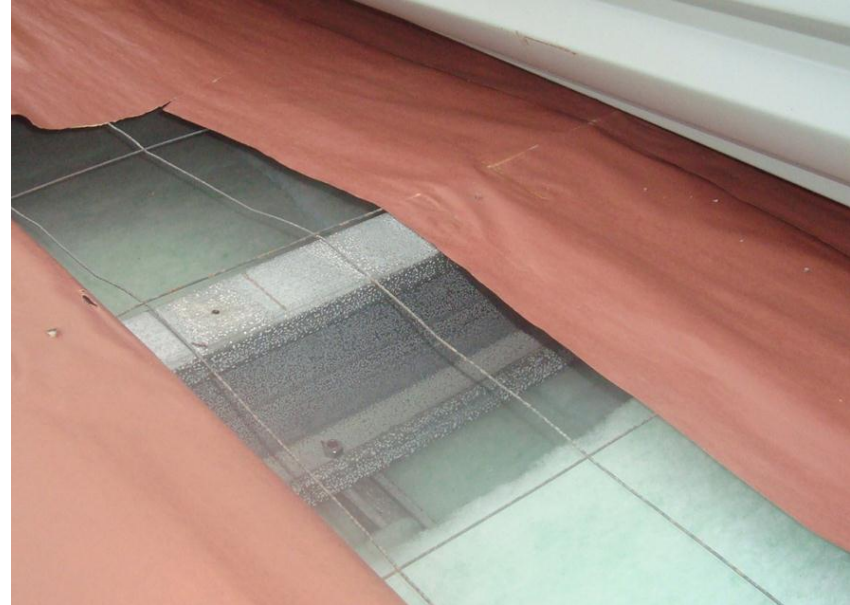
A photograph of a steel-framed roof structure under construction, showing the intricate network of steel beams and trusses. The structure is set against a clear blue sky.

# Condensation in Large-Cavity, Steel-Framed Roof Spaces: Causes and Cures

Malcolm Cunningham, Luca Quaglia, Stephan Rupp, BRANZ

# The Problem

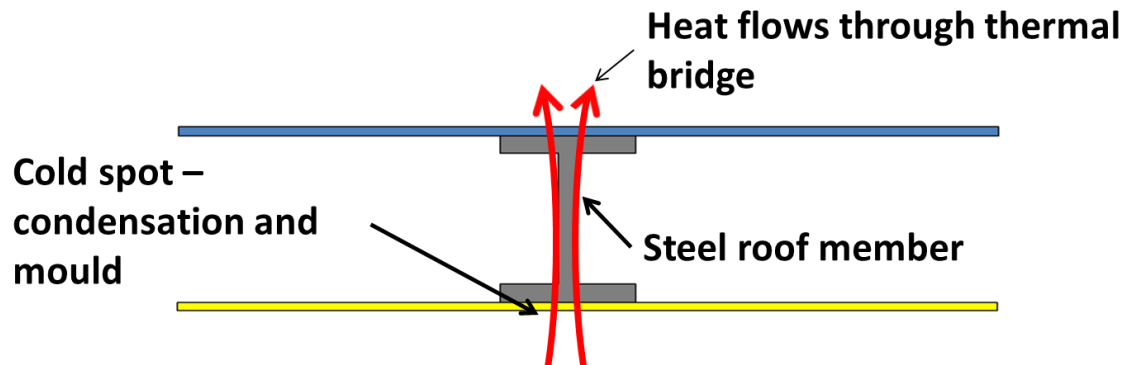


**Problems with steel-framed institutional (commercial buildings, schools, halls, etc.) roofs through:**

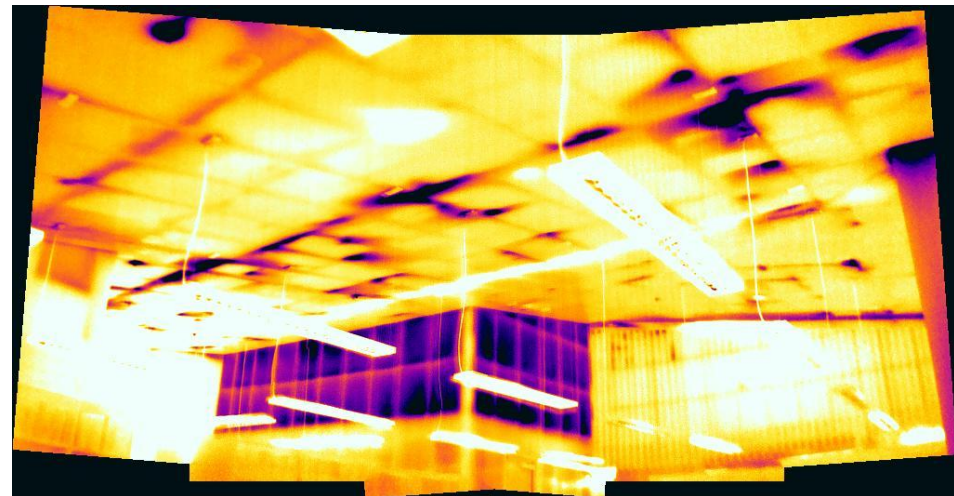
- ▶ **Straightforward mistakes**
- ▶ **a more complex problem.....**

# Simple Thermal Bridging

**Defining feature: roof and ceiling connected by high conductive path**



**Defining symptom: patterned lining mould growth**





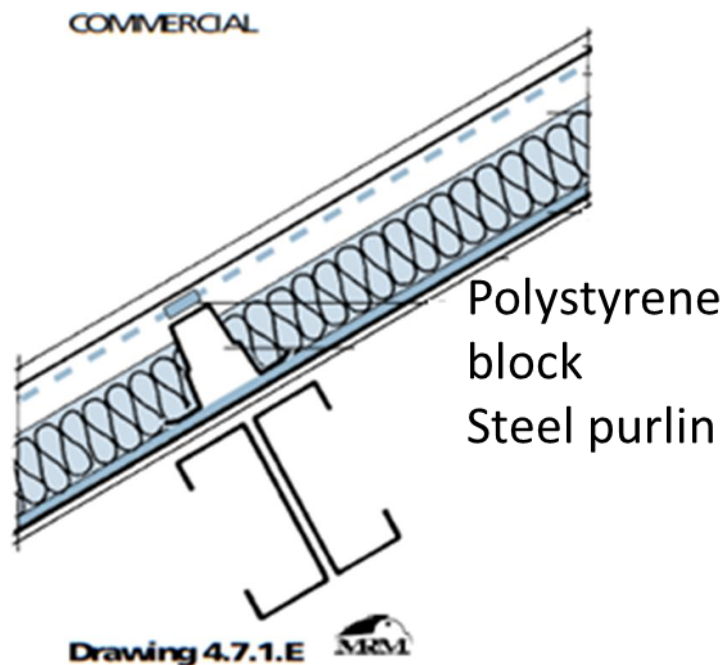
# Simple Thermal Bridging

Acceptable Solution E3/AS1

INTERNAL MOISTURE

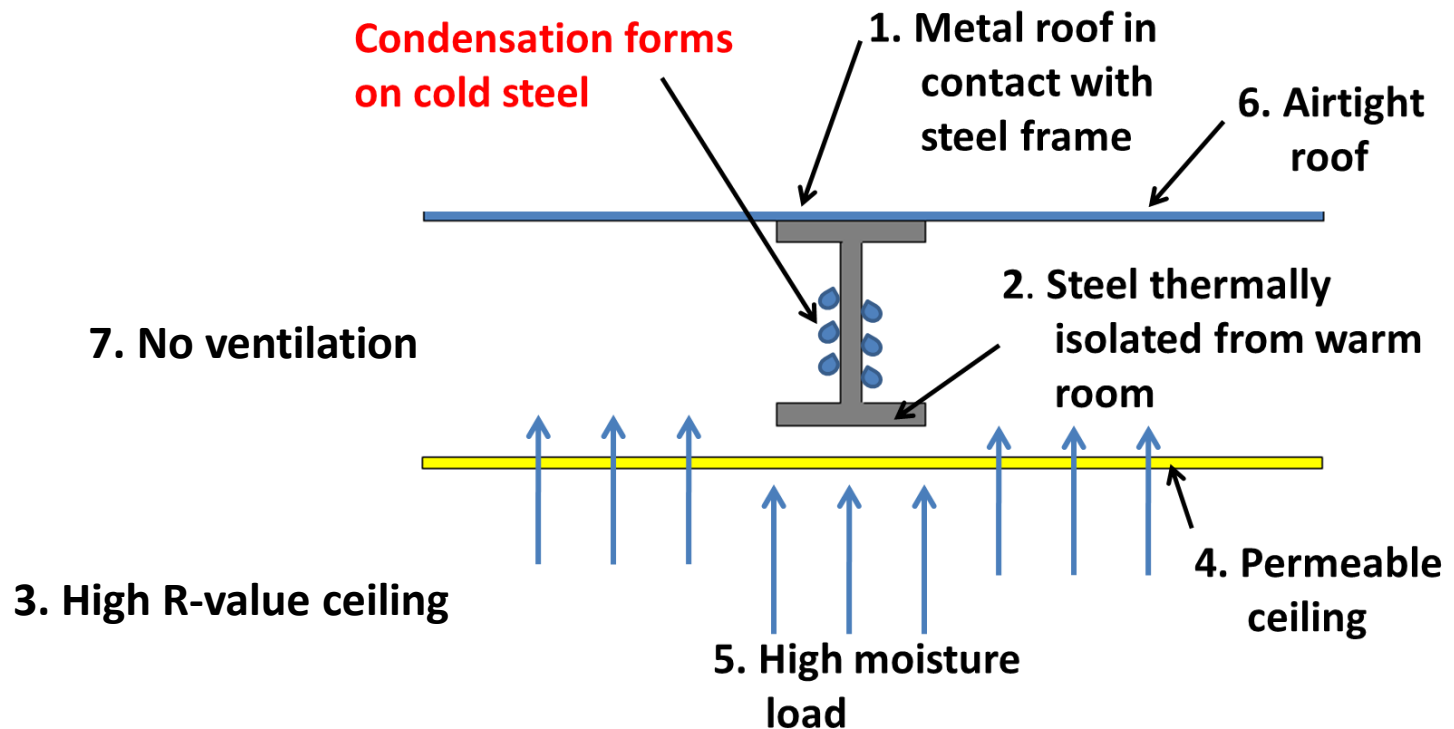
## Acceptable Solution E3/AS1

- d) Where steel studs are used, a thermal break shall be provided for each steel member. Wood fibre insulating board or expanded polystyrene (EPS) strips, 12 mm minimum thick and fixed directly behind the external cladding provide an effective thermal break.

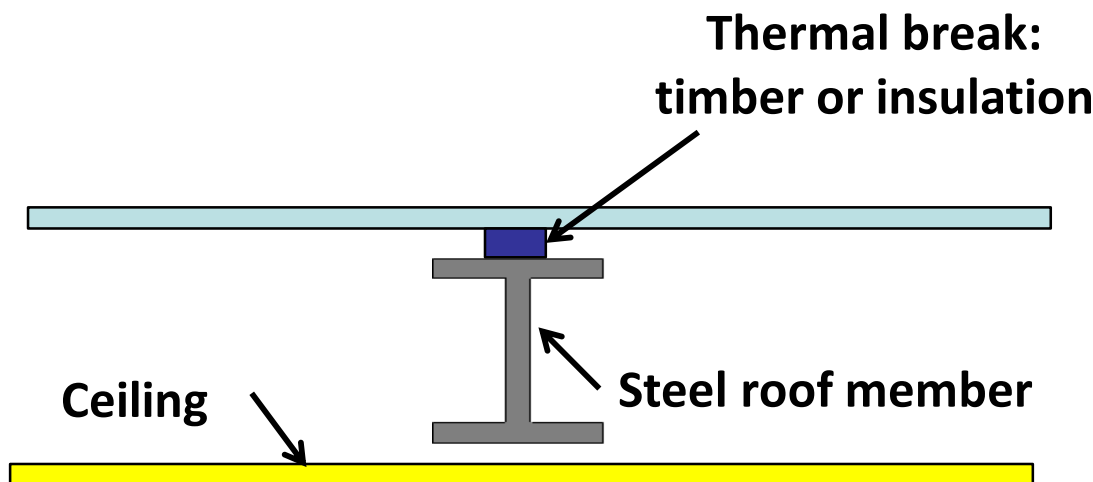


# A new type of problem

- ▶ Several trouble-shooting jobs in the roofs of new buildings
- ▶ Many buildings with these problems
- ▶ Of a subtle nature



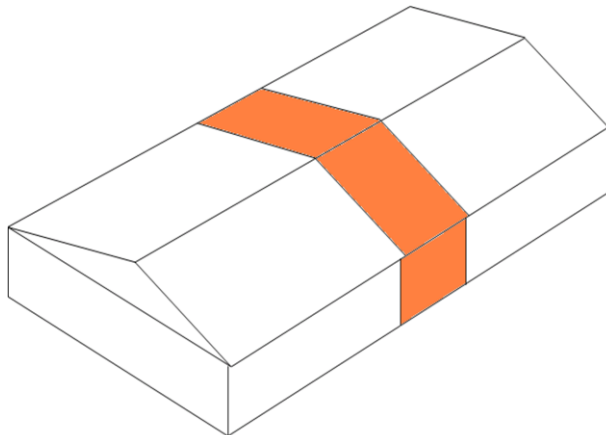
# Aggravated Thermal Bridging



**For aggravated bridging,  
timber isn't always  
enough**

# Project: Institutional Roofs

## ► What are possible, cost effective remedies to aggravated bridging

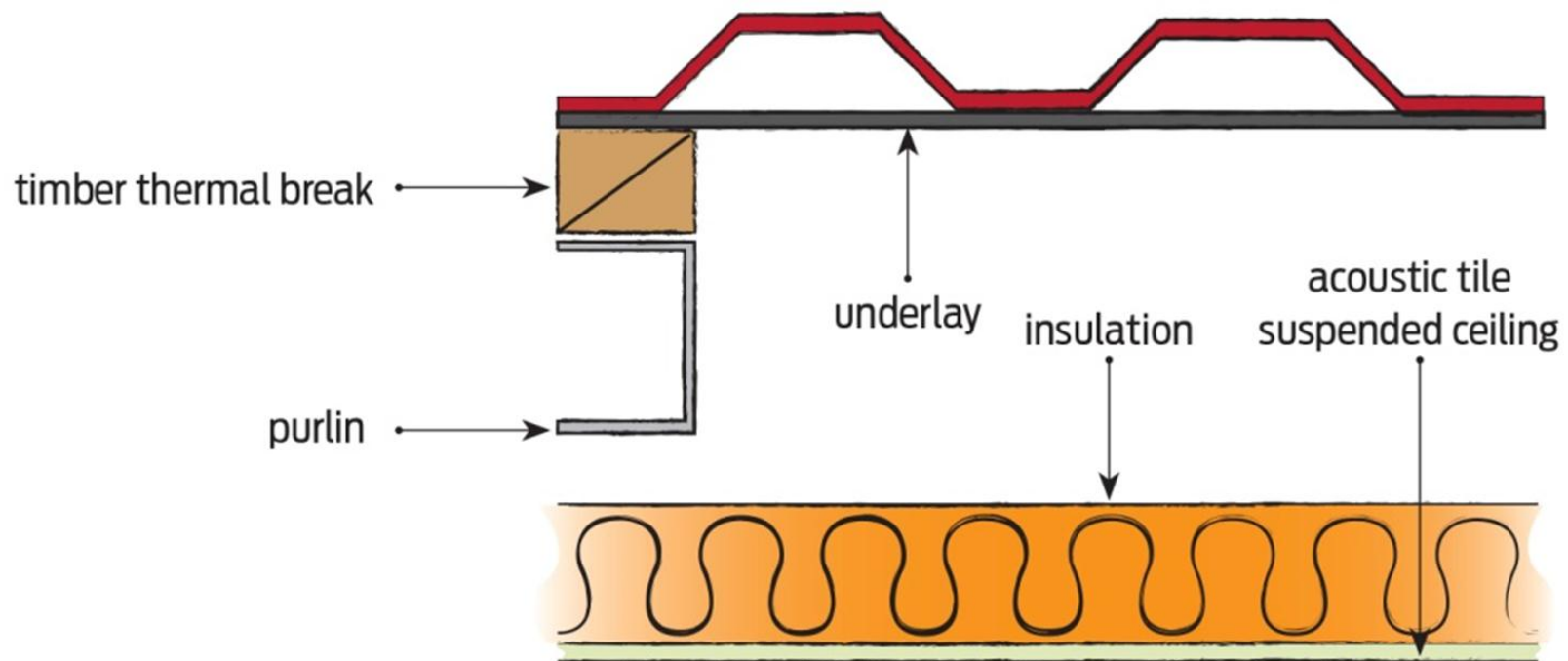


Roof Test Rig Container with 4 different roofs trialled:

- Transportable (different climate zones)
- Full control of indoor climate (temperature and humidity)
- Extensive sensing & data acquisition

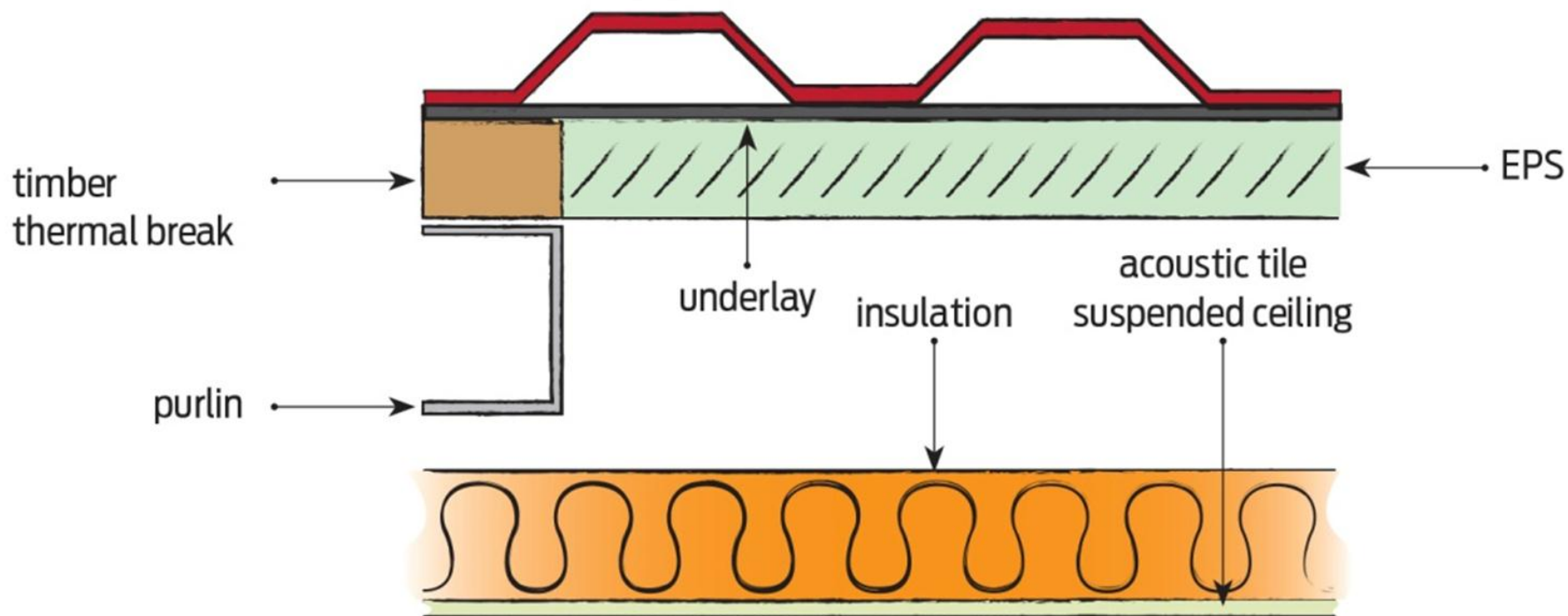
# Specimen 1: Timber Thermal Break

## Reference Case

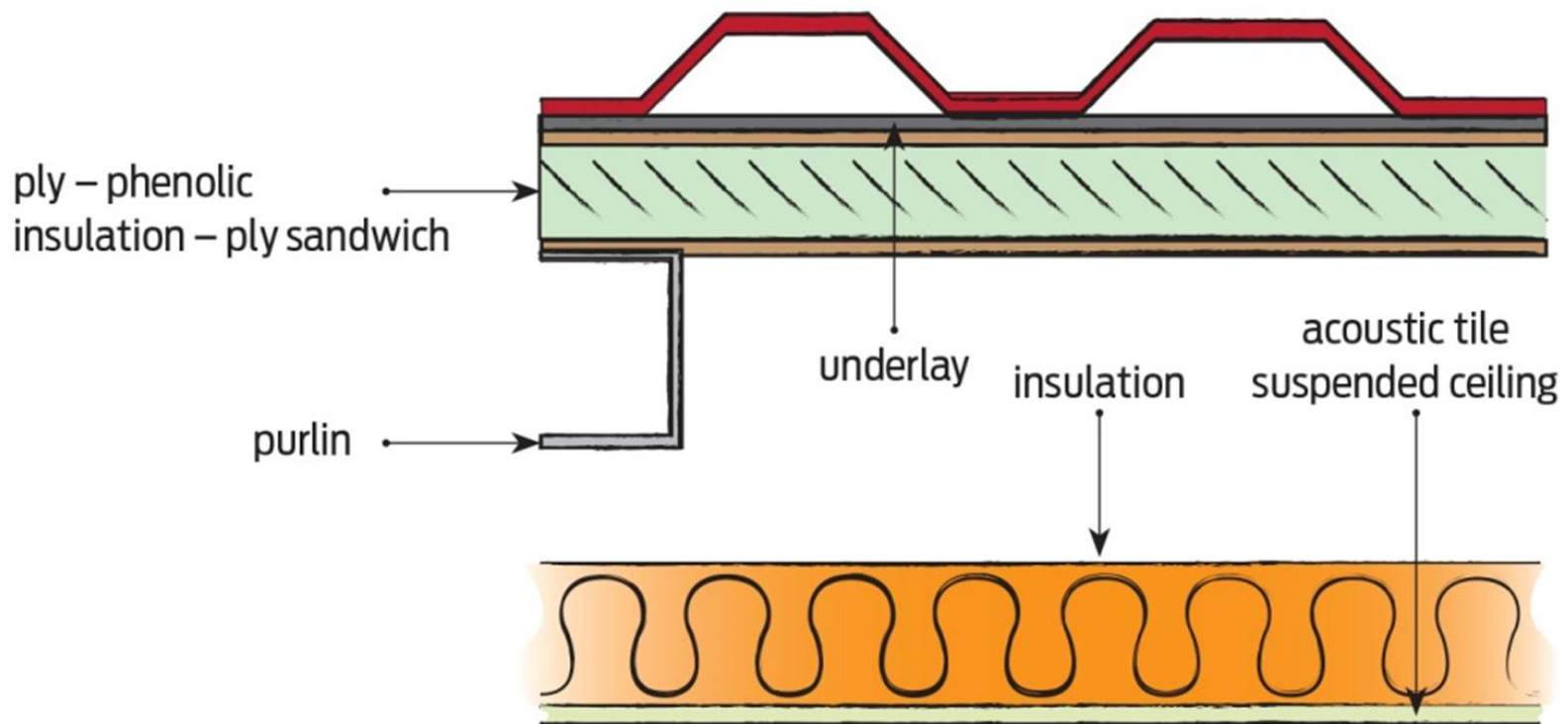




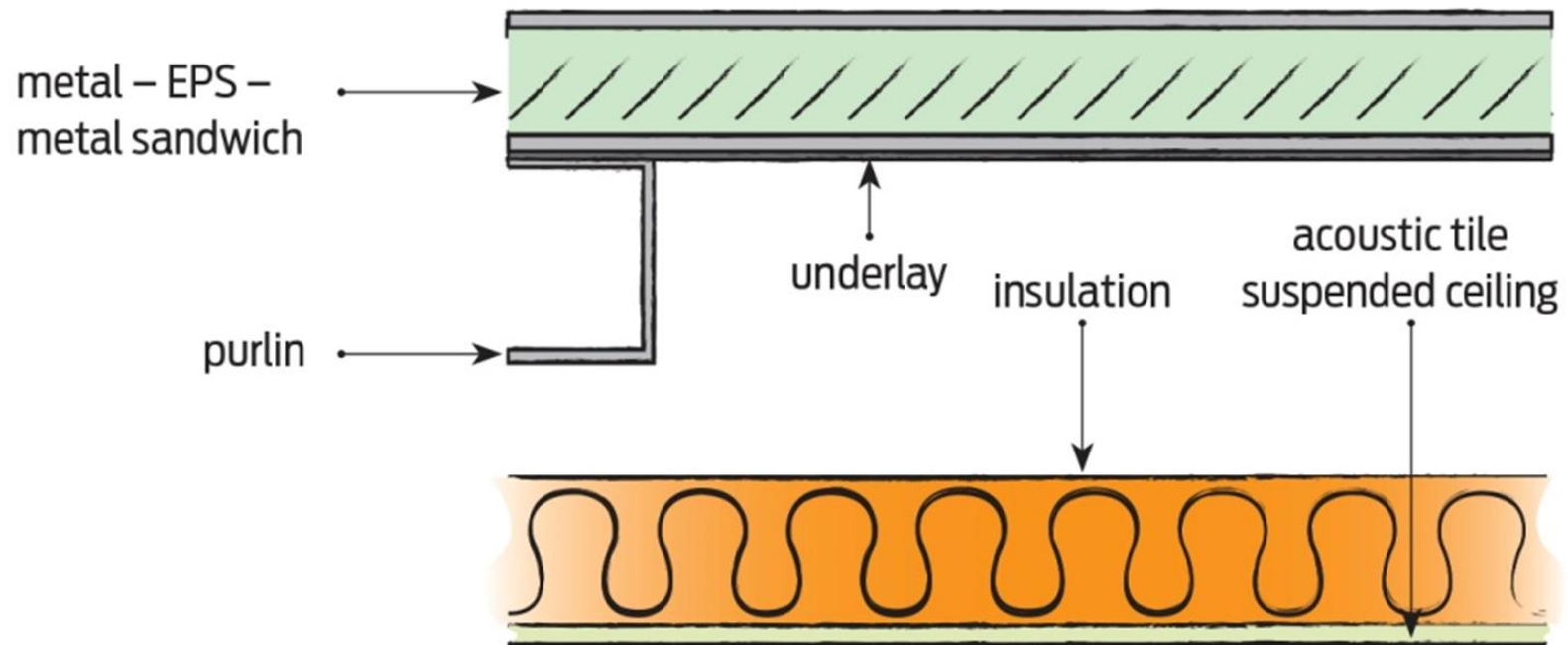
# Specimen 2: EPS panels



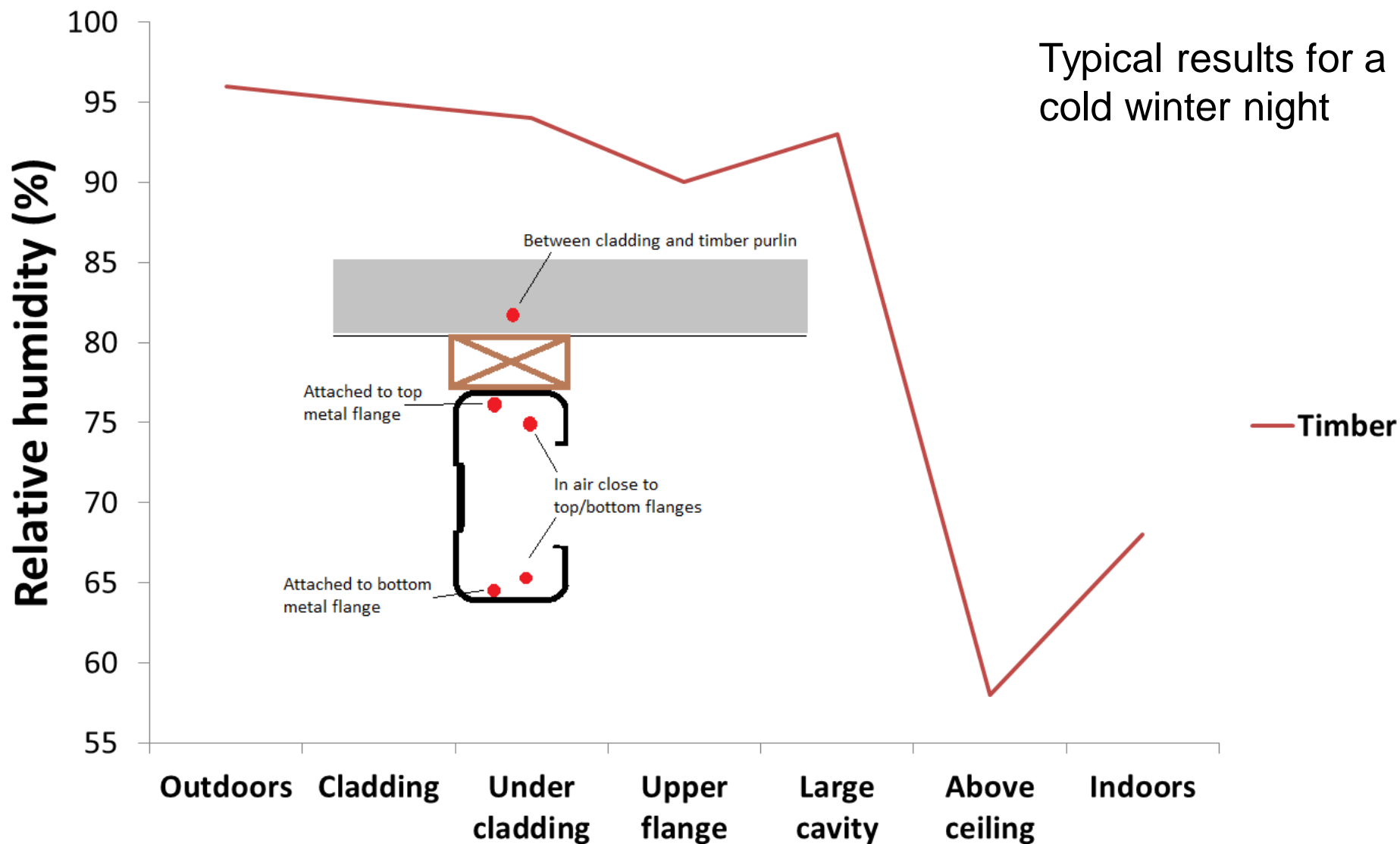
# Specimen 3: Phenolic/Ply sandwich



# Specimen 4: Metal/EPS sandwich

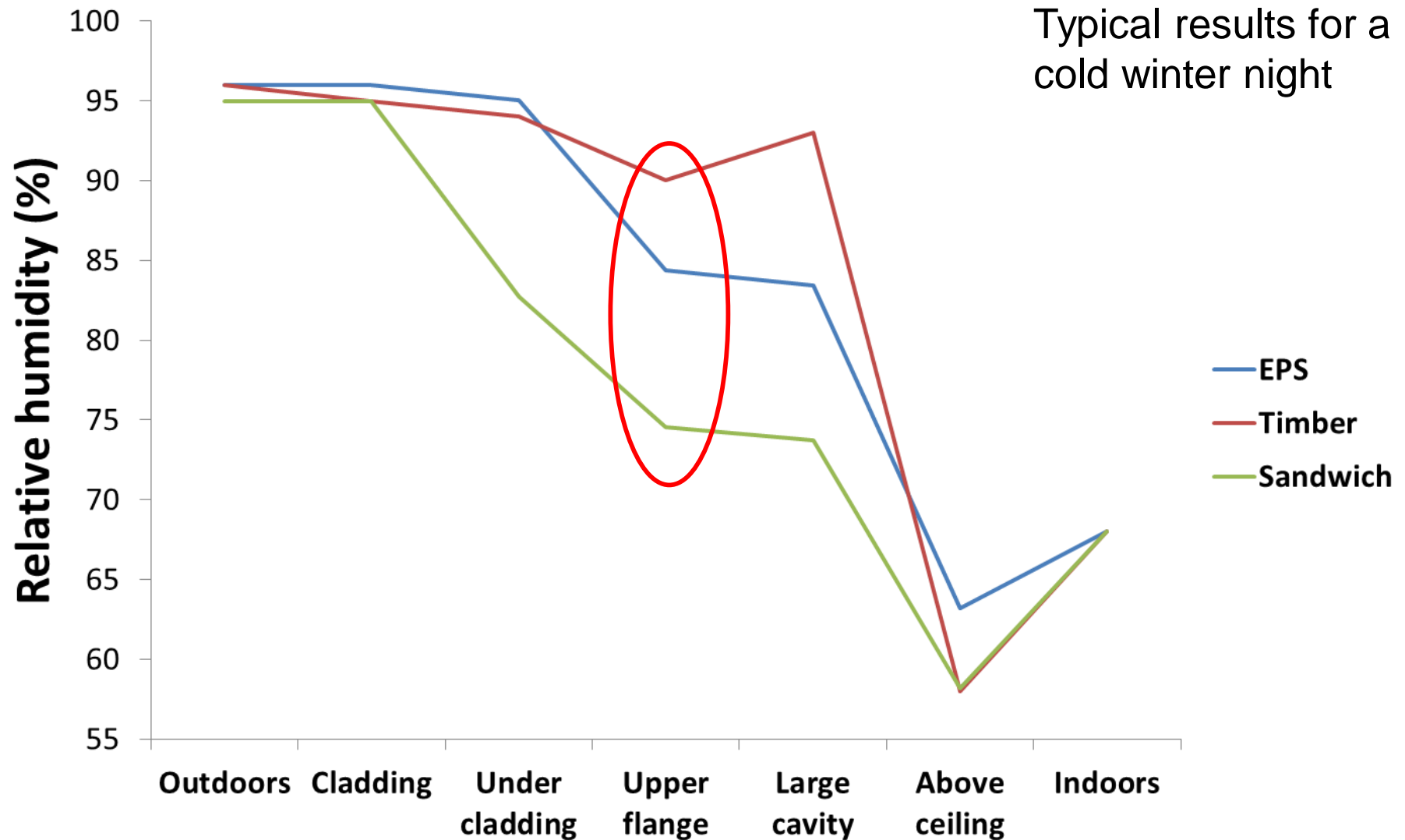


# Results: Relative Humidity



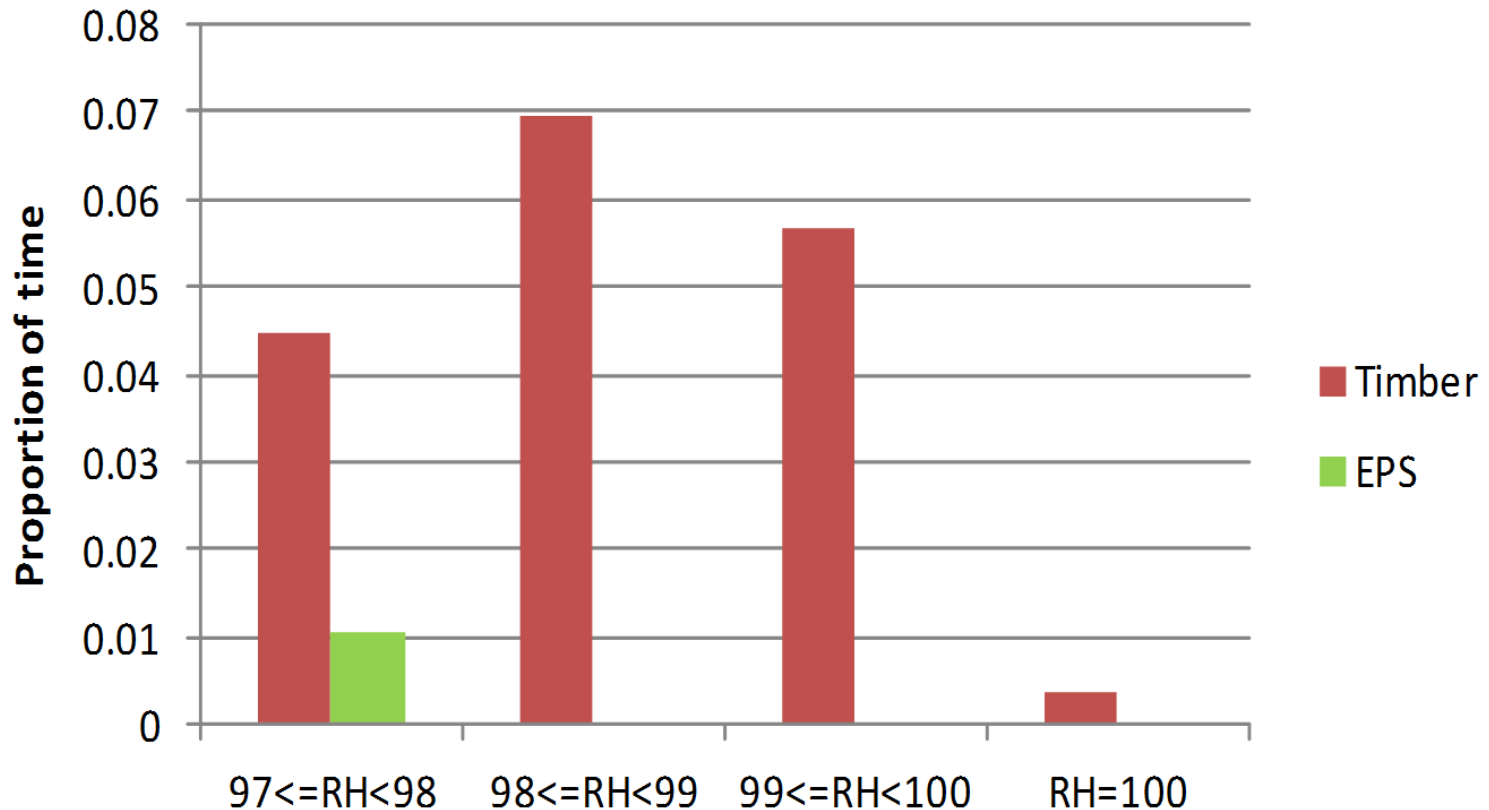


# Results: Relative Humidity



# Results: Relative Humidity

**By metal purlin. Proportion of time at high relative humidities**



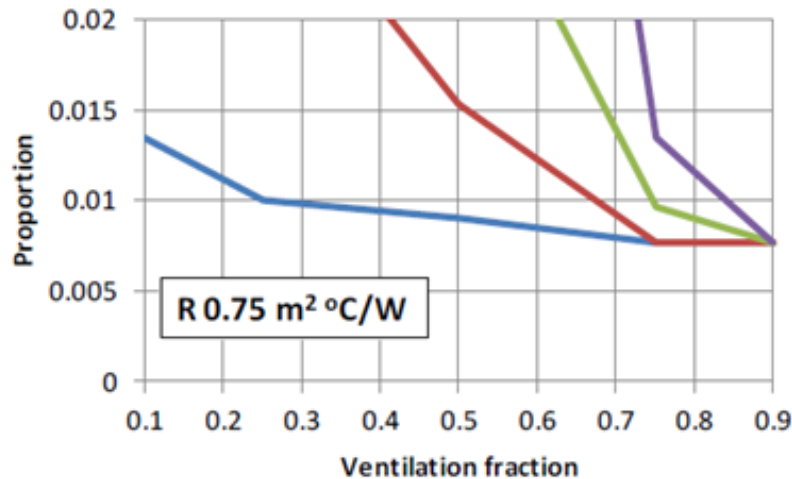
▶ This experimental data needs to be expanded by numerical modelling to explore a larger parameter space:

- indoor climate (temperature and humidity)
- insulation
- permeability
- ventilation
- geographic location

→ Initial **model** using *insulation*, *indoor climate* and *ventilation* as parameters

# Modelling Results

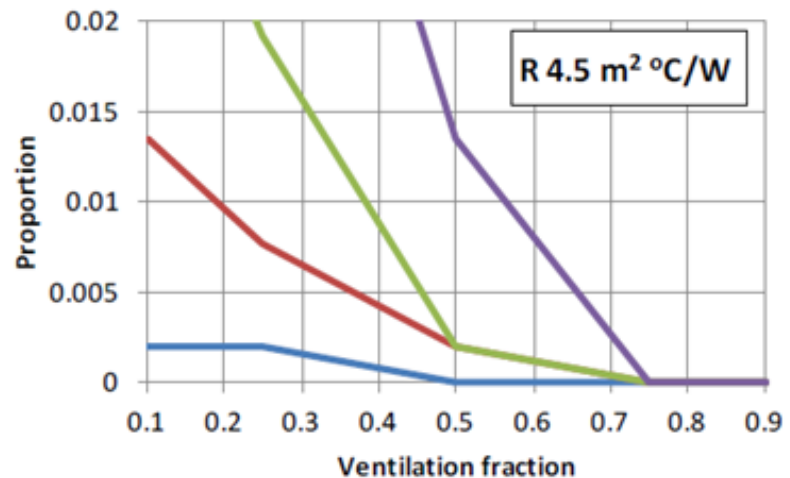
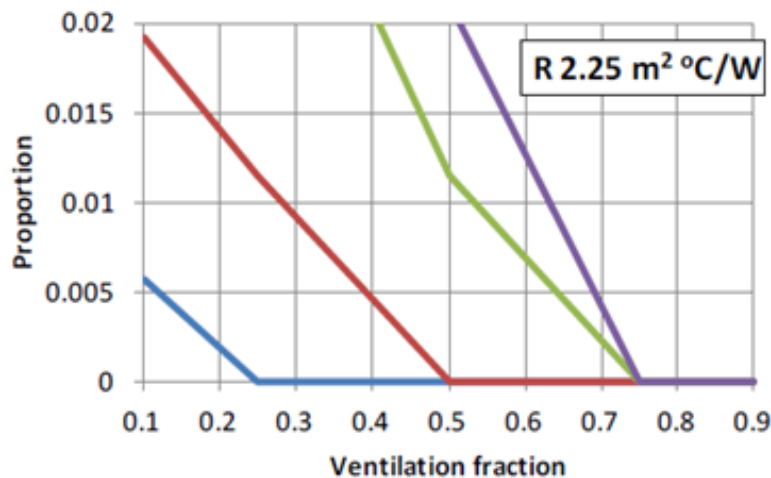
## Proportion of time cavity greater than 98% RH



### Indoor climate

- Dry
- Moderate
- Wet
- Very wet

- R-values for insulation above cavity
- Ventilation Fraction: Ratio of outdoor to indoor ventilation rates





- ▶ **Full-width board insulation can fix aggravated thermal bridging problems**
- ▶ **Preliminary findings:**
  - ▶ **R-value  $\geq 2.25 \text{ m}^2 \text{ }^\circ\text{C/W}$**
  - ▶ **Ventilation fraction of 0.75 or higher**
- ▶ **EPS system: relatively cheap, no structural loadings, needs to meet fire regulations**

# Current Work: Skillion Roofs

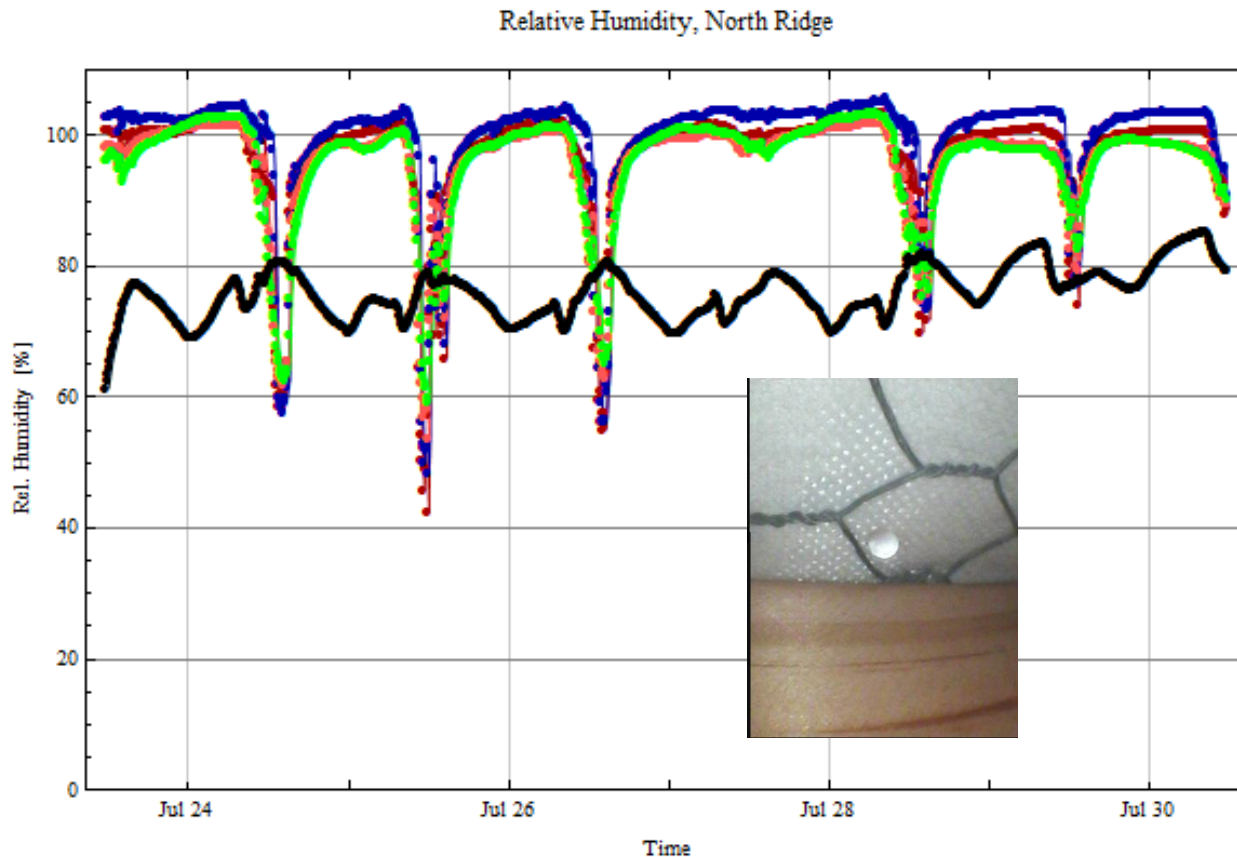
View into Roof Testing Rig with Skillion-Type roof



Level of roof cavity ventilation can be varied

# Current Work: Skillion Roofs

Humidity Sensors across roof and ceiling, measurements taken over a cold week without minimal ventilation: extended periods of 100 % Rel. Humidity with some visible condensation on the underlay



# Conclusions & Outlook

- Phenomena of 'aggravated thermal bridging' (which is encountered in many institutional roofs with metal structures) described and understood.
- First design guidelines established for necessary insulation and/or ventilation levels as function moisture loading.
- Experimental work started on Skillion Roof Ventilation project.

▶ **Results are flowing into the development of a nodal model, capable of simulating different roofs under various climatic circumstances to yield ventilation requirements**