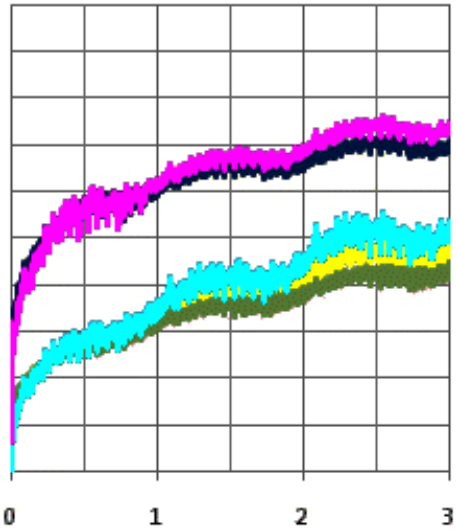

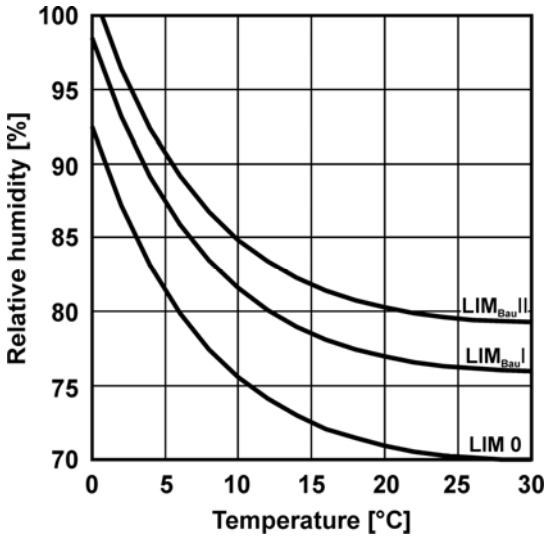

Hygrothermal simulation study

that raises questions about domestic retrofit standards and energy targets

Joseph Little - MRIAI, BArch, MSc Archit. AEES

Overview

- Building Life Consultancy
- What is hygrothermal assessment?
- Dew-point assessment vs. numerical simulation
- Demonstrating the importance of hygrothermal simulation:
  - a case study

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Building Life Consultancy

Joseph Little Architects formed in 2003 - low energy, airtight focus

Masters in Centre for Alternative Technology, Powys, Wales

Increasing focus on primary research, & teaching

Building Life Consultancy formed as building fabric-focused consultancy in September 2009

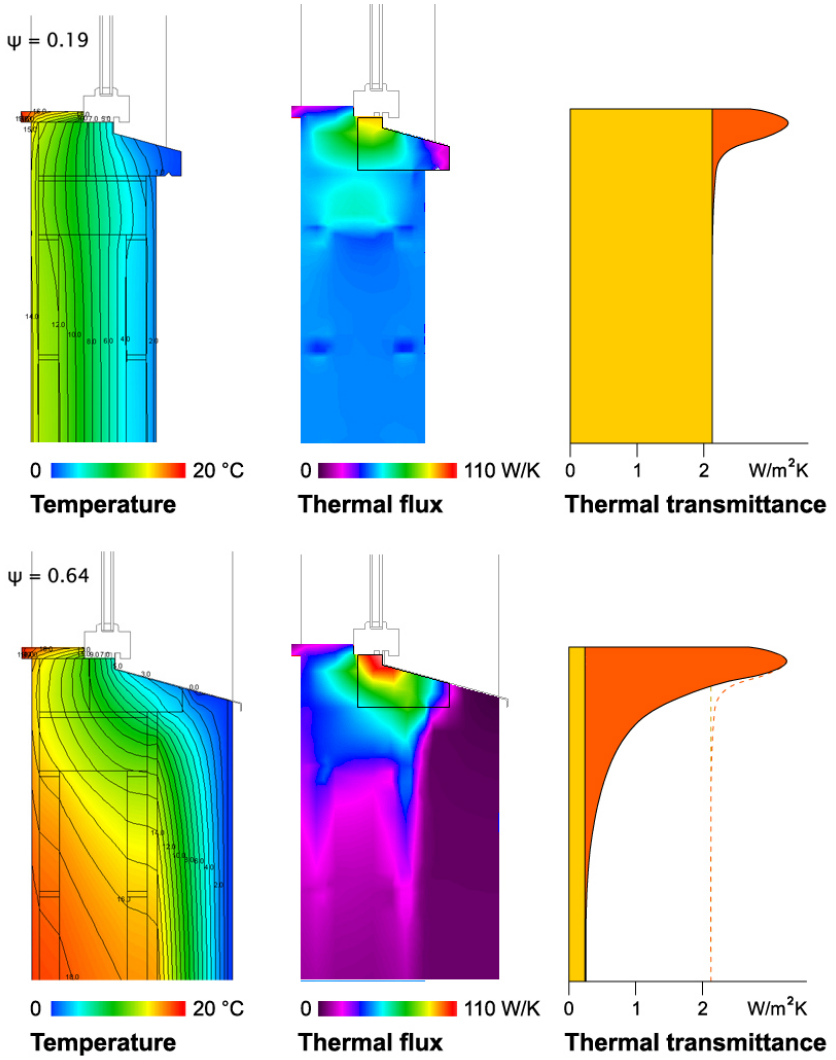
'Breaking the Mould' articles I – V & 'Top Tips' in Construct Ireland magazine

Advising local authorities, & UK & Irish manufacturers & architects

Providing independent inter-stitial condensation and insulation support

Helping Industry create new products

Creating courses for architects and builders for building to higher standards



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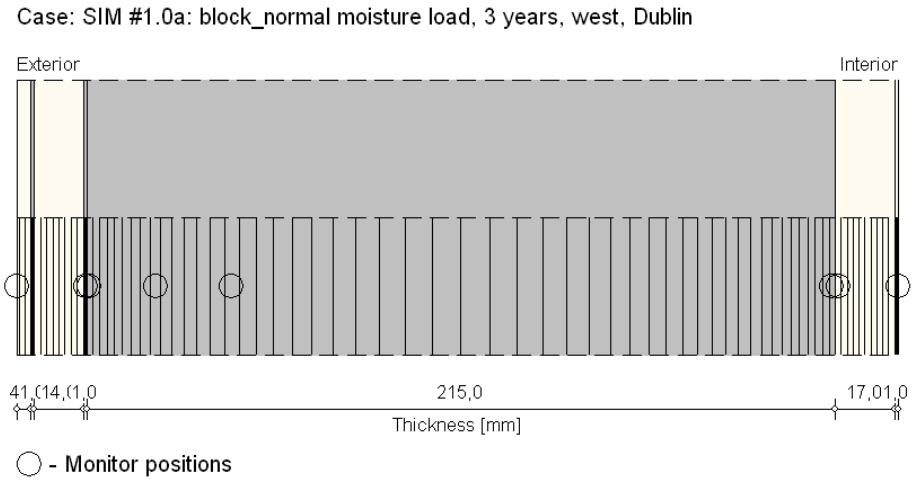
What is Hygrothermal Assessment?

Hygrothermal assessment is the analysis of heat, vapour & moisture transfer through building elements.

It provides valuable information relating to:

- Temperature
- Relative Humidity
- Water Content

within multi-layered building elements over time.



Results of hygrothermal assessments provide important information for:

- Surface Condensation Risk Assessment
- Interstitial Condensation Risk Assessment
- Energy impacts

What is Hygrothermal Assessment?

Surface Condensation Risk Assessment

- Damage to Interior Finishes
- Surface Mould Growth

What is Hygrothermal Assessment?

Interstitial Condensation Risk Assessment

- Damage to Exterior Finishes

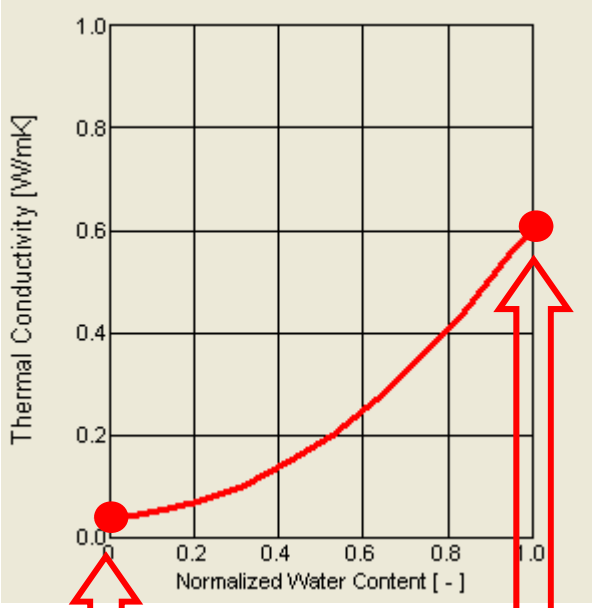
  (Due to Freeze/Thaw Cycles)

- Interstitial Mould Growth
- Structural Damage

What is Hygrothermal Assessment?

Energy Impacts

- Moisture Dependent Thermal Conductivity/U-Value



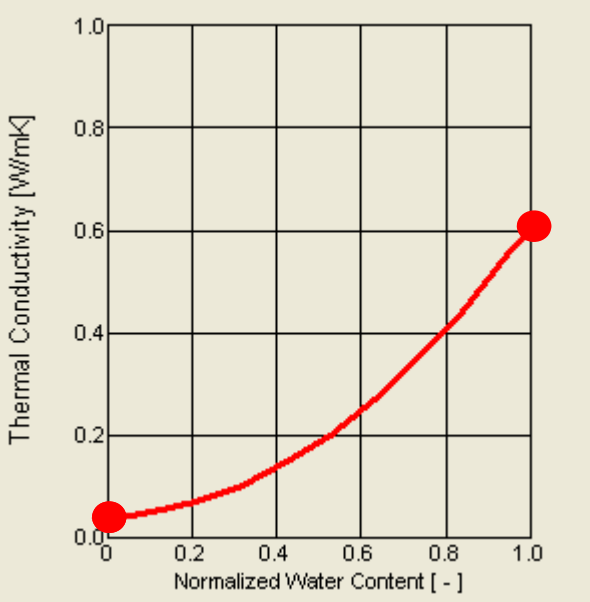
Conductivity of dry mineral wool (reported on data sheets)

Conductivity if completely saturated (i.e. every air space filled with water)

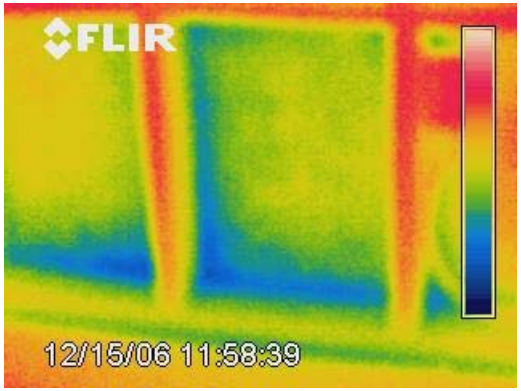
What is Hygrothermal Assessment?

Energy Impacts

- Moisture Dependent Thermal Conductivity/U-Value



Variation in conductivity as moisture accumulates



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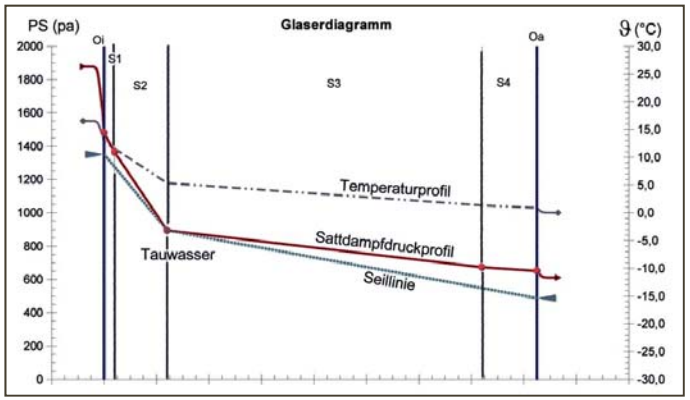
Dew-Point Assessment vs. Numerical Simulation

Steady-State/Dew Point Assessment (Glaser Method)

- Applicable Standard: IS EN 13788 – 2002

- Glaser Method developed in 1958 for light-weight buildings, it uses a simplified calculation procedure based on mean monthly temperatures & vapour pressure, & steady-state conduction of heat to determine if critical condensation points are reached within one year



Hygrothermal Numerical Simulation

- Applicable Standard: IS EN 15026 – 2007

- Uses computer software (WUFI, hygIRC etc.) to solve moisture, vapour and temperature equations for each location in a numerical grid for every hour of a year, accounting for heat and moisture storage, latent heat effects, and liquid and convective transport under realistic boundary and initial conditions.

Steady-State/Dew-Point Method vs. Numerical Simulation

Steady-State/Dew Point Assessment (Glaser Method)

Quotes from IS EN 13788 (2002):

*"... this standard lays down **simplified calculation methods**, based on experience and commonly accepted knowledge. The standardisation of these calculation methods **does not exclude** use of more **advanced methods**."*

*"The method used **assumes built-in water has dried out** and does not take account of a number of important physical phenomena including:*

- *the dependence of thermal conductivity on **moisture content**;*
- *the release and absorption of **latent heat**;*
- *the **variation** of material properties with moisture content;*
- ***capillary suction** and liquid moisture transfer within materials;*
- ***air movement** through cracks or within air spaces;*
- *the **hygroscopic** moisture **capacity** of materials.*

"Consequently the method is applicable only to structures where these effects are negligible."

Steady-State/Dew-Point Method vs. Numerical Simulation

Hygrothermal Numerical Simulation

Quotes from IS EN 15026 (2007):

"In contrast to the steady-state assessment of interstitial condensation by the Glaser method (as described in EN ISO 13788), transient hygrothermal simulation provides more detailed and accurate information on the risk of moisture problems within building components and on the design of remedial treatment."

"The following examples of transient, one-dimensional heat and moisture phenomena in building components can be simulated by the models covered by this standard:

- *drying of initial construction moisture;*
- *moisture accumulation by interstitial condensation due to diffusion in winter;*
- *moisture penetration due to driving rain exposure;*
- *summer condensation due to migration of moisture from outside to inside;*
- *exterior surface condensation due to cooling by long-wave radiation exchange;*
- *moisture-related heat losses by transmission and moisture evaporation."*

"The application of such models has become widely used in building practice in recent years, resulting in a significant improvement in the accuracy and reproducibility of hygrothermal simulation."

Steady-State/Dew-Point Method vs. Numerical Simulation

Key points for those working in UK & Ireland

Glaser method is not sufficiently complex to accurately predict temperature and moisture transport within heavy-weight (e.g. masonry) walls or account for transient effects such as driving rain or repeated freeze-thaw cycles which can have a significant effect

Internal or external insulation for masonry walls should never be assessed with the Glaser Method (under IS EN 13788). It's very important that specifiers understand this and require that the assessments carried-out use methods that are appropriate to the wall type. For masonry this means using hygrothermal simulation (under IS EN 15026)

Despite this, building regulations & energy efficiency grants make no reference to hygrothermal numerical simulation, relying instead on product suppliers to assess the risk of condensation

Suppliers aware of the differences can be reluctant to move away from Glaser because it's quicker to use and gives a yes-no answer which is often more positive for them

Consequently almost all assessments of interstitial condensation in Ireland and the UK use the Glaser Method under IS EN 13788 & BS 5250

A continued reliance on this out-dated method will result in inaccurate prediction of component conditions & lead to failures as buildings become more insulated & airtight

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Joseph Little Architects

Building Life Consultancy
A JOSEPH LITTLE ARCHITECTS SERVICE

Demonstrating the Importance of Hygrothermal Simulation: A Case Study

To the best of our knowledge no Irish or UK building regulations, and certainly no Irish grant scheme:

- Puts a limit on the amount of internal insulation that is appropriate
- Differentiates between one type of insulation and another
- Highlights that different substrates might result in very different performance
- Mentions whether or not internal moisture load affects insulation
- Gives a value judgment on what to promote to clients: internal or external insulation

Only BS 5628 and BR 262 (referenced in some insulation BBA Certificates) refer to driving rain levels & location

Building Life Consultancy therefore carried out a series of simulations to see if these omissions are of interest and if so to what degree.

More can be read on this issue in articles 'Breaking the Mould IV' and 'V' in Construct Ireland magazine

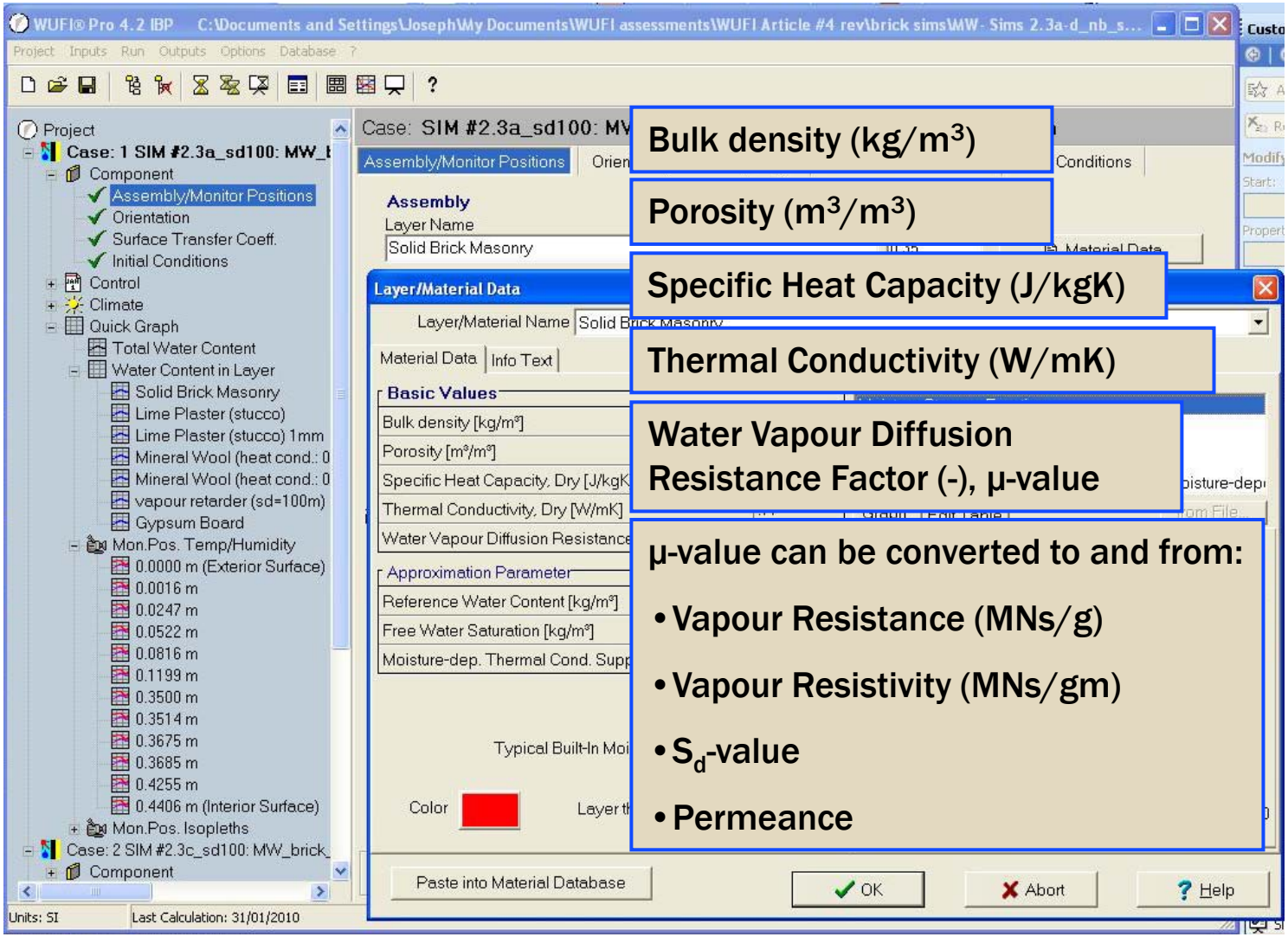
We used **WUFI Pro hygrothermal simulation software** from Fraunhofer Institute in Germany. A trial version is freely downloadable

It conforms to **IS EN 15026** the standard for numerical simulation

Demonstrating the Importance of Hygrothermal Simulation: A Case Study

Performance of insulated walls – **comparative simulation** – the software

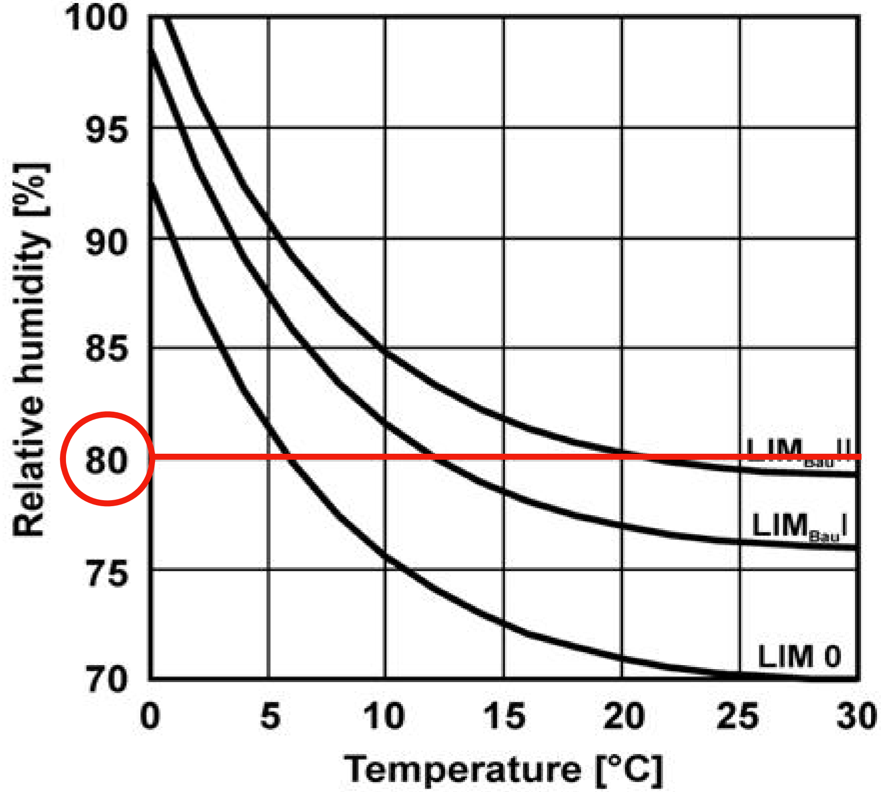
Material properties
internal conditions



WUFI Pro 4.2 - hygrothermal simulation software from Fraunhofer Instit.

Demonstrating the Importance of Hygrothermal Simulation: A Case Study

Performance of insulated walls – **boundaries to mould growth** - stay below 80%



Substrate groups:

LIM BAU II
non-biodegradable substrates (mineral board materials etc)

LIM BAU I
biodegradable substrates (wood, wall paper etc)

LIM 0
(biological full medium)

Graph courtesy of the Fraunhofer Institute in Germany

Mould spores are everywhere in the atmosphere, but only grow when they find the nutrition, oxygen, the right temperature and usually water. This is a moisture.

'Studies have shown that moulds do not require the presence of water, but can germinate and grow if the relative humidity at a surface rises above 80%. This is a considerably less severe criterion than the 100% RH [Relative Humidity] *required for surface condensation to occur.'*

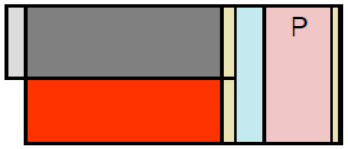
BS 5250, 6.3, Mould growth, pg. 8

Demonstrating the Importance of Hygrothermal Simulation: A Case Study

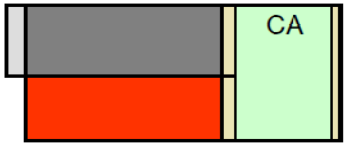
Performance of insulated walls – **comparative simulation** – the software

original wall, block and brick

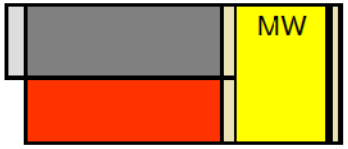
20mm lime render on 215mm conc blockwork on 20mm lime plaster finish



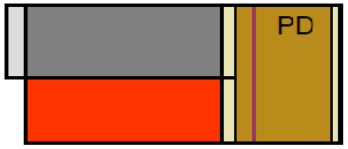
Phenolic & air cavity
insulation mech. fixed to studs, often composite with gypsum plasterboard finish



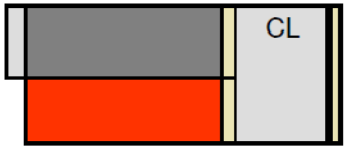
"Calsitherm"
calcium-silicate boards bonded to (lime-plastered) substrate, with lime plaster



Mineral Wool
friction-fixed between studs or pinned in place by proprietary system, VCL & plasterboard finish

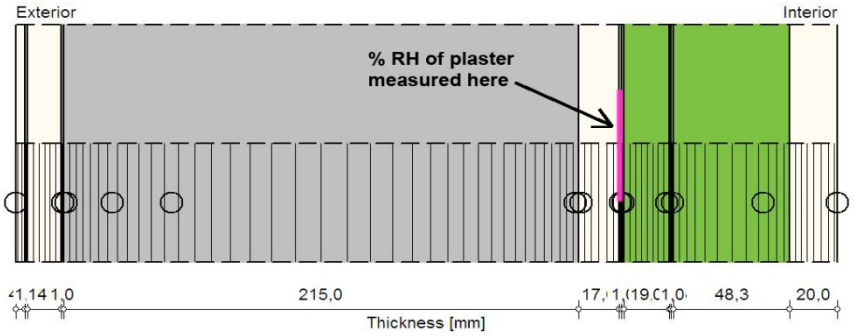


"Pavadentro"
woodfibre boards 'mushroom head'-fixed against substrate lime plaster finish



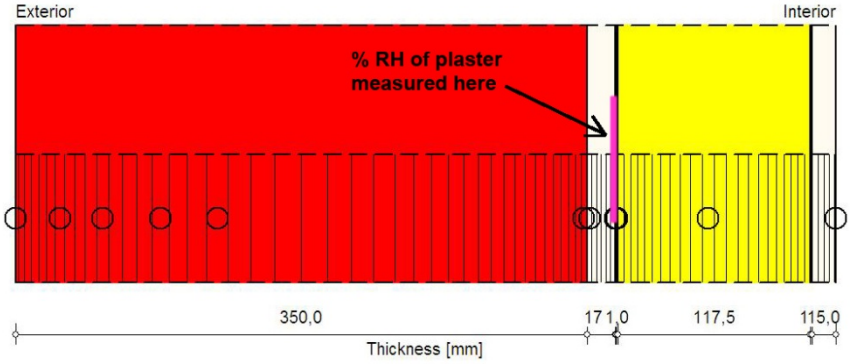
Cellulose
cellulose fibre insulation blown into voids between studs thru' VCL, gypsum

Case: SIM #1.4c: PD_block_high moisture load, 0.45, 3 years, west, Dublin



○ - Monitor positions

Case: SIM #2.5b: CL_brick_normal moisture load, 0.27, 3 years, west, Dublin

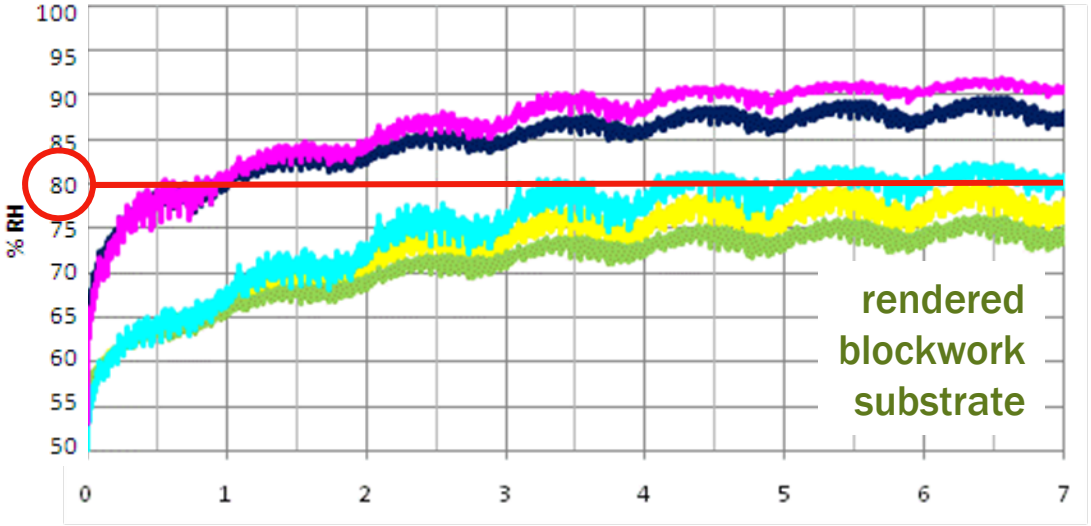


○ - Monitor positions

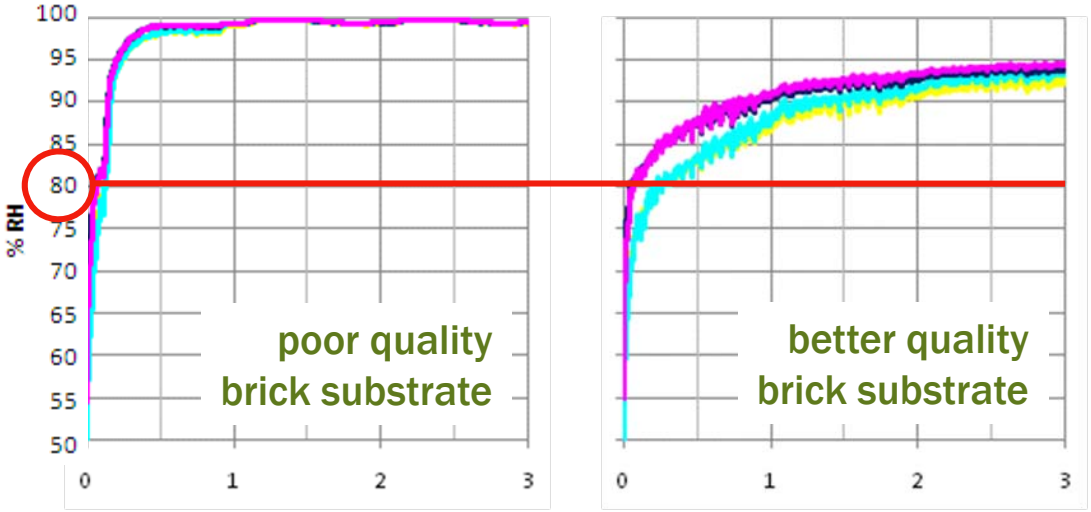
We focused on what was happening in the 1mm of original plaster facing the insulation

Demonstrating the Importance of Hygrothermal Simulation: A Case Study

Performance of insulated walls – **comparative simulation** – % RH in plaster

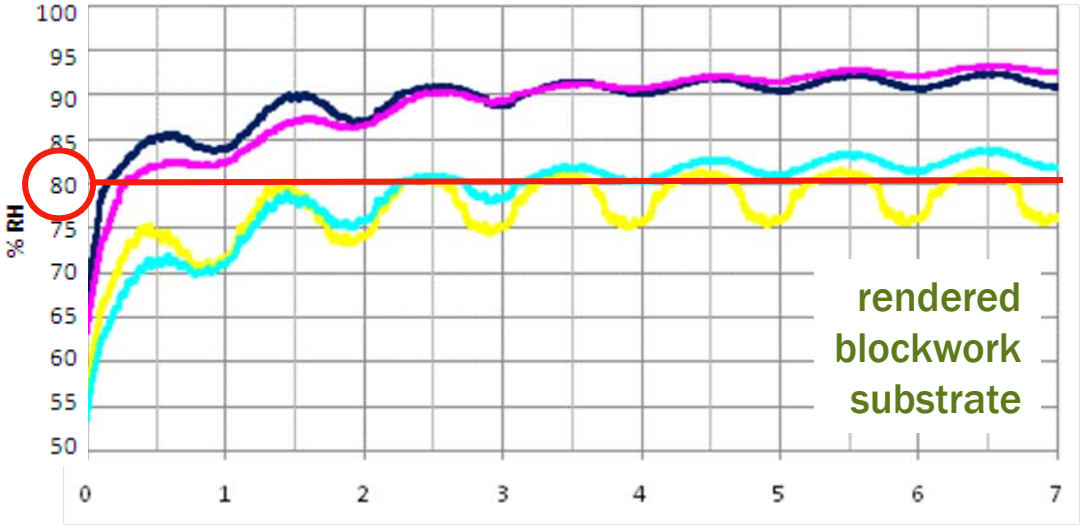


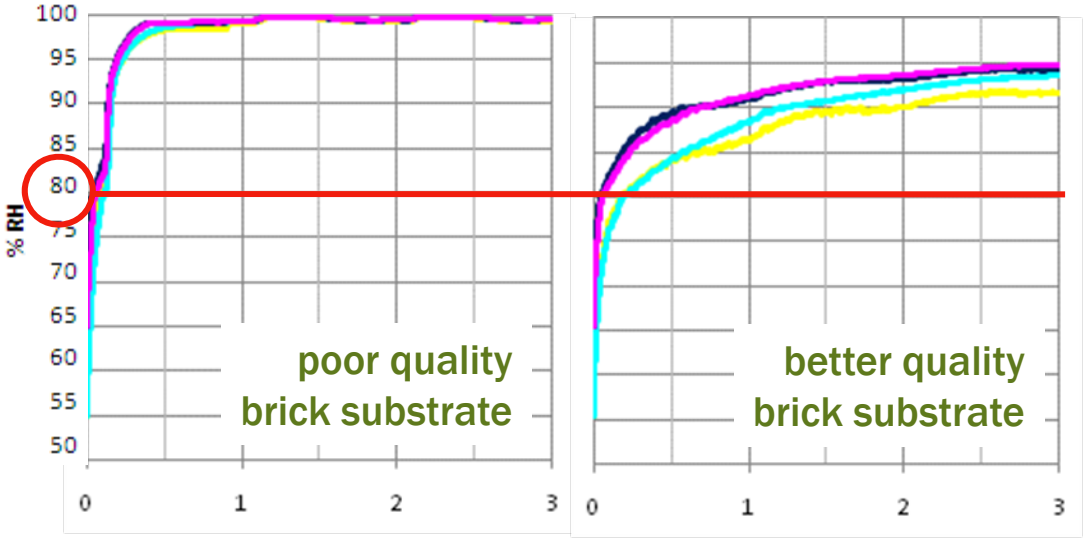
Mineral wool
internal insulation



Demonstrating the Importance of Hygrothermal Simulation: A Case Study

Performance of insulated walls – **comparative simulation** – % RH in plaster



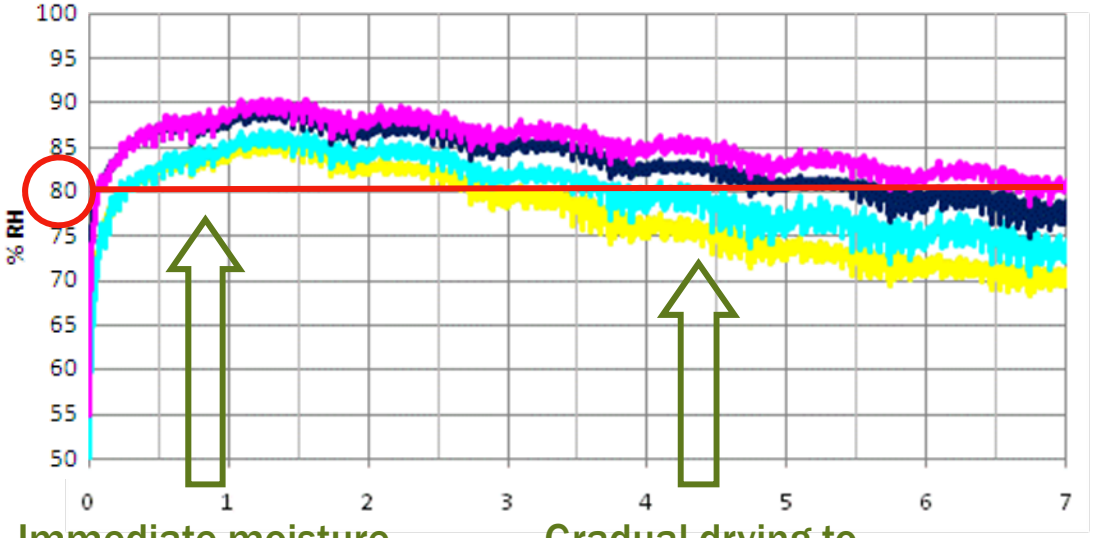


Air space & phenolic internal insulation

Phenolic, 0.45, normal
Phenolic, 0.27, normal
Phenolic, 0.45, high
Phenolic, 0.27, high

Demonstrating the Importance of Hygrothermal Simulation: A Case Study

Performance of insulated walls – **comparative simulation** – % RH in plaster



Immediate moisture accumulation on cold plaster due to internal insulation

Gradual drying to exterior that is possible due to impregnation

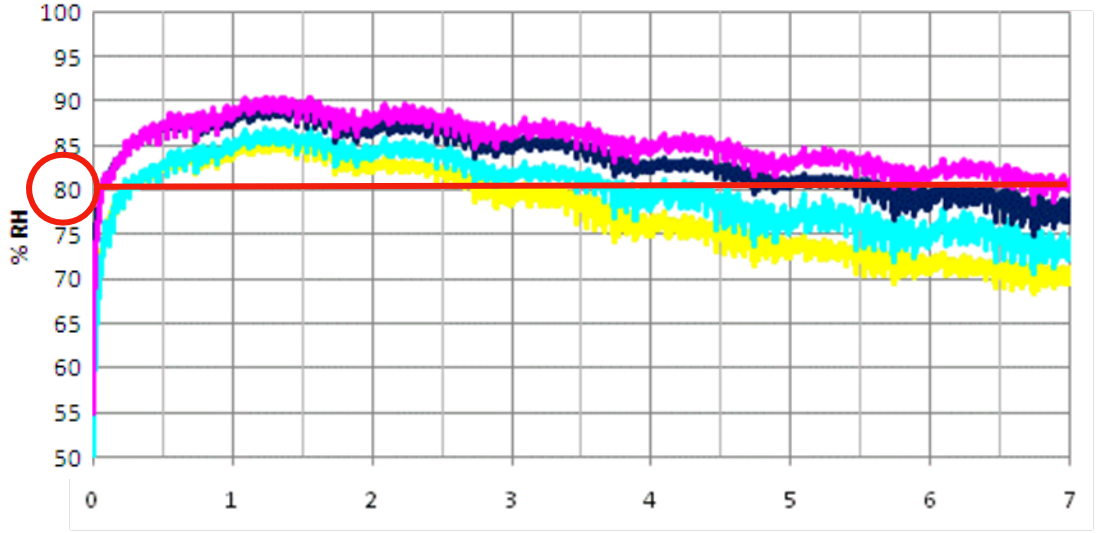
Mineral wool internal insulation on solid brick substrate

External brick surface treated against driving rain ingress (silane or siloxane impregnation)

Contact Larsen or Stoneco

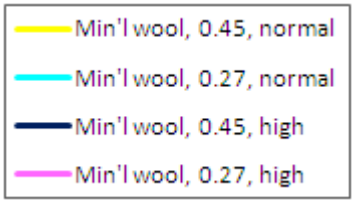
Demonstrating the Importance of Hygrothermal Simulation: A Case Study

Performance of insulated walls – **comparative simulation** – % RH in plaster

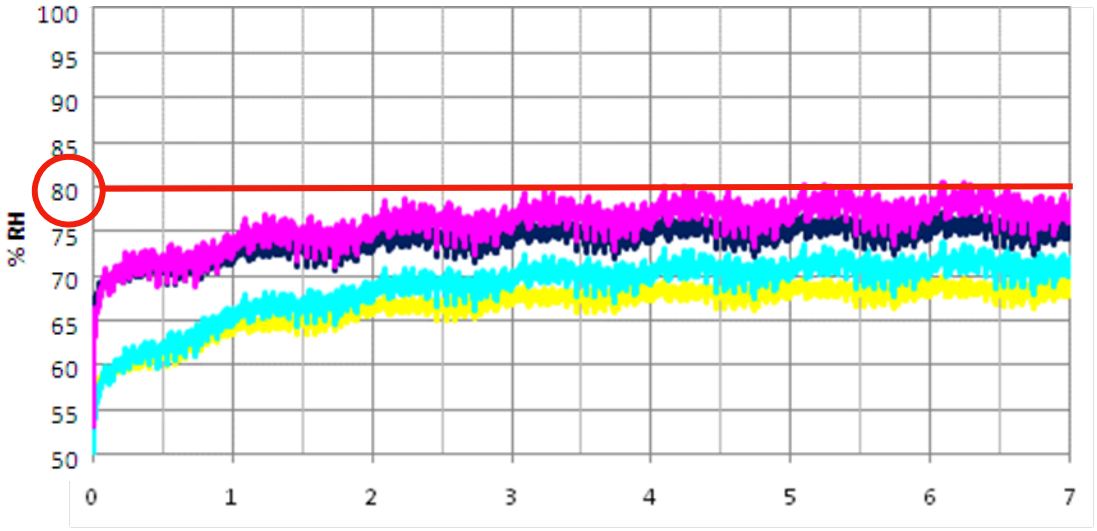


Mineral wool internal insulation on solid brick substrate

External brick surface treated against driving rain ingress (silane or siloxane impregnation)



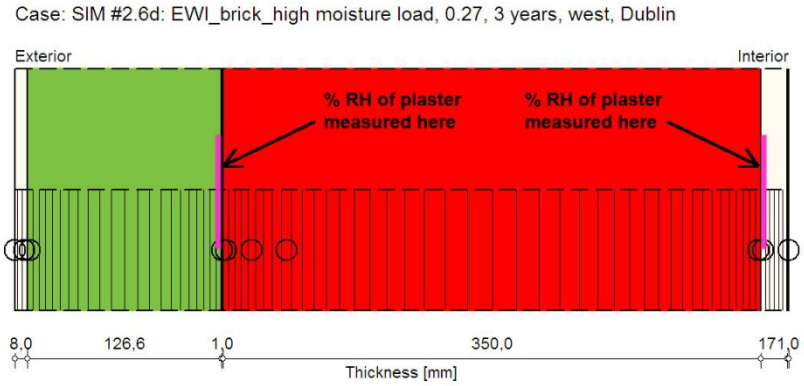
So, what if the wall is impregnated prior to being insulated...



External brick surface treated against driving rain ingress 3 years prior to adding insulation

Demonstrating the Importance of Hygrothermal Simulation: A Case Study

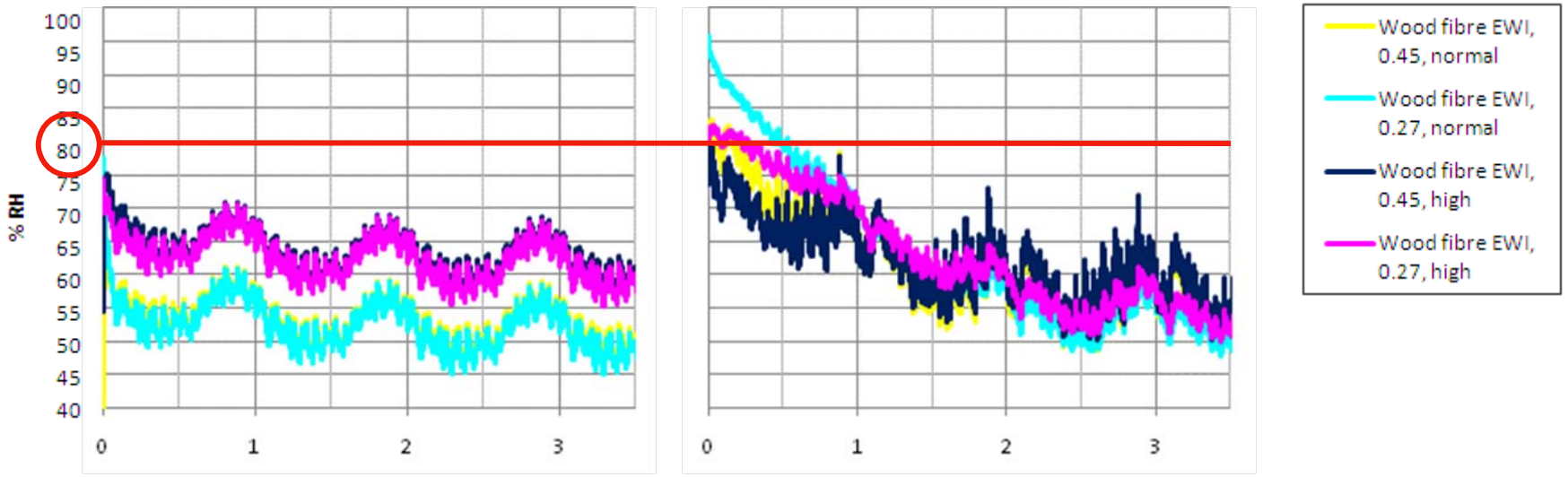
Performance of insulated walls – **comparative simulation**



External wall insulation on solid brick

Left: %RH in inner insulation

Right: %RH in plaster



Hygrothermal Simulation Study – Conclusions #1

The location of insulation within a wall has a large bearing on how moisture and vapour moves through it, and to what level it can be insulated.

It is useful to think of **driving rain**, **internal moisture load**, the **masonry substrate** and the level of insulation used as **macro issues** that must be addressed for a successful installation

It's also useful to think of **type of insulation** and **hygroscopic characteristics** as **micro issues** that can have additional influence on performance and on embodied carbon

Based on our simulations it appears that grant aid for any internal insulation (new build or retrofit) should not be for a higher U-value than 0.50 W/m^{2}K. Bodies offering grants for high levels of internal insulation in retrofits may unwittingly be subsidising bad practrice & future failure

Single leaf brick walls are a special case in that the risk of failure is greater when internally insulated. Impregnation of the outside must form part of retrofit works

Hygrothermal Simulation Study – Conclusions #2

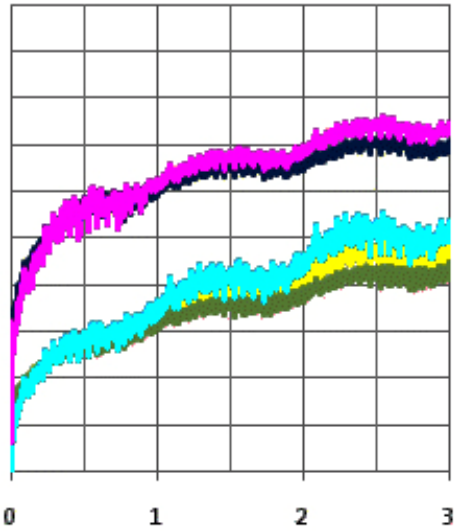
Given the emergence of powerful simulation software in the last 10 years and a related standard IS EN 15026 in 2007 it is no longer defensible that Glaser is used to evaluate internal and external insulation of masonry walls

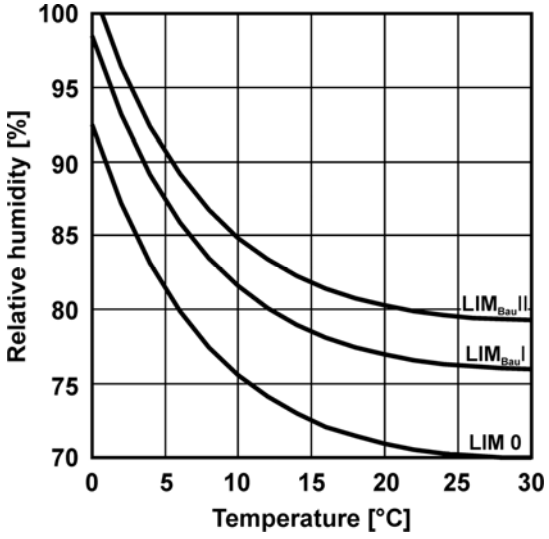
The comparative simulations were based on materials tested by the Fraunhofer Institute. They do not therefore exactly represent materials sold in Ireland. The study does raise the question as to how typical Irish brick, block, plasters and insulations would perform: testing is needed urgently

Far greater guidance is needed for specifiers. The issues shown here are not trivial: Damaged walls, collapsed insulation and worse homeowners' health could be at risk

This study needs to be challenged, conclusively proven and expanded. Final conclusions need to be encoded in a well-thought out code of practice for retrofit for the guidance of authorities, architects and builders.

If you agree make your opinion known to the relevant authorities and get changes made





Thank you for listening

Joseph Little & his team can be contacted at:

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