Monitoring of VIP in Building Applications

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Goal:

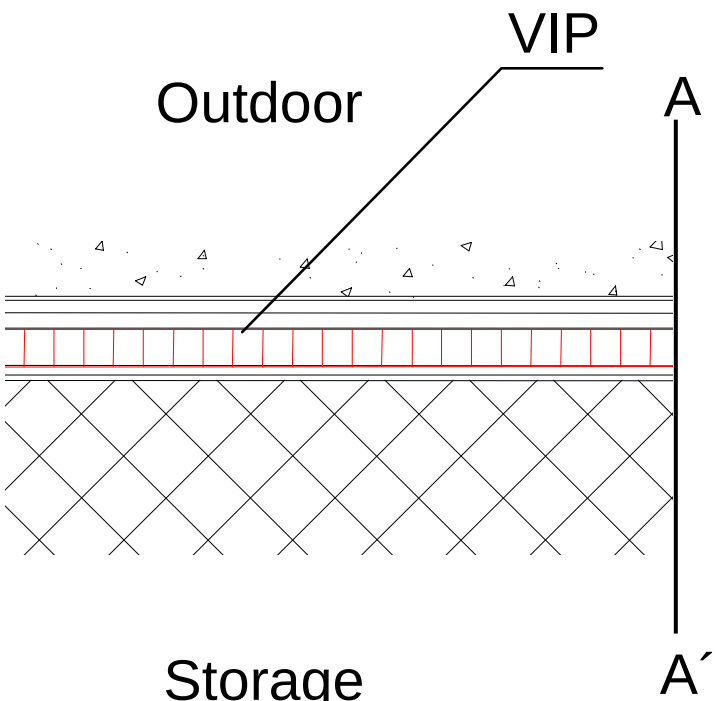
check the predictions based on lab experiments

Outline

- Introduction
- Experimental set-up
- Results
- Comparison with laboratory aging data
- Conclusions

Most common application in Switzerland nowadays are terrace insulation with > 10’000 m^2

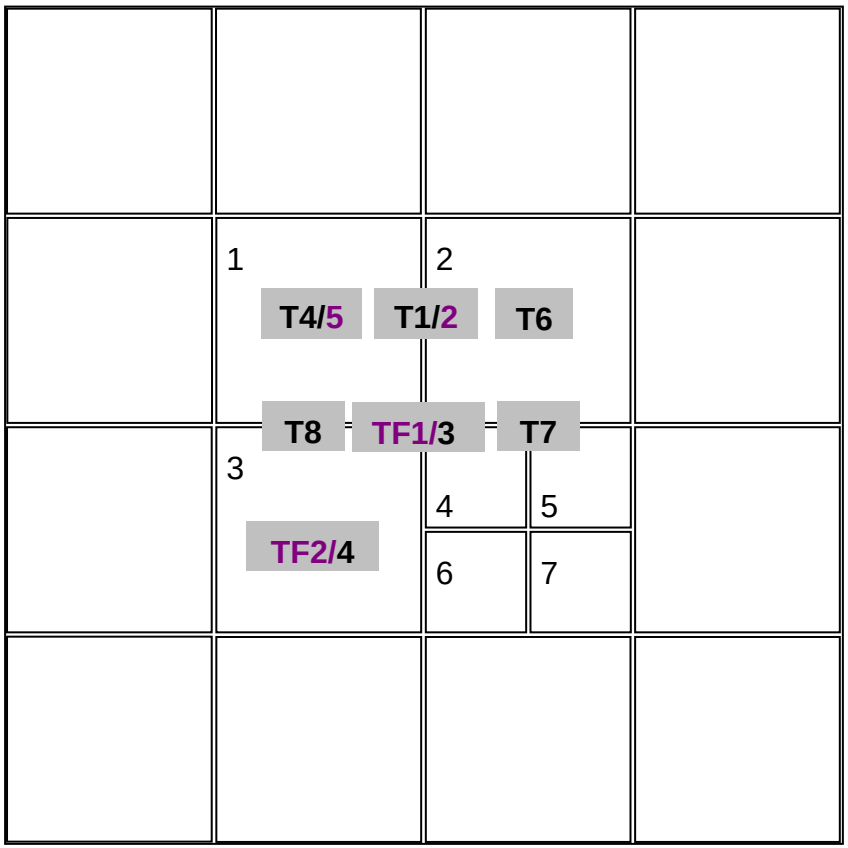
Flat roof with VIP made for monitoring



Layer (AA´ from top to bottom)	**Thick-ness [mm]**
Crushed gravel	30
Bituminous water barrier (3 layers)	10
Protective layer	7
VIP	20
Protective layer	5
Water barrier (previous construction)	10
Porous concrete (previous construction)	200

Experimental set-up

top view



25 x 25 x 2 cm³ “small” and
50 x 50 x 2 cm³ “middle” sized

Experimental set-up side view

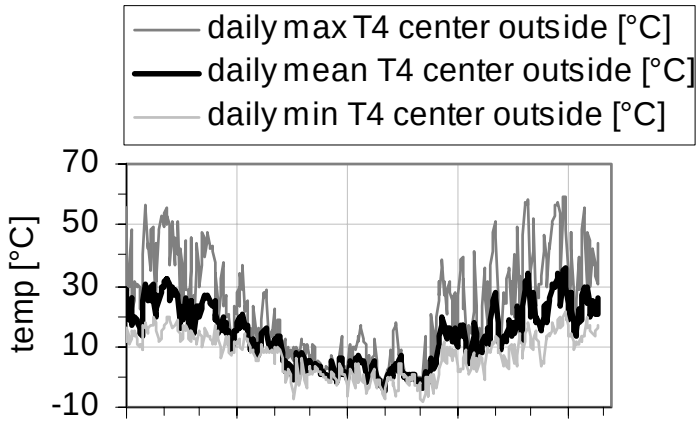
Monitoring

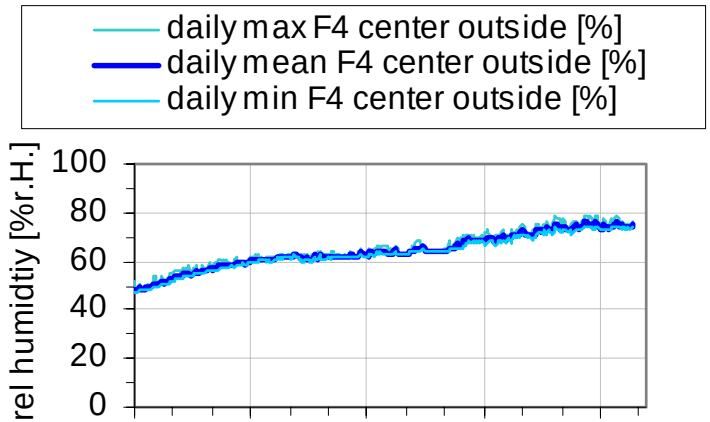
Logging

- Temperature
- Humitidy
- Climatic conditions

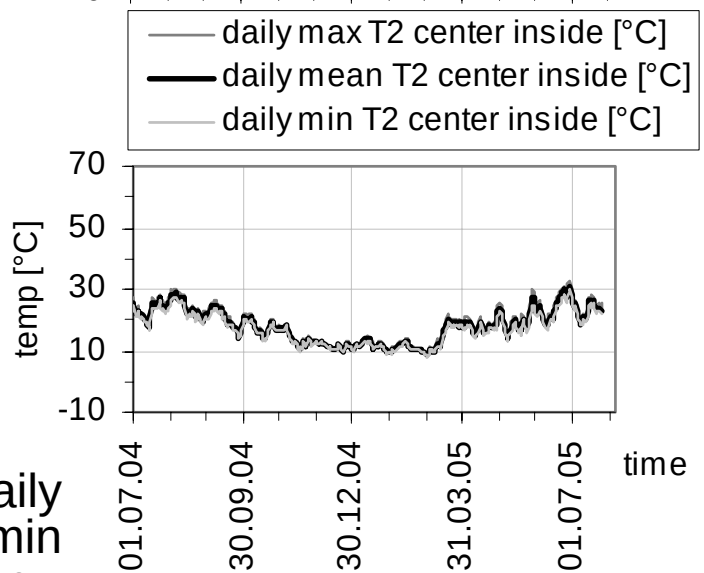
Results: Temp RH

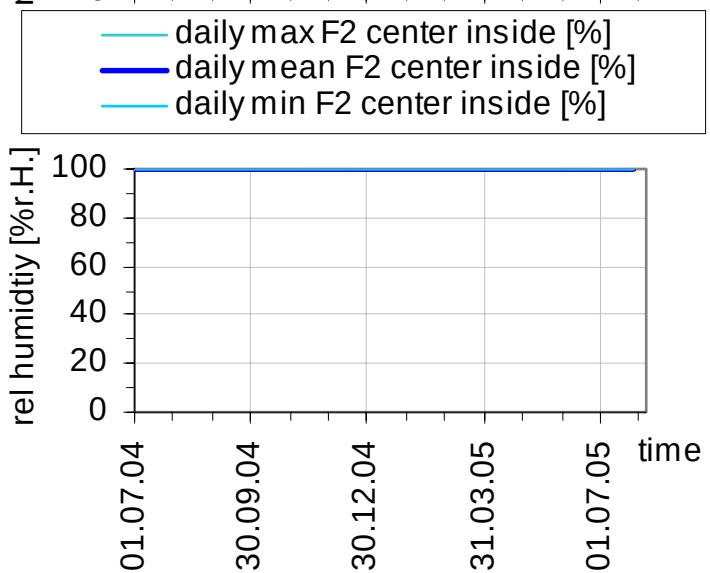
above VIP





Below (inside)





shown as daily max/mean/min calculated on hourly basis

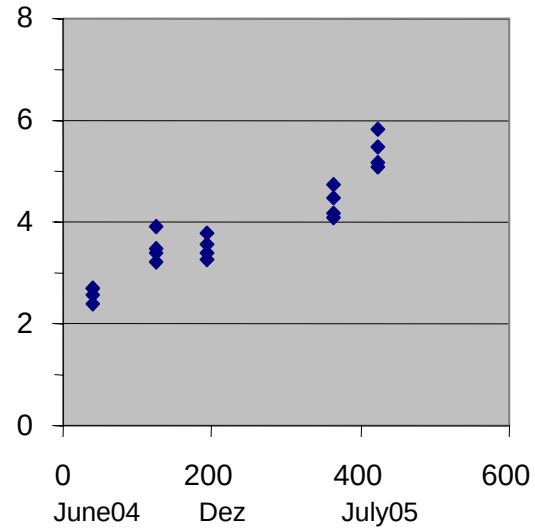
Results: Raw data

25x25x2 cm³

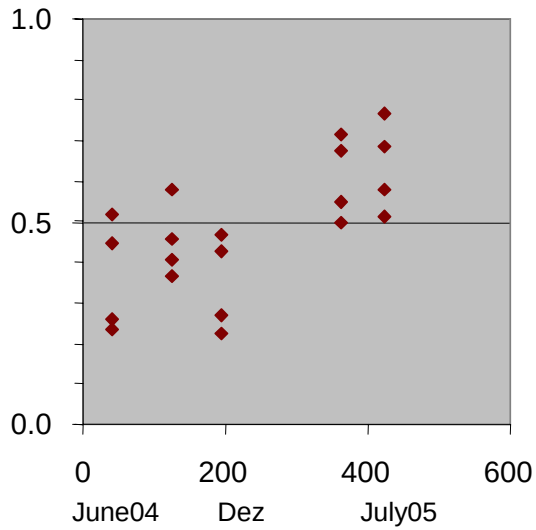
and

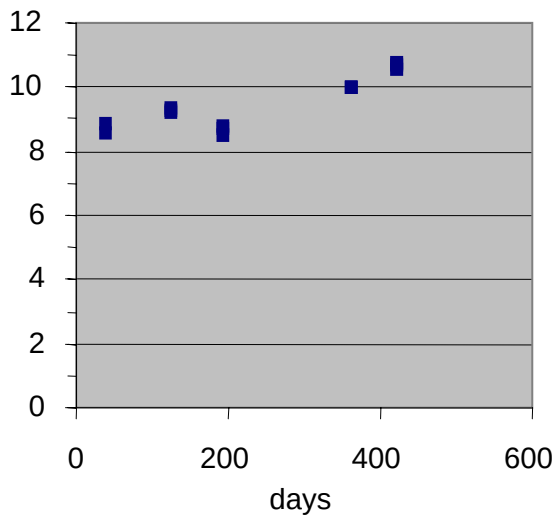
50x50x2 cm³

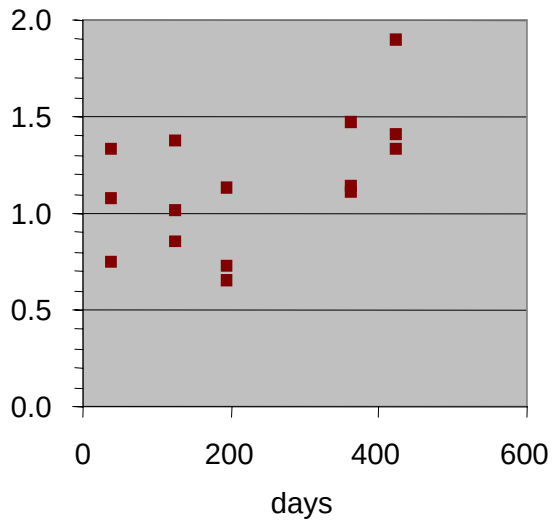
Internal pressure [mbar]



weight increase [g]







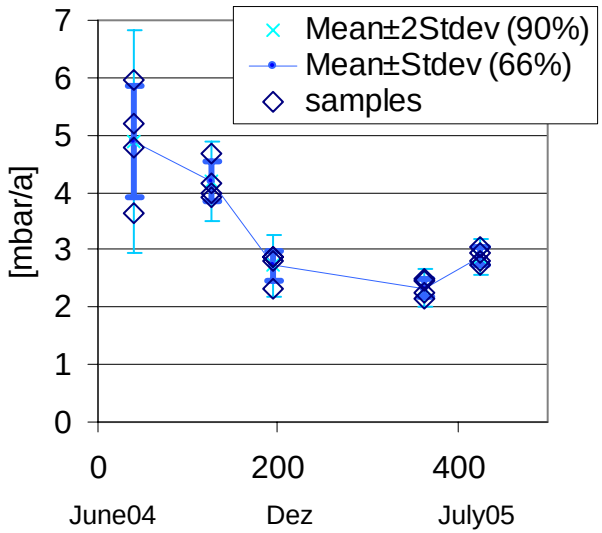
Results: yearly values

25x25x2 cm³

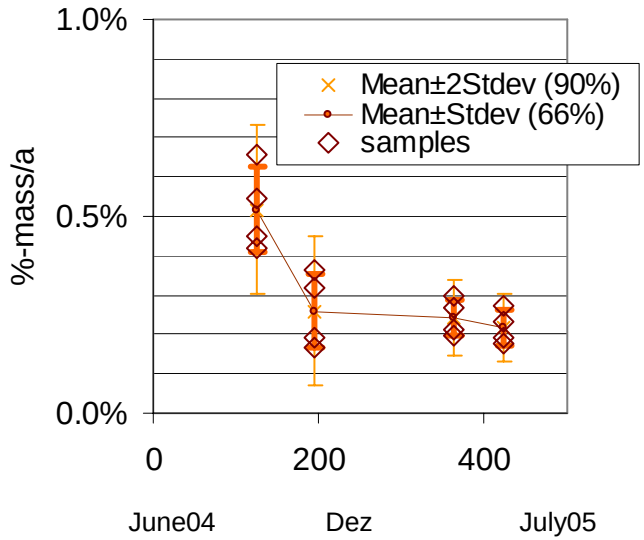
and

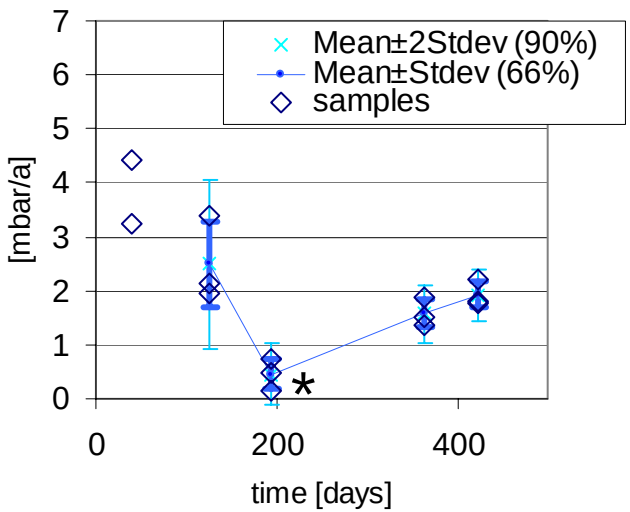
50x50x2 cm³

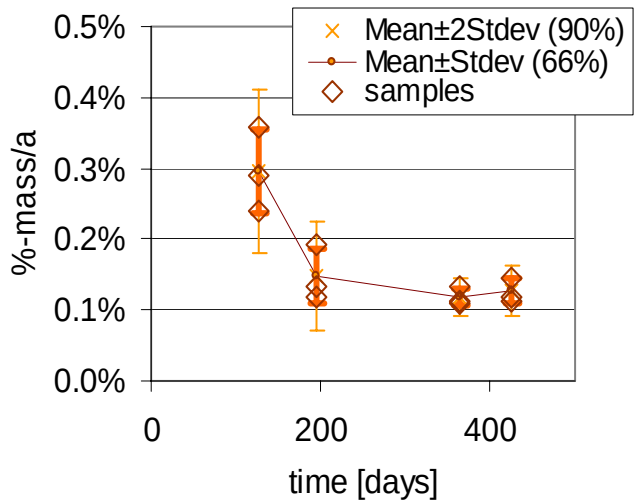
Pressure increase



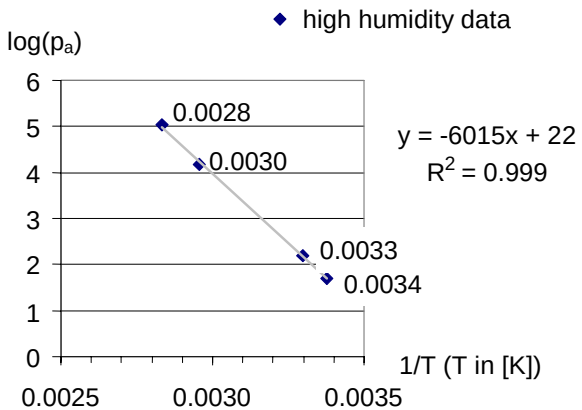
mass increase

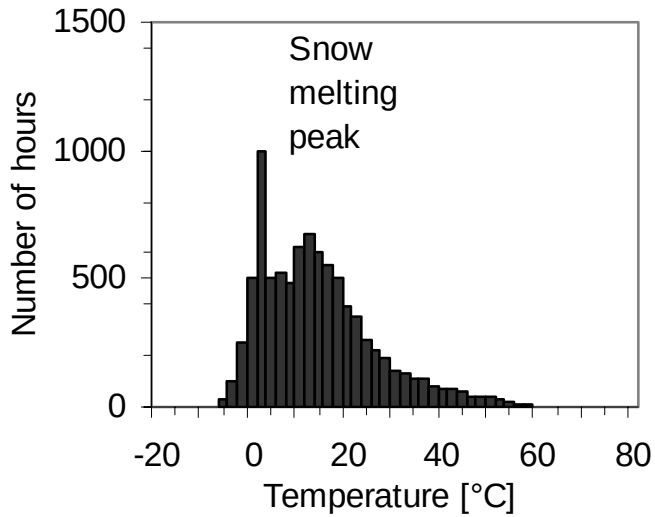






Comparison with laboratory aging data





$$A\exp\left(-\frac{E_a}{RT_{effective}}\right) \equiv \sum_i A\exp\left(-\frac{E_a}{RT_i}\right)\Delta t_i \Big/ \sum_i \Delta t_i$$

$$p_a = A\exp\left(-\frac{E_a}{RT_{effective}}\right)$$

	Inside	Outside
$T_{effective\_pa}$	18.8 °C	19.5°C
$T_{average}$	17.6 °C	12.9 °C

Comparison of measured and calculated data

Panel size	Quantity [mbar/yr]	Calculation based on the temperature data (1 year)			Measurement after 424 d	
		Inside	Outside	Mean		
25 x 25 x 2 cm^3	p_a ($T_{effective}$)	2.72	2.89	2.8	2.9	±0.2
	p_a ($T_{average}$)	2.48	1.70	2.1		
50 x 50 x 2 cm^3	p_a ($T_{effective}$)	2.04	2.17	2.1	1.9	±0.2
	p_a ($T_{average}$)	1.86	1.27	1.6		
	[%-mass/yr]					
25 x 25 x 2 cm^3	X_{wa} ($T_{effective}$)	0.26%	0.29%	0.28%	0.22%	±0.04%
	X_{wa} ($T_{average}$)	0.23%	0.16%	0.19%		
50 x 50 x 2 cm^3	X_{wa} ($T_{effective}$)	0.15%	0.17%	0.16%	0.13%	±0.02%
	X_{wa} ($T_{average}$)	0.14%	0.09%	0.11%		

What will the λ-value in 25 years for a "big" format 100 x 60 x 2 cm³ ?

separated area and edge length influence
=> values for this size: p_a 1.5 mbar/yr and X_{wa} = 0.10 %-mass/yr

time constant for moisture saturation $\tau = X_{w,equilibrium} / X_{wa}$ = 64.0 yr

with $X_{w,equilibrium} \approx$ 6.4 %-mass at 80 % RH

the predicted thermal conductivity increase as function of time t (in years) is then

$$\Delta\lambda(t) \approx 0.035 \cdot 1.5 \cdot t + 0.50 \cdot 6.4\left(1 - \exp(-t / 64.0)\right)$$

$\lambda_{25years} = \lambda_{initial} + \Delta\lambda(t)$ [10^{-3} W/(m K)]

= ~ 4.5 +2.3 = 7 (6 to 8) [10^{-3} W/(m K)]

As center-of-panel value

Conclusions (part 1)

- flat roof with VIP insulation show aging effects quantified with reasonable accuracy after one year.
- aging characteristics from lab based aging of specimens can be related to the in-situ behaviour by linear or non-linear weighting
- pressure increase rate obtained by non-linear weighting is in good correspondence to the data.
- moisture content increase seems to be overestimated
- linear weighting - lower values than observed for both
- Basically in-situ as well as laboratory based aging results suggest a service life in the range of several decades.

Conclusions (part 2)

- A long-term increase of the thermal conductivity must be taken into account in building applications.
- The increment depends on barrier properties, panel dimensions and boundary conditions. For the described flat roof application a long-term value of 7·10-3 W/(m K) may be appropriate for actual SiO2–VIP with polymer-based barrier.
- Monitoring results from periods of several years are still needed to clarify existing uncertainties, to quantify additional aging effects not taken into account so far, and to further strengthen confidence in vacuum insulation.

Thanks

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enabled

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