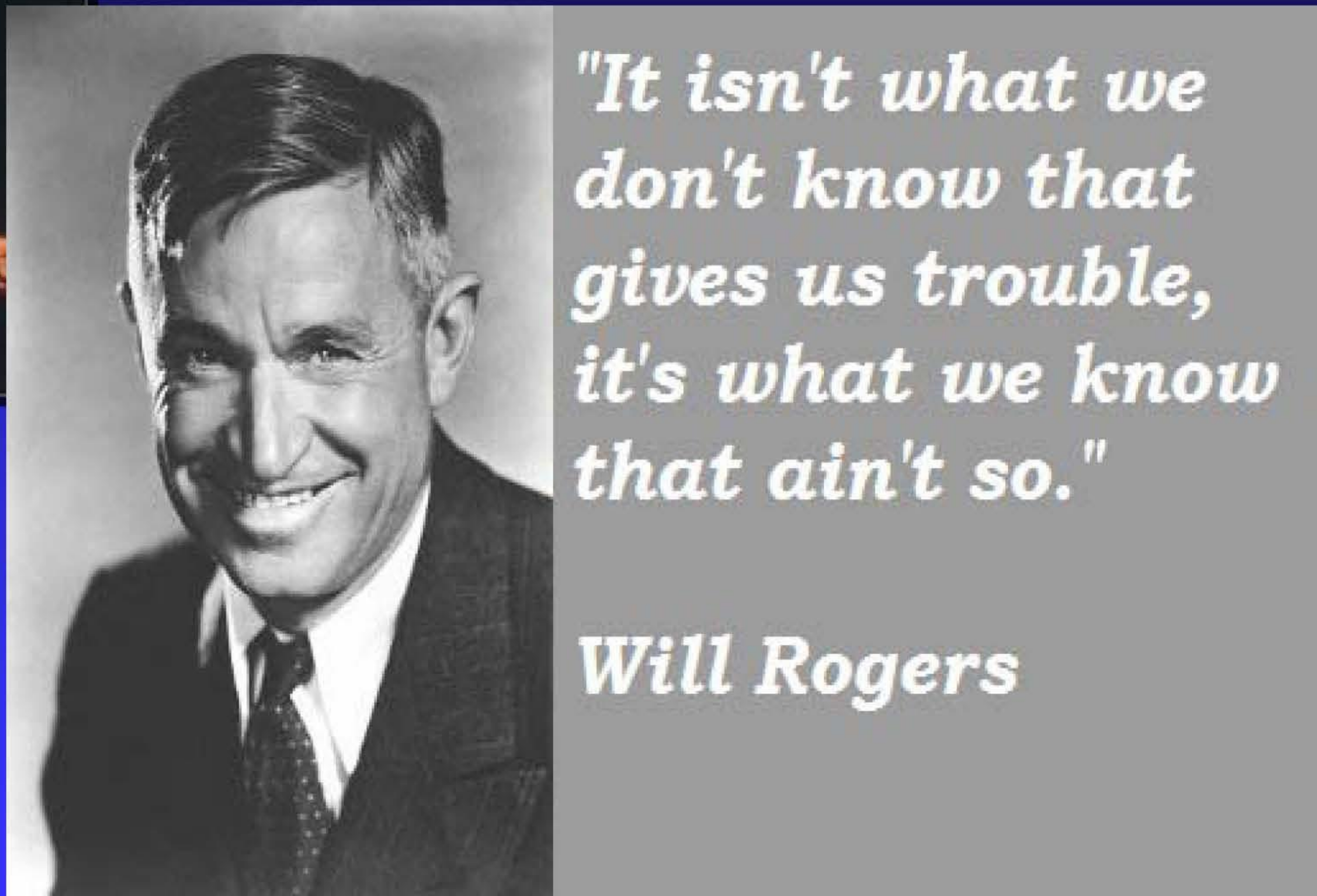
The tradition, though the simplified science, became the law (codes)

Water vapour permeance of a diffusion barrier



Cowboy, entertainer, philosopher





Why is the Glazer 's model not suitable for calculating moisture flux?

1. Water evaporates and diffuses further
2. Presence of liquid phase modifies the moisture flux
3. Condensed water also moves with osmotic, capillary and other forces

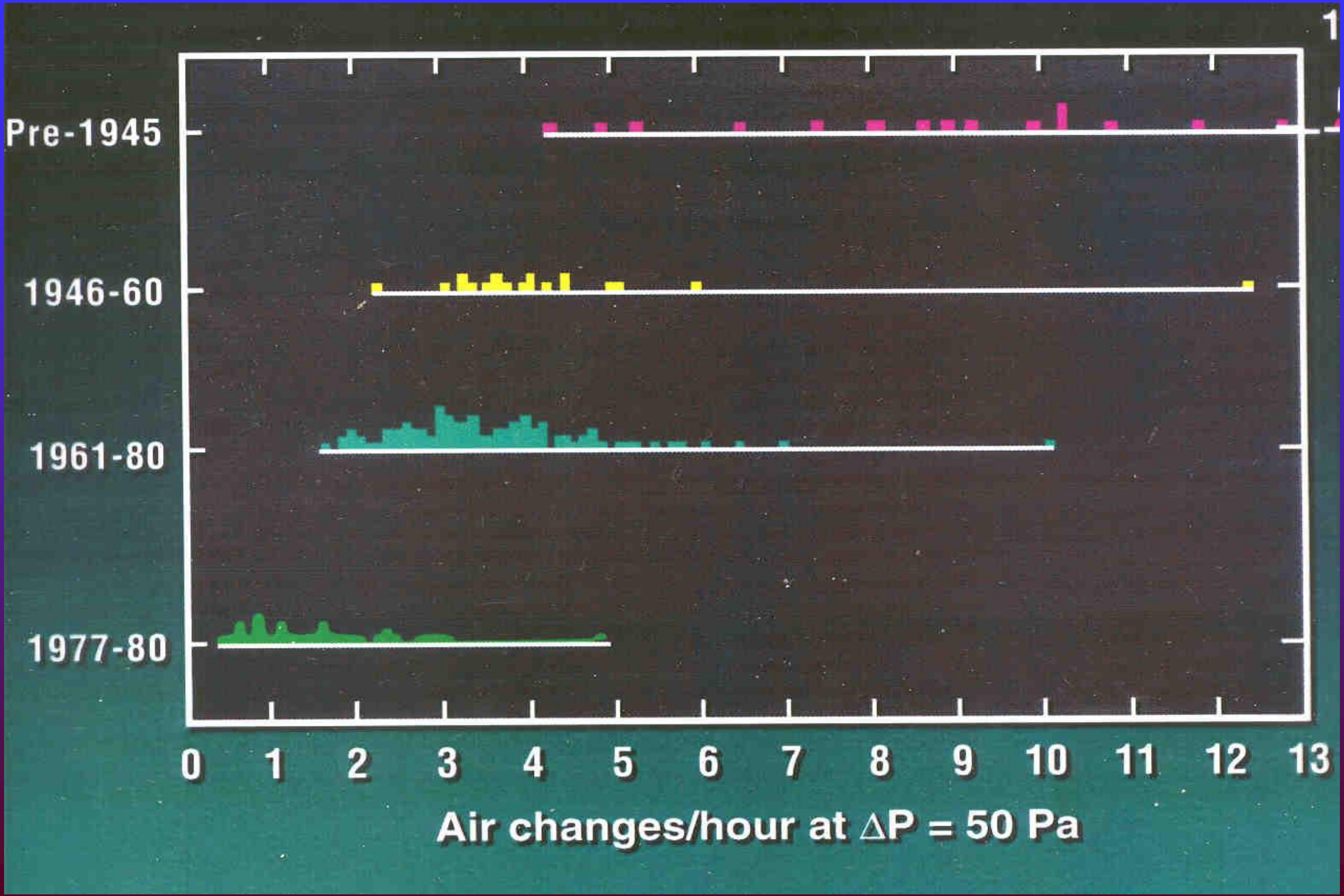
- In 1972 researchers at moisture center in Sweden showed it but all European codes used simplified science for making the real decisions

(nobody cares about science)

This confirms that the building physics does not lead the construction practice

But try to explain the failures of the practice

Air tightness increases with time because of construction practices



Moisture condensation when carried by air in exfiltration under the roof?

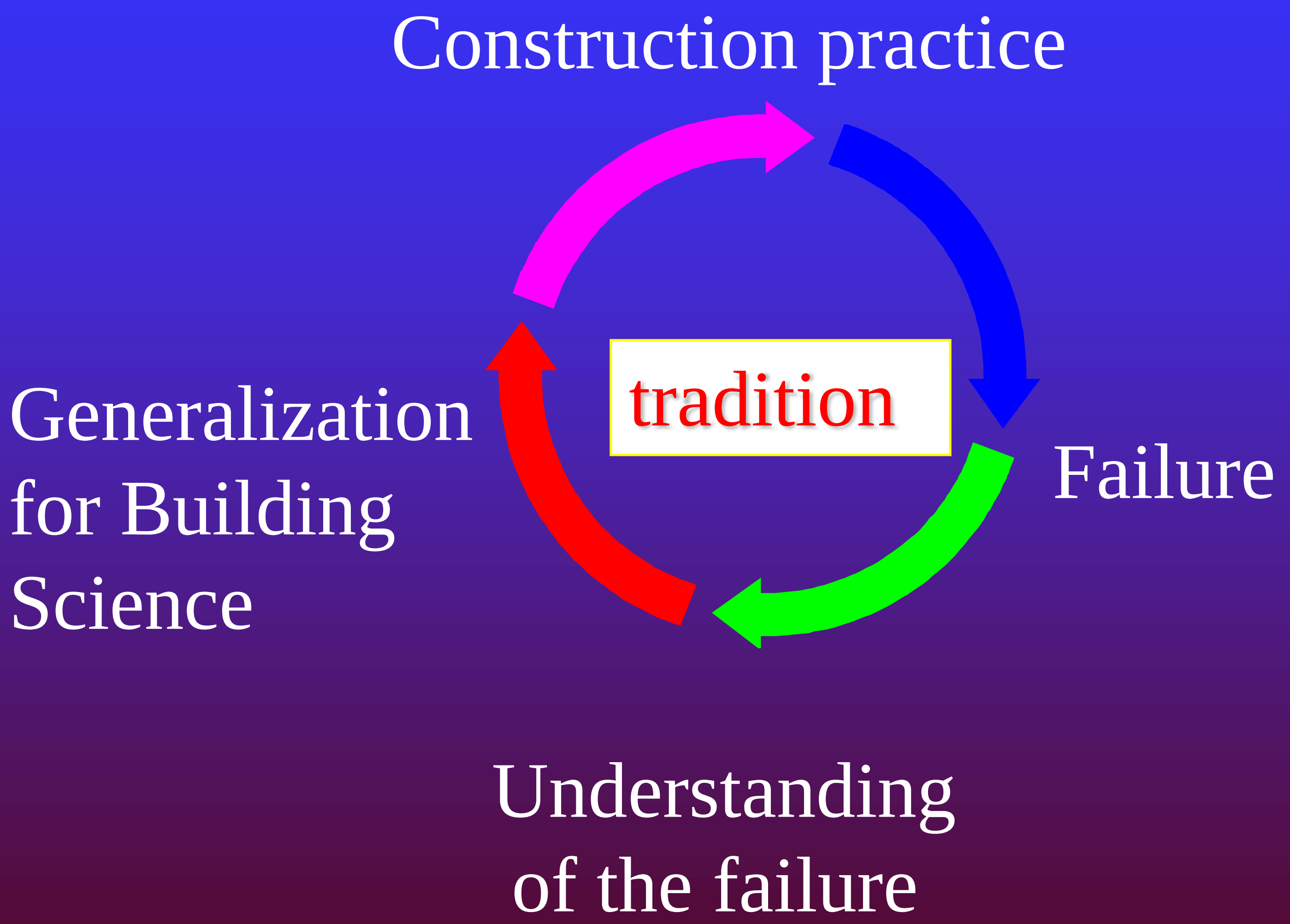
Q4

Why was the problem not solved in 1972 when we already knew all mechanisms of environment (Heat, Airm Moisture) control?

There are a few reasons:

1. Fragmentation of building process with NOBOBY in control of the whole building
2. Proliferation of new materials with unknown   NOBODY field performance because of predicting capability does not existed
3. Building physics that needed failures to define performance

System performance is defined only through defining the failure



Building science community understood the cause and effect

But it had no effect on construction because there was no linkage between building science and construction practice <u>as long as there were no failures</u>

Remember

the definition of performance!

Q5

Did we get enough failures?

Failures came plenty to the US and Canada

- Sick building syndrome = Canada's code all houses to have mechanical ventilation
- Leaking composite windows in USA = industry to have drained ETICS
- Leaky condo Vancouver , Canada = water managed stucco is required
- Introduction of the flue-less heating = public perception changed to "building as a system" a building envelope specialist – courses and certifications

Tradition: repairs are only undertaken when conditions are intolerable

Q6 (world reacts to global warming)

What caused the major change in the whole process of the building design and automatically changed the approach to building physics?

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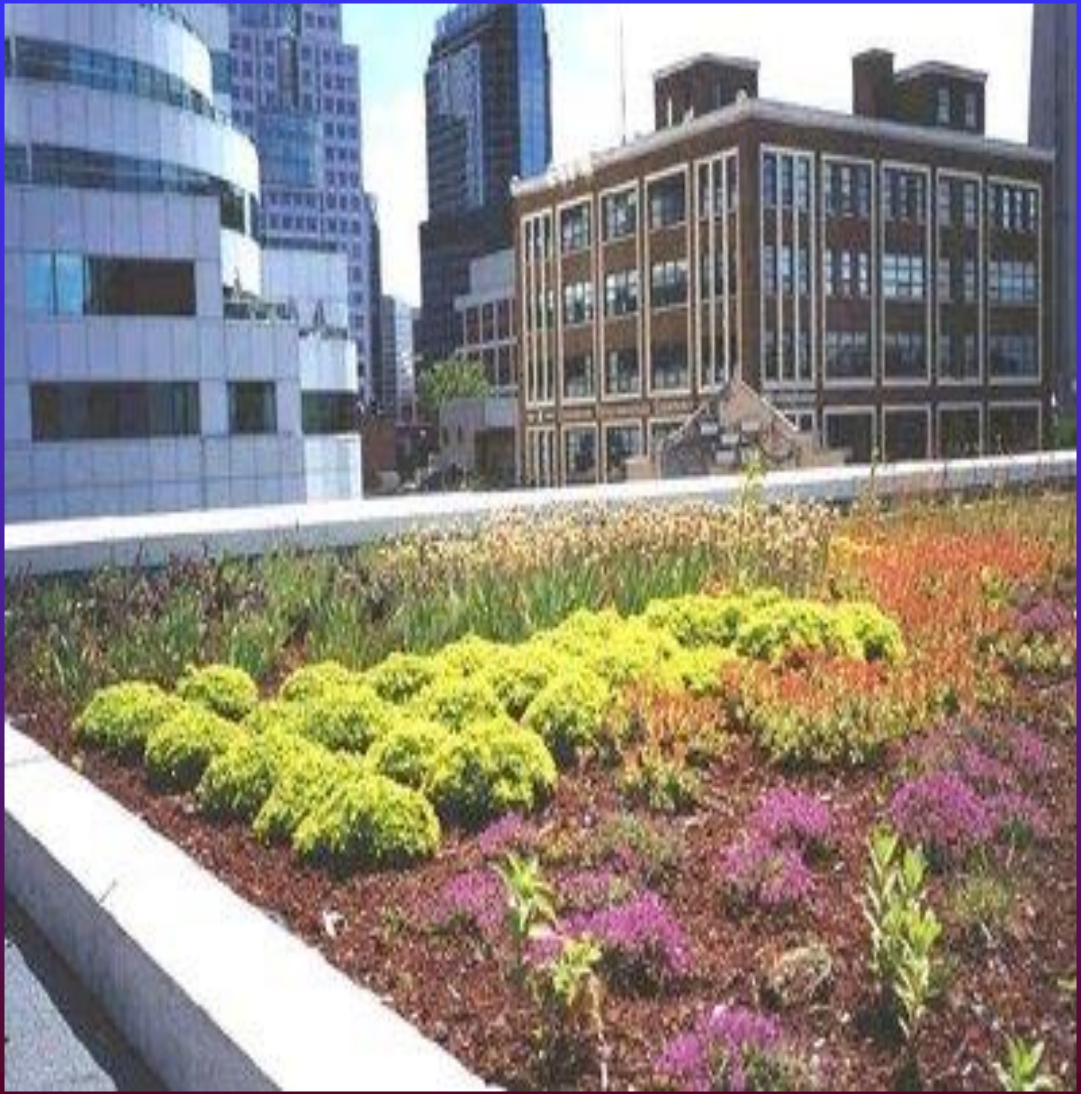
PART 2: The integrated solutions

A new proactive building physics
(Structure of the scientific revolutions by Stephen Kuhn)

Let' start with the end in mind: defining sustainability

Nature in the city

- Green roofs
  - Reduce cooling loads
  - Reduces rain run off
  - Reduces heat island effect
  - Cleans the air



(from Chris Mattock)

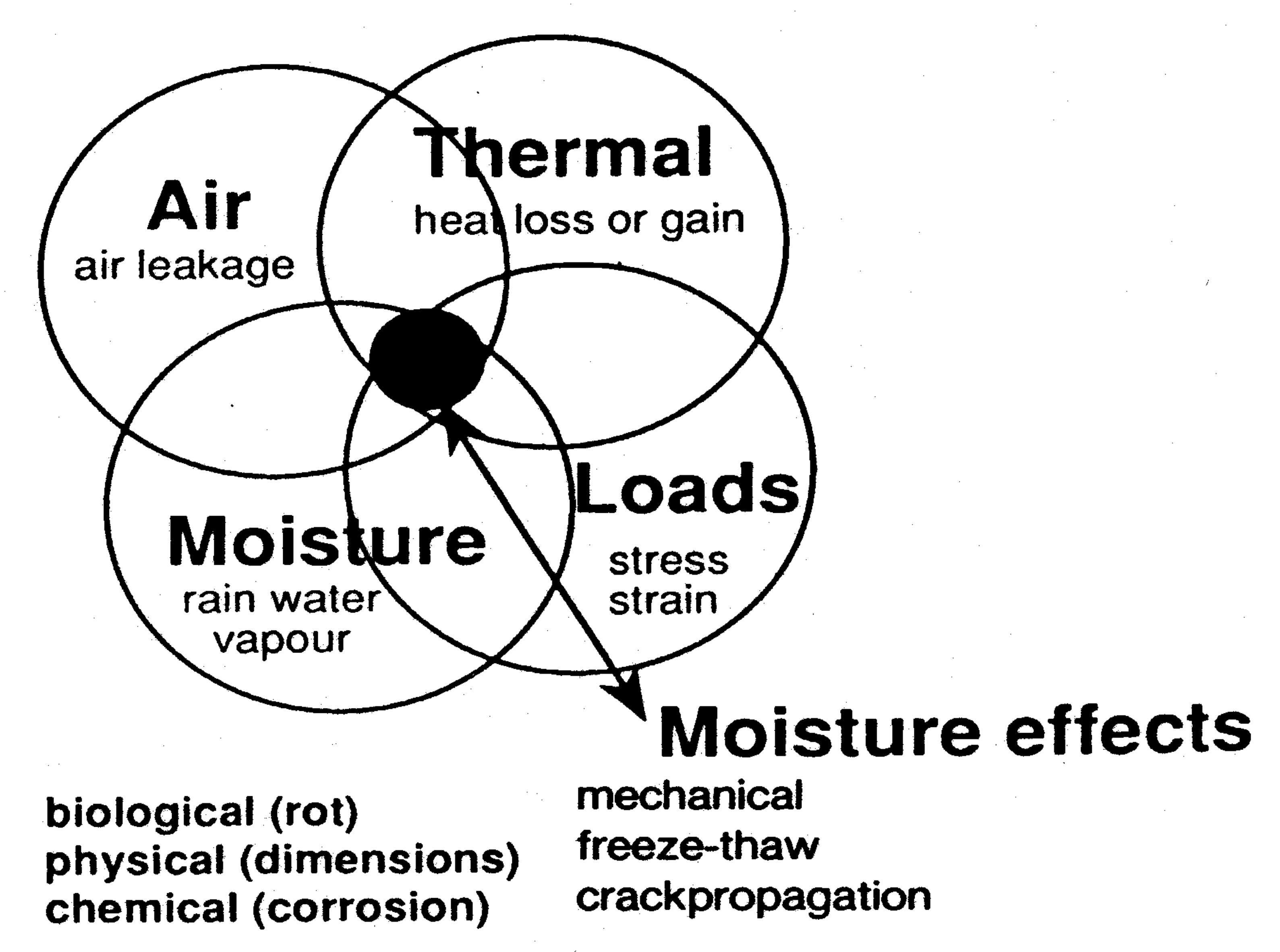
Building physics new vision to respond to the society call for sustainability

(from Mattock)

The integrated solutions

1) *Integrated Design Process (IDP) includes Energy Analysis and Life Cycle Analysis in pre –/ conceptual design*
2) *Integrated approach of building physics – use modeling for setting the criterion of performance (use limit states approach to durability and serviceability of buildings)*

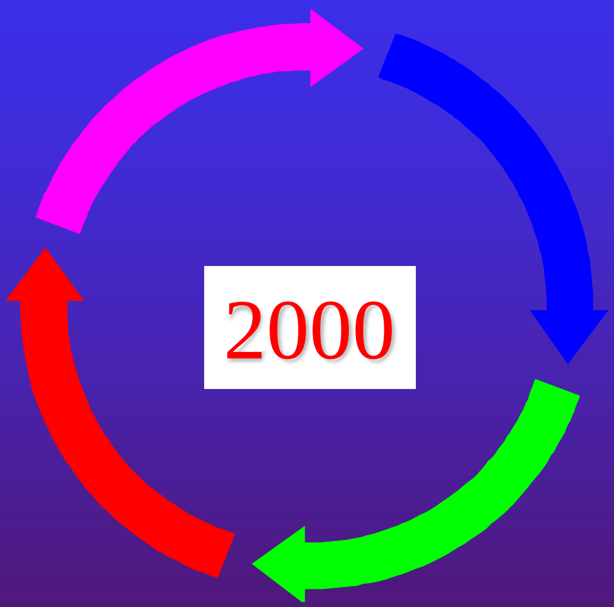
Damage is complex - includes both mechanical and environmental loads



Current building science deals with failures in terms of the probability

Construction practice

Building science



Simulated failure (test + models)

Failure definition and conditional probability

Why is building durability the key to urban sustainability?

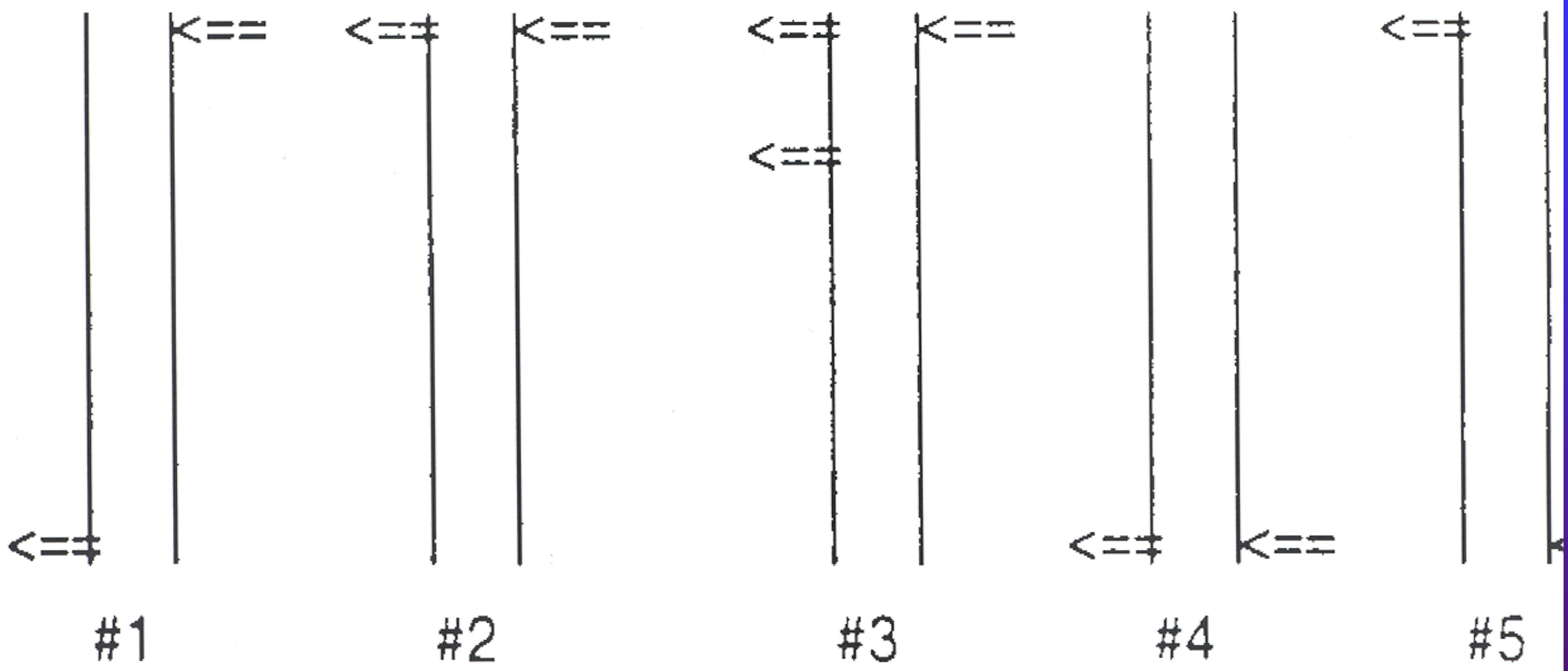
- Extend service life by 20% and count:

  1. Reduction in new construction means less infrastructure (roads, sewers etc)
  2. Reduction in energy for new materials
  3. This reduces new energy mfg plants,
  4. Saved energy is used: manufacturing
  5. Saved energy reduces CO_2 emissions

- Effect is 3 to 5 x – i.e., 60% to 100% more saving for the industrial society level

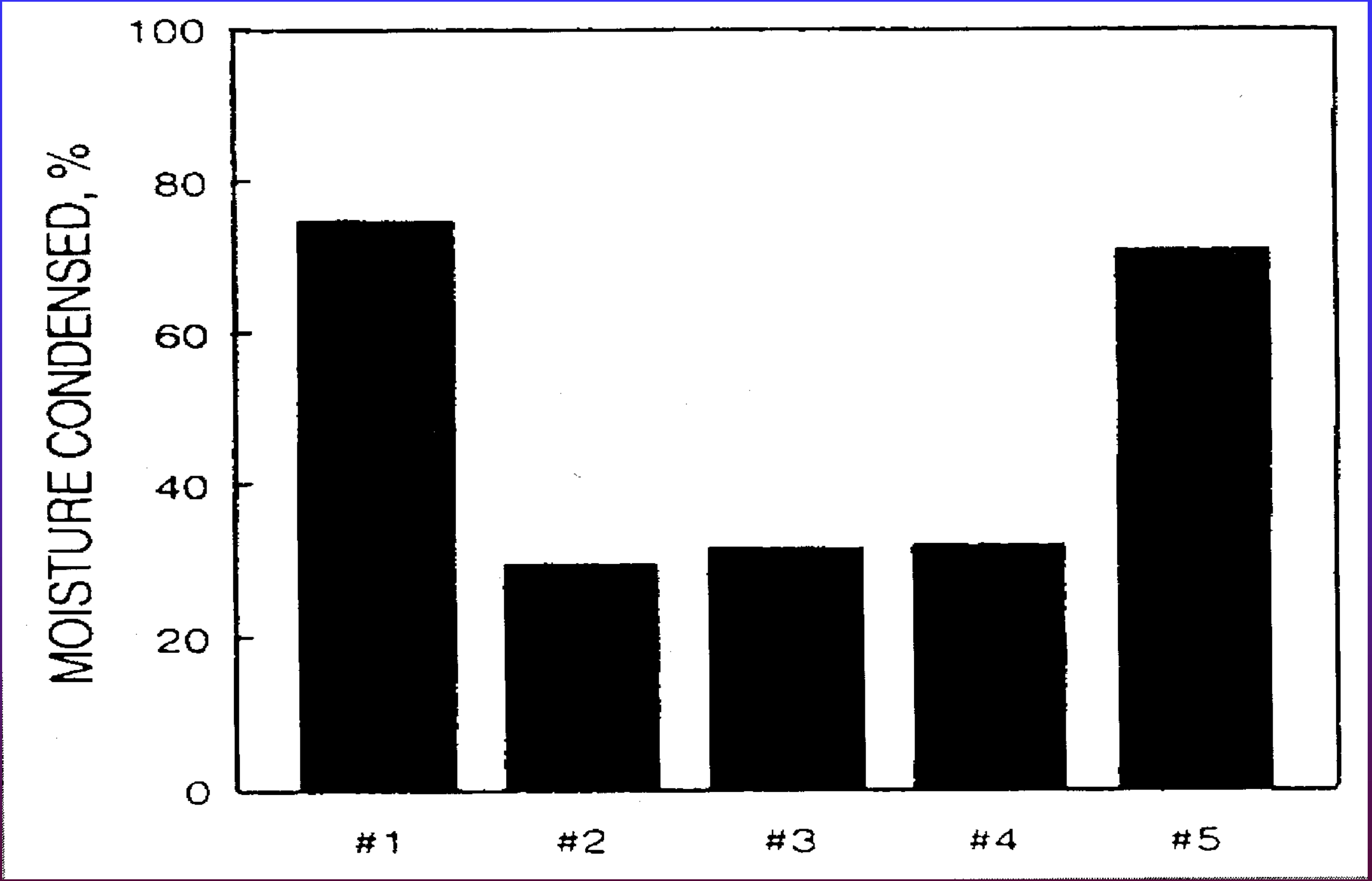
Modeling of the thermal upgrade with cellulose fiber insulation in1926

Air leakage to walls, effect of the flow pattern

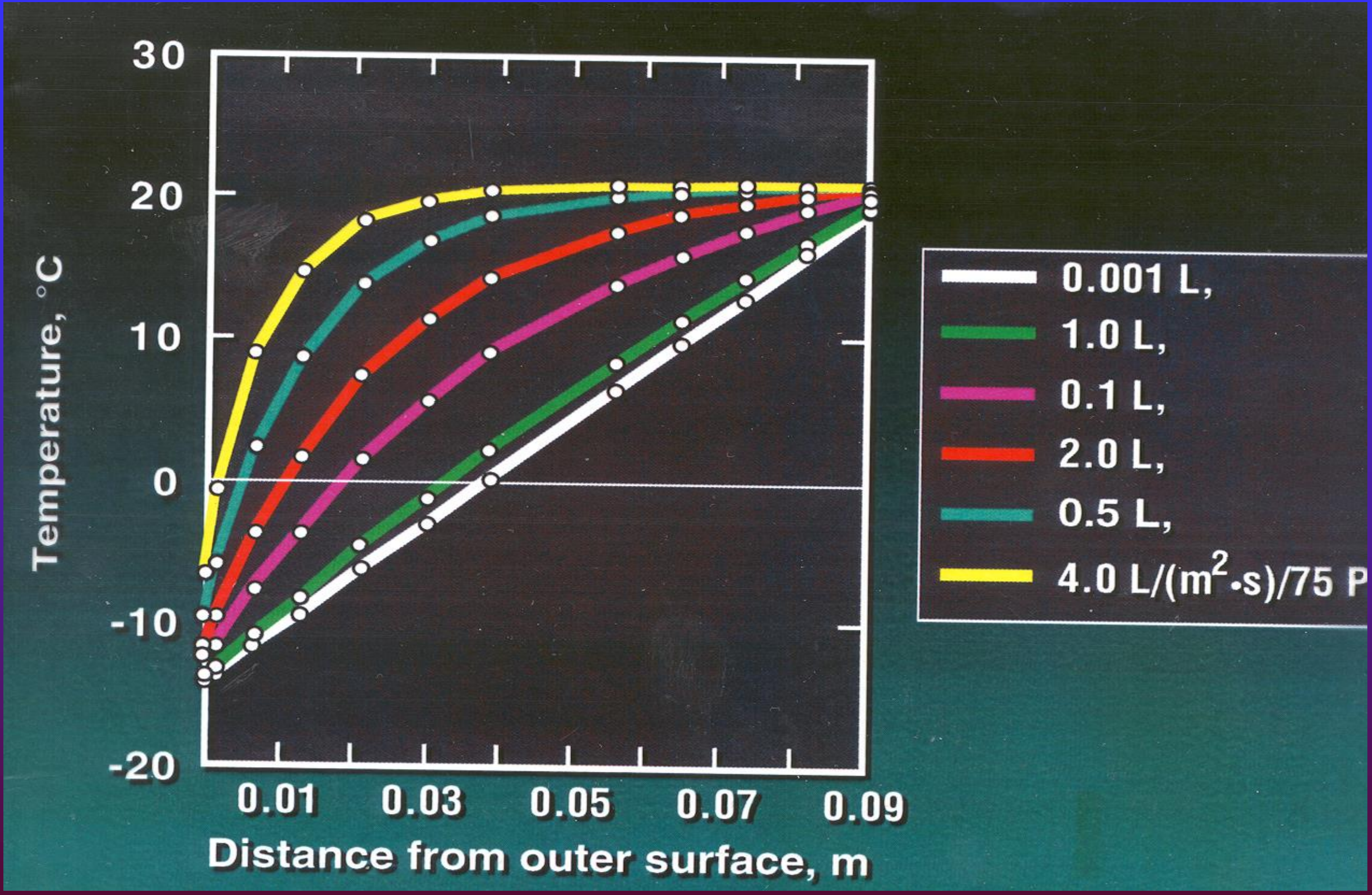


*/ Ojanen & Kumaran (1996) JTIBE p. 219

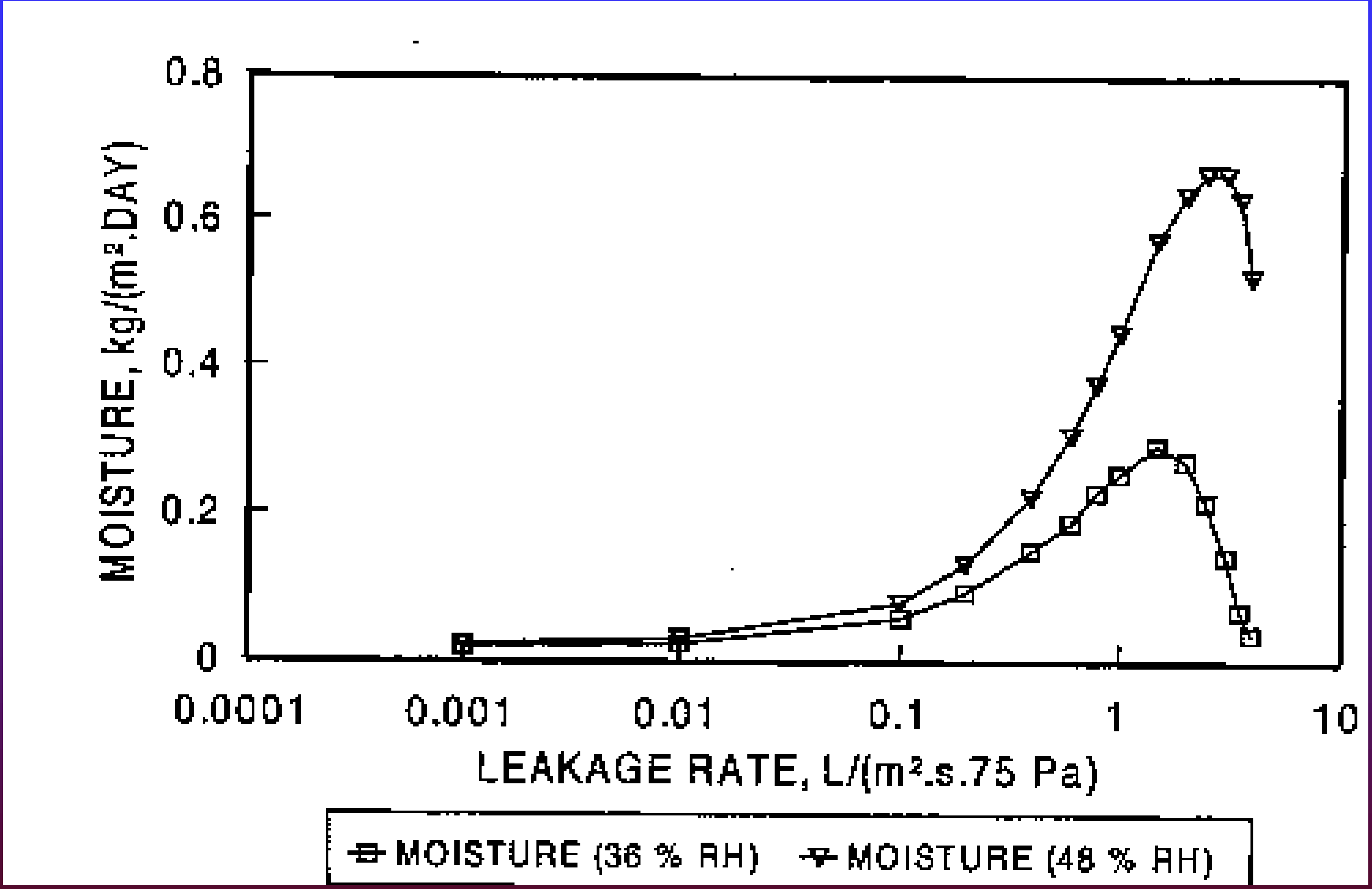
Condensation in those flows



MFI temperature profile during air exfiltration



Exfiltration of air flows warms the cavity and reduces the condensation



To define green buildings we need to quantify the following:

- *Building performance – particularly long-term performance = durability*
- *Quality of indoor environment*
- *Design life (service life) of a building*
  - *Note: performance means knowing the safety margin from conditions of damage; it can be evaluated for an assembly but not for a material*
- *Functions of local, regional and global ecosystems*

How to select materials for green buildings?

- Analytic approach e.g., BEES 3.0

Simplified approach:

1. Define alternatives
2. Review their environmental aspects
3. Review their contribution to the system performance

Application of BEES 3.0 to review alternatives

Cladding	A	B	C	D
Brick + fa mortar	0.0580	6.60	2723	41.4
Vinyl siding	0.0023	2.28	927	23.5
3-coat stucco	0.0026	2.63	1377	8.95
AA+ flying ash	0.0018	2.63	830	7.99

A = overall environmental performance
B = economic performance (cost)
C = global warming effect
D = embodied energy

So let's redefine green materials as these that can make a significant contribution to the system performance

Summary of the discussion on sustainability

We have learned integrated design process (IDP) because the society set the sustainability as the norm, but we still do not understand the principles of building

Q7

What are the principles of environment control in buildings?

Objectives

A1. Provide continuity of functions (heat, air, moisture, fire control etc)

A2. Provide redundancy (second line of defence, eg face seal or water resistive barrier)

A3. Integrate interactive effects with a view to optimizing performance (interior temperature depends on thermal mass, insulation, infiltration and ventilation, widows, etc.

Constrains

B1. Consider separate lives of components or assemblies (tall and small buildings next to each other)

B2. Consider flow of energy and fluids from high to low levels (high to low energy or chemical potential)

B3. Consider moisture-originated deterioration mechanisms (chemical, biological, deformation, strength etc.)

A balance between objectives and constrains

C1. Keep balance between continuity and separation

C2. Evaluate effects of heat, air and moisture flows (with or without inter-action with mechanical stress or strain)

C3. Use economic considerations for interactive effects (any specific problem can be solved by a combination of different actions; C3 needs more explanation)

Q8

Now, we have passive houses in Europe and zero energy buildings in North America, we must be on the road to sustainable buildings. Do we still have a problem?

Yes, we still have a problem

- *We are making similar simplification as we did in 1955; while the Passive House is a step forward it is not the complete solution, much like water vapor barrier was one of the elements of moisture management, but alone was not enough.*
- *On the other side, the Zero Energy Building is an objective or a solution, but without a road map how to reach it.*

It is not a product but the process itself that is the important issue

- Think about the field performance of a building as it was a quality of the building. Improvement of the quality is a slow and continuous process because our expectations grow with time and we need to develop a process for improvement
- We have to stop building codes using the same criteria for different buildings in various climates.

Q9

All right, but this process need to have the name and path through linking the critical steps of the design process;

what do you propose?

Buildings with High Quality Environment (HQE)

- The process has four stages:

1) Pre-design, what fraction of solar input makes economic sense in this case
2) Design passive house with thermal mass, thermal and moisture buffers
3) Design geothermal and solar thermal contribution
4) Design PV contribution to the energy

Q10 (Engineers want to have demonstration of the concept)

Can you give us an example of the real case?

Example of the process

- *Dynamic mode of building operation that include temperature floating (6 oC) with thermal and moisture buffering*
- *Walls and windows are adjusting thermal resistance to the weather*
- *Integration of Building Enclosure and Heating, Cooling and Ventilation.*

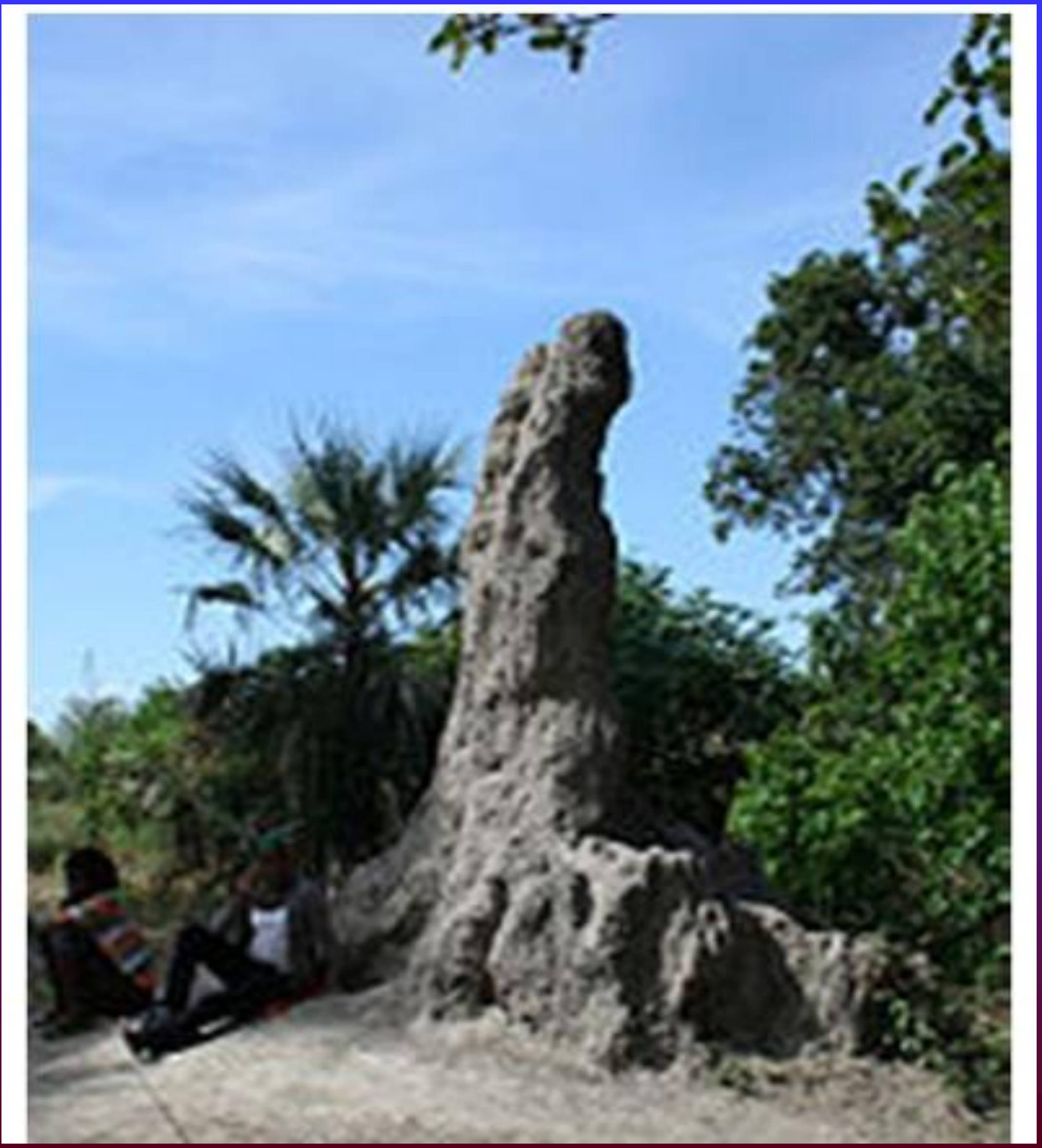
Note: Termites do not have HVAC and they manage to control T within 1 o^C

Passive house with large windows will reqire large interior mass and cooling

This requires: (1) Hydronic heating and cooling on interior walls that increase mass and provide asymmetric control

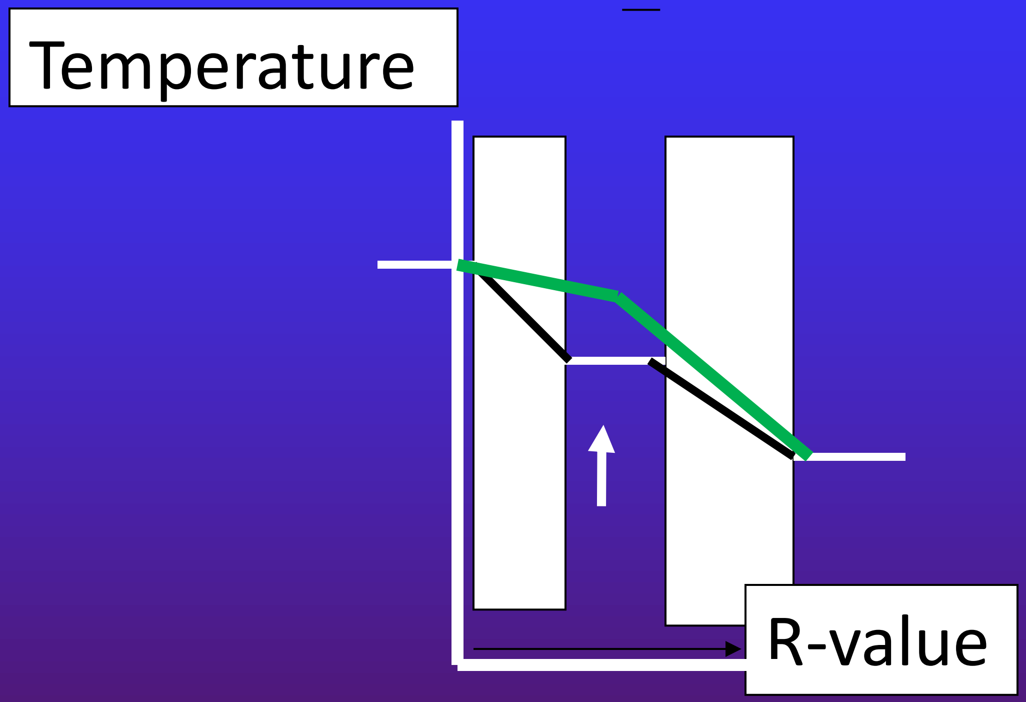
(2) Balanced central ventilation (heat distribution) and (3) individual ventilation: air intake is near the floor, ventilation groves made during the manufacture of polystyrene insulation and exhaust above windows

Geothermal pre-conditioning of air



A multitude of ventilation channels and geothermal pre-conditioning of air allows termites to maintain a constant temperature within one degree Celsius

Interior hygrothermal panels integrated with HVAC



Green line – preheated air in the cavity, result in different heat flux to and from the air cavity

Switchable insulation and mass for mixed climate located buildings

- *Ventilation with geo-conditioned air may warm or cool the layer of thermal insulation*
- *Introducing a temperature sink/ source in the middle of the wall causes the difference between het flux entering and heat flux leaving the exterior wall and allows using low grade energy sources*

Proposed design of the direct outdoor air supply (DOAS)

- *Central air intake for a large part of building, with air filters, dehumidification*
- *Delivery through small diameter, high velocity, flexible ducts (stairs, corridors)*
- *Intake at floor, exhaust of quiet ventilators above each window operating manually or on sensors for the night ventilation*
- *Exterior wall is a heat exchanger, no HRV*

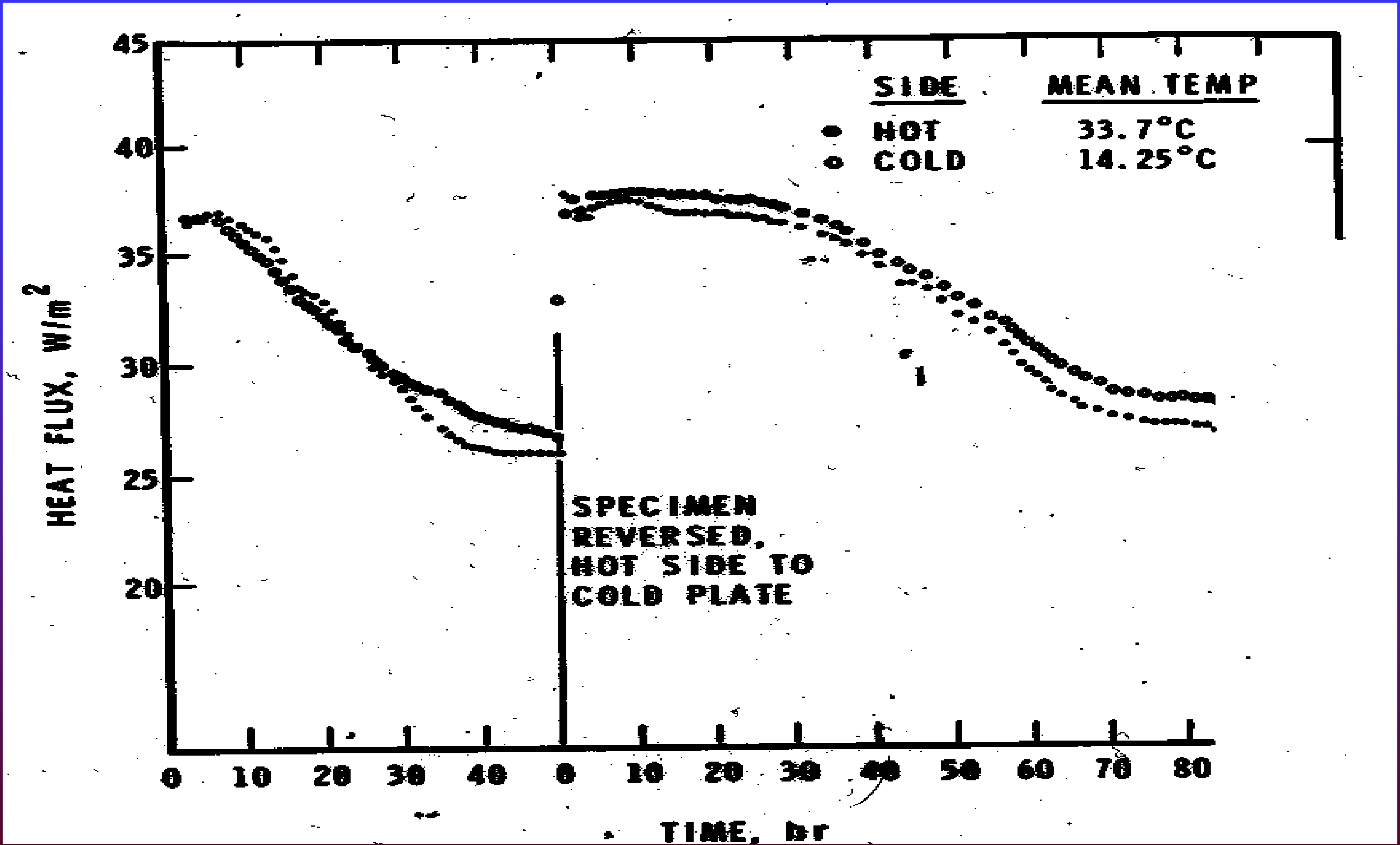
Hydronic heating /cooling added on the interior walls or on the floor

- Hydronic heating /cooling panels should be in contact with thermal mass and the interior walls or floor are preferred
- These panels should be integrated with solar thermal collectors and water to water heat pump so that all solar energy is used for domestic hot water or for warm terminal of HP during the cooling season. A switch to allow heating instead of cooling is a part of control system.

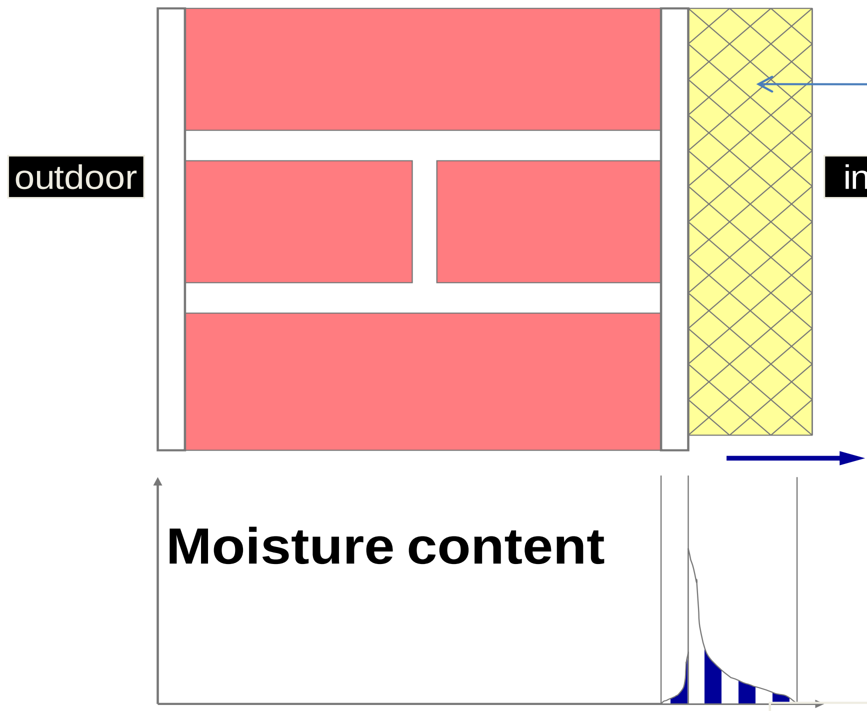
Termites again

Even without underground storage but involving air movement with a phase changing of water termites live without HVAC.

From quasi-steady state to the dynamic equiliblium at the same MC



3.6 Hygrothermal insulation intoduced as capillary active layer (Haeupl, 1999)



Open for diffusion
a capillary active
thermal insulation

Capillary forces brings back the condensed moisture

Moisture condenses on the cold side

Functions:
- **Moisture protection**
- **High capillary activity**
- **Thermal protection**

Conclusions -1-

- Reviewing the history of Building Physics we saw that technology development based on market forces takes many generations to achieve progress
- Only one aspect is addressed at the time , e.g. the American LEED program dealt with ecology alone and because of social pressures included energy efficiency
- Sustainability requires 3 considerations: ecology, social and economics

Conclusions 2

To address the new socio-economic agenda of sustainable built environment the building physics must now complete the transition to become ***a proactive science leading the construction development of low energy buildings through the system integration***

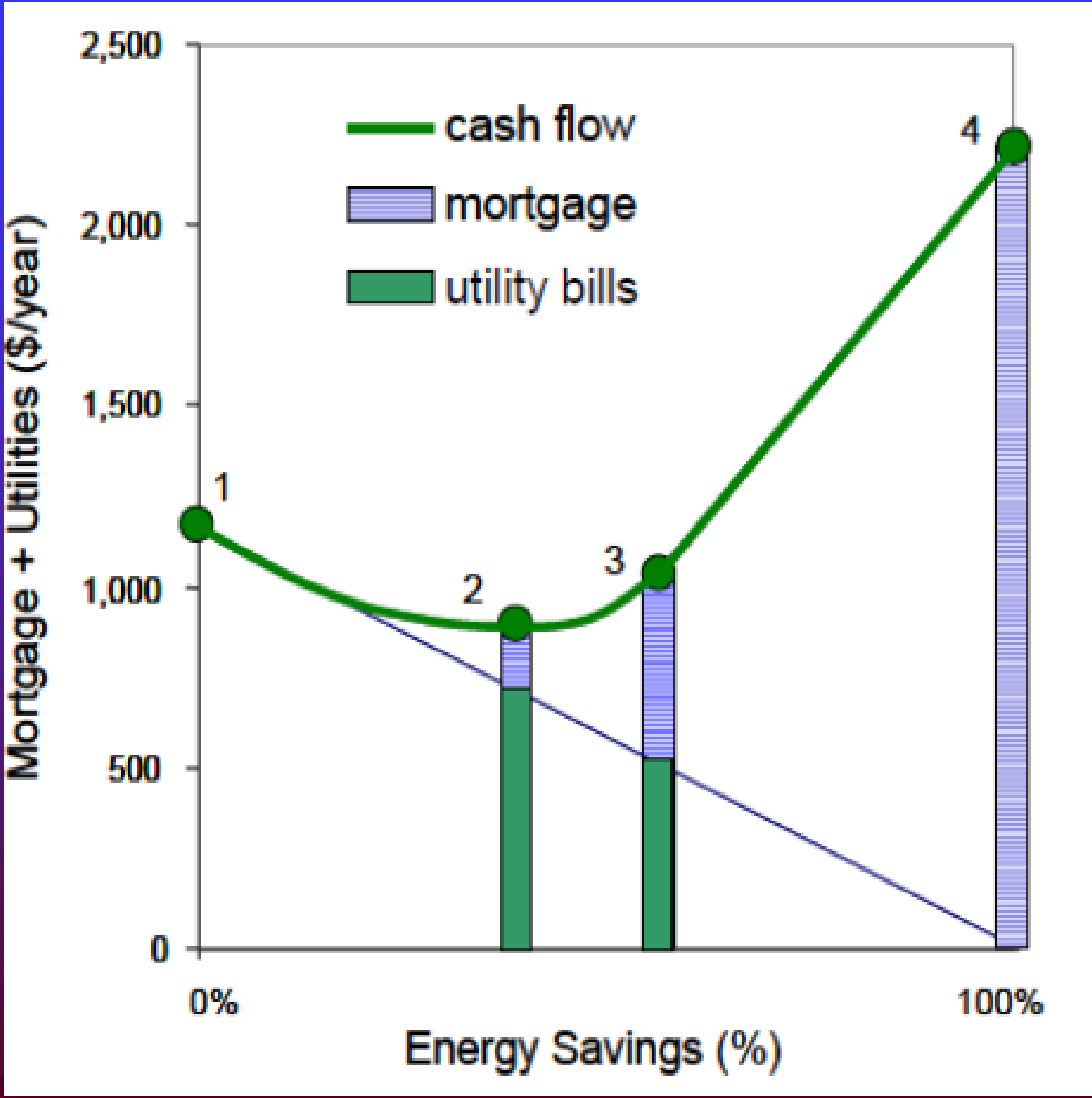
Conclusions -3-

- *Sustainable design includes energy efficiency, durability and the occupant well being*
- *We saw significance of design with air gaps:*

1) *On exterior = ventilative cooling and capture of solar thermal energy in winter*
2) *On interior = for indoor environment air quality and moisture control and as the heat exchanger for the exhaust of the ventilating air*

- *Water based HP with hydronic wall heating is also a trend of future*

Analysis of German PH buildings



For a given weather and local economics
2 = optimum of the passive measures,
3 = PV becomes more economic than further passive measures
As weather changes so the break point of PH criteria

Thank you for your attention