NATURALLY VENTILATED EARTH TIMBER CONSTRUCTIONS

Research results from [H] house project

ZRS monitoring data and best practice example

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Organisers: CONSTRUCTION INDUSTRY COUNCIL 建造業議會 HKGBC 香港綠色建築議會

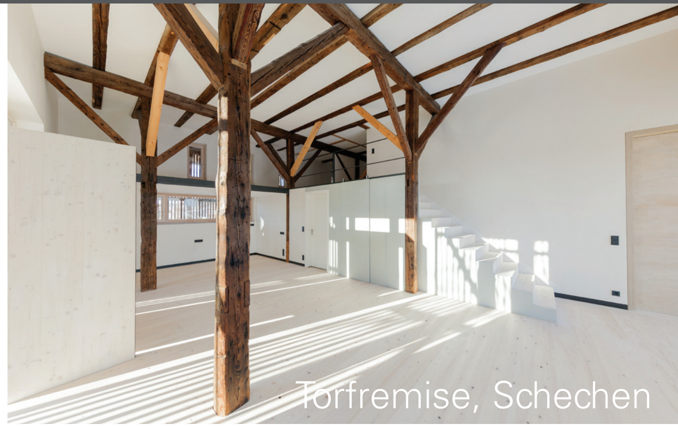
SBE SERIES

International Co-owners: CIB iiSBE UNEP Sustainable Buildings and Climate Initiative FIDIC Global Alliance for Buildings and Construction

ZIEGERT | ROSWAG | SEILER ARCHITEKTEN INGENIEURE

Creating natural change - researching, designing, building with earth, wood, bamboo

Artis GmbH Workshop, Berlin



Torfremise, Schechen

School handmade, Bangladesh

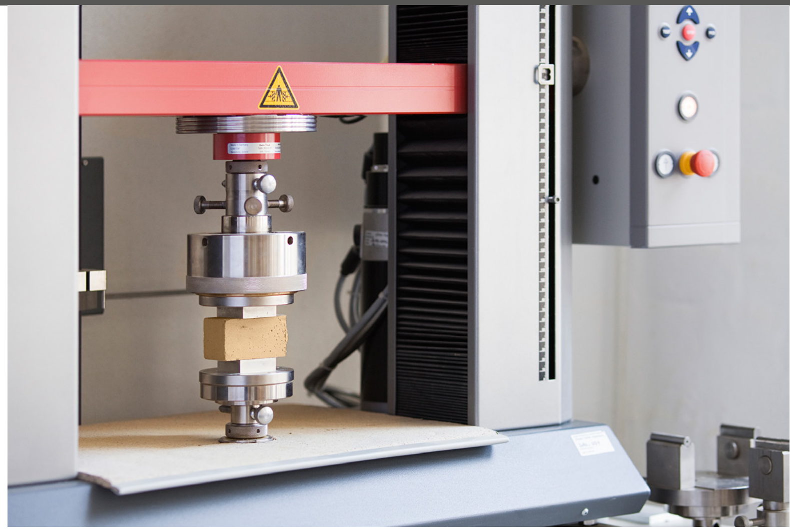
ZRS office and lab, Berlin

ZIEGERT | ROSWAG | SEILER – MATERIAL LAB

Development and testing of earthen building materials

Researching indoor environmental quality and building from waste

Development of DIN standards for earthen building materials (plaster, mortar, earth board)

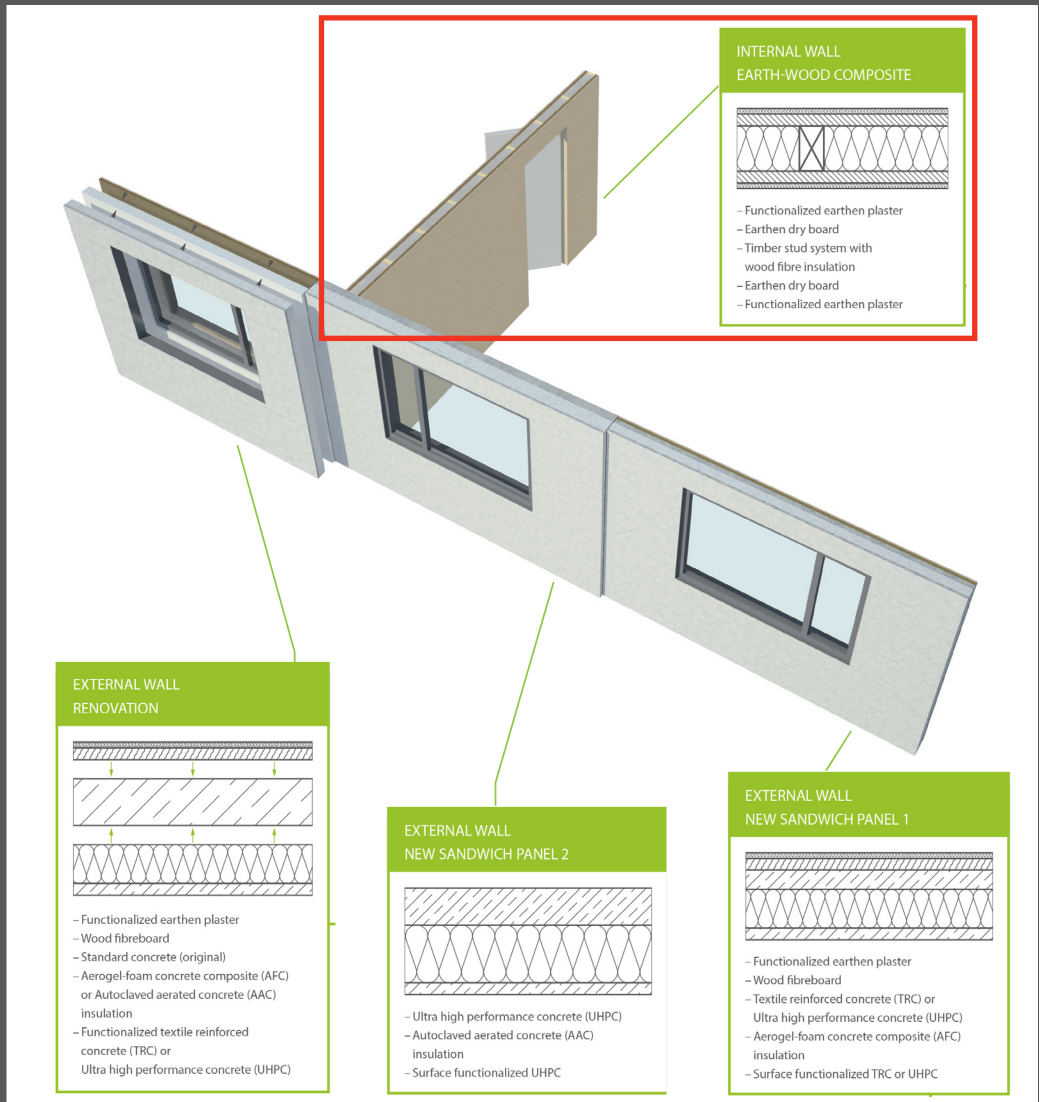


[H] house - EU RESEARCH PROJECT

Healthier life for Eco-Innovative Components for Housing Construction

GOALS & OBJECTIVES

- Innovative materials & construction
- Improved Indoor Environmental Quality
  - Thermal comfort
  - RH - Water vapour adsorption
  - Prevention against overheating in summer
  - Low emitting materials
  - Adsorption of air pollutants
  - Sound insulation and acoustic
- LCA / LCC
- Energy efficiency
- Affordability



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Improved Indoor Environmental Quality - IEQ

Address shortcomings associated with modern airtight buildings

> increased relative humidity levels indoors, damp problems and condensation

> higher concentration of air pollutants

Develop robust solutions that are able to react to reduced air exchange rates and address associated problems in combination with natural ventilation

Mould growth

Material emissions

Chemicals & odors

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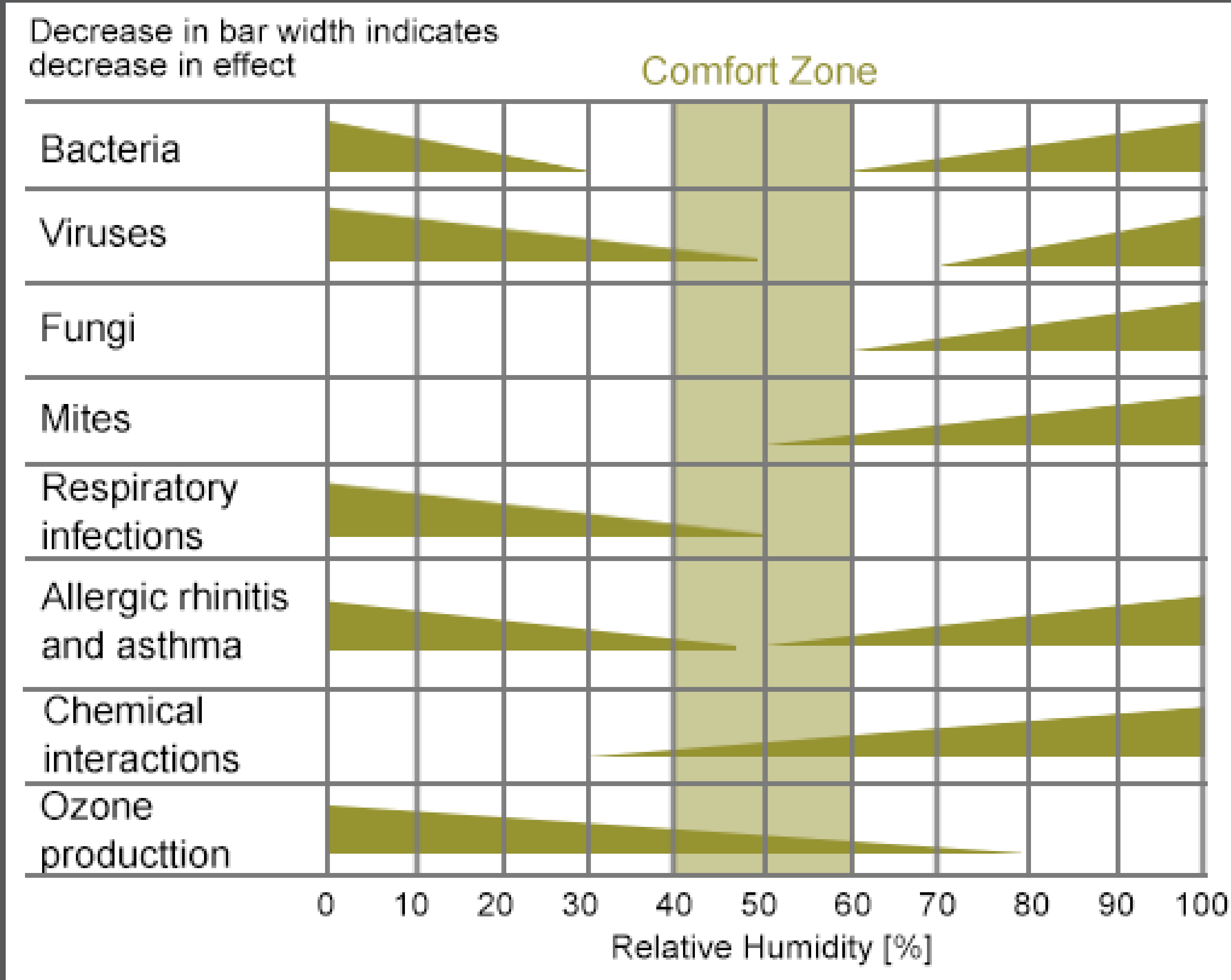
Improved Indoor Environmental Quality - IEQ

Scofield - Sterling Diagram
1985

Relevant interdependencies of microbioms and relative humidity

Optimal Zone
Between 40% - 60% RH
activity of unwanted health risk for building occupants through bacteria, viruses, fungi etc. is minimal



HYGROSCOPIC PROPERTIES OF EARTHEN BUILDING MATERIALS

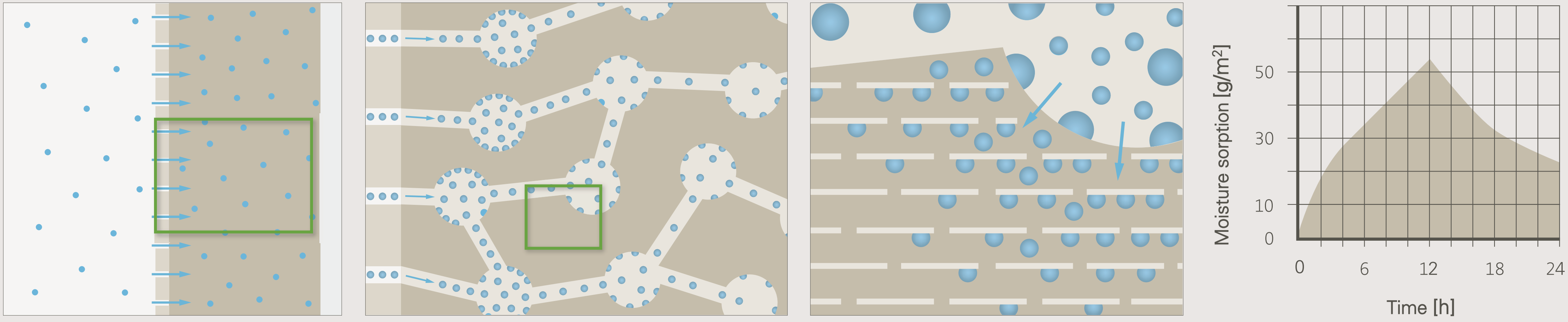
Humidity ad- and desorption through capilarity

Storage of humidity in three layered clay minerals within earthen materials

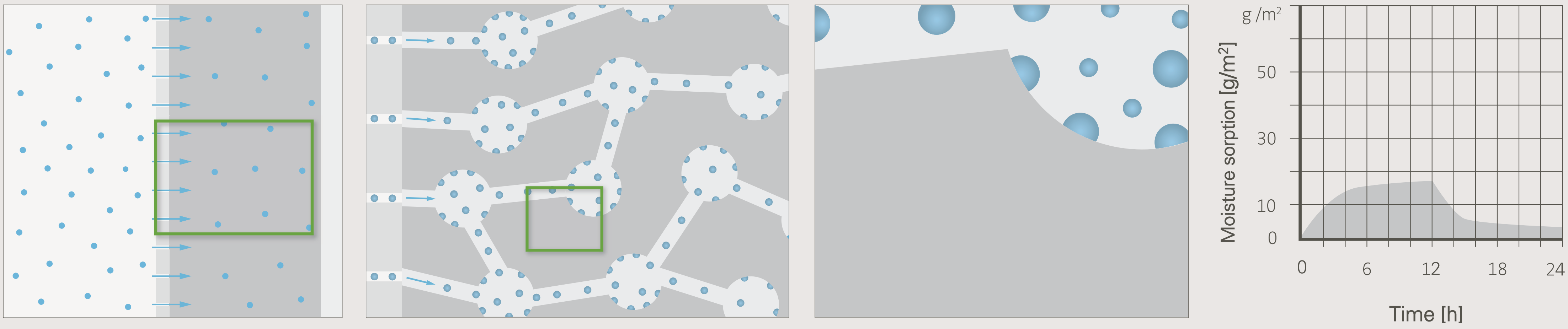
Comparison: Humidity adsorption of earthen and cementitious plasters

Ad - and desorption in 24 h

Earthen plaster



Cementitious plaster



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Material development: Aerogel modified earth plasters

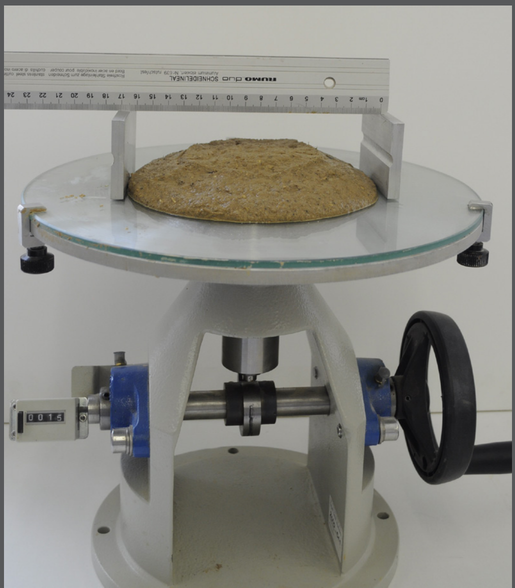
Aerogel (silicate based) highly porous solid objects (ND / CMS / E9)

Bulk density between 40-150 kg/m^3, surface area 750 m^2 / g

Very cost efficient material production

Material development so far achieved TRL 5, Demonstration is anticipated

Tested against DIN 18947 (earth plasters) strength + shrinkage, new standard required



Flow diameter

Drying shrinkage

Compressive strength

Microscopy

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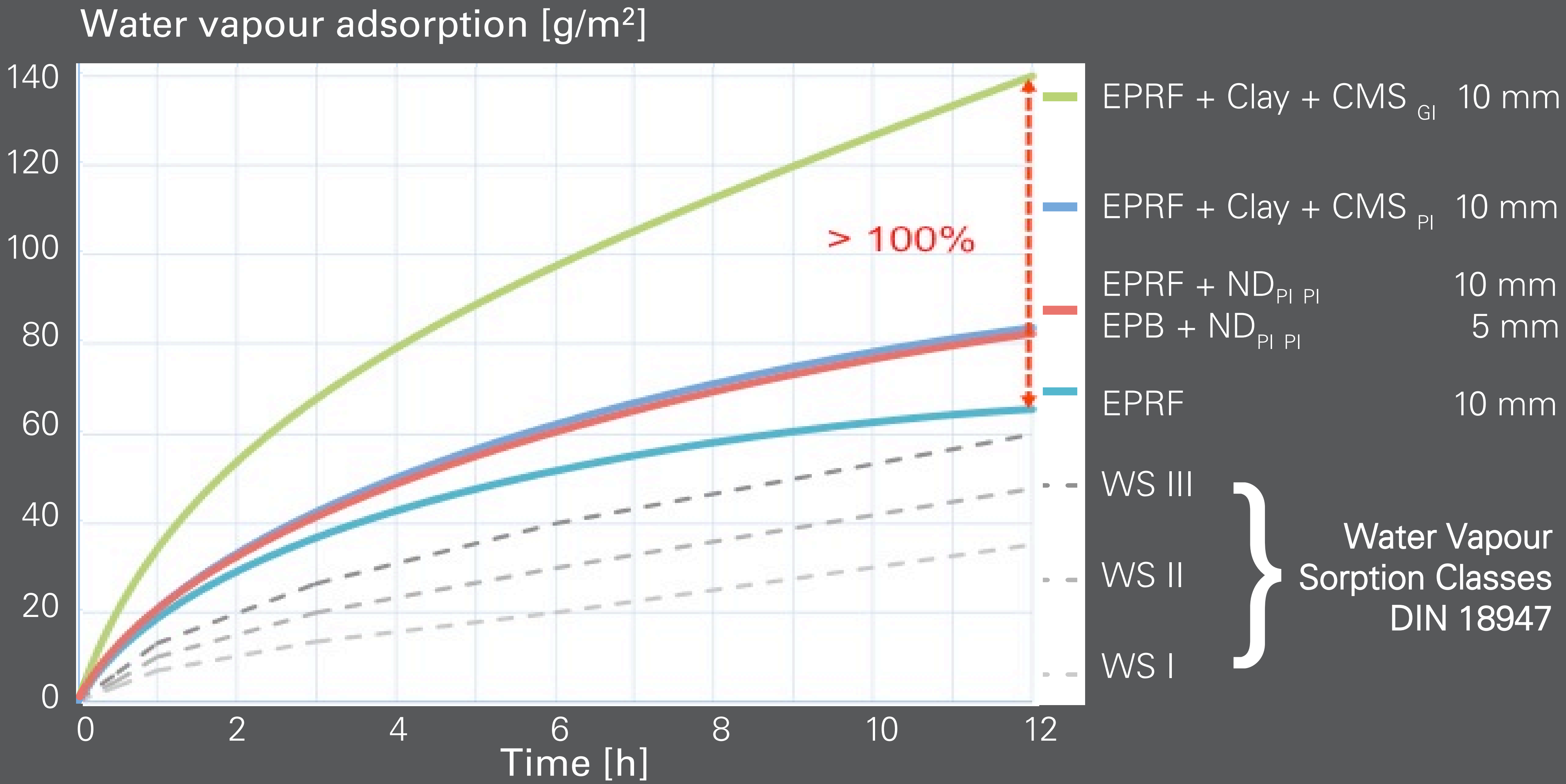
Material development: Aerogel modified earth plasters

Water Vapour Adsorption Tests (DIN 18947)



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Material investigation of natural building materials for internal partition walls

Water Vapour Adsorption Tests (DIN 18947) + emission tests (ISO 16000-9 | prEN 16516)

Earth plaster

Earth dry-, earth cellulose board

Wood fibre, wood fibre sandwich boards

Wood fibre, hemp and clothes insulation

Wood fibre flax board, strawboard

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Material investigation - Water Vapour Adsorption Tests

Wall build-ups

Earth plaster rough (straw) + earth adhesive + wood fibre board + wood fibre insulation

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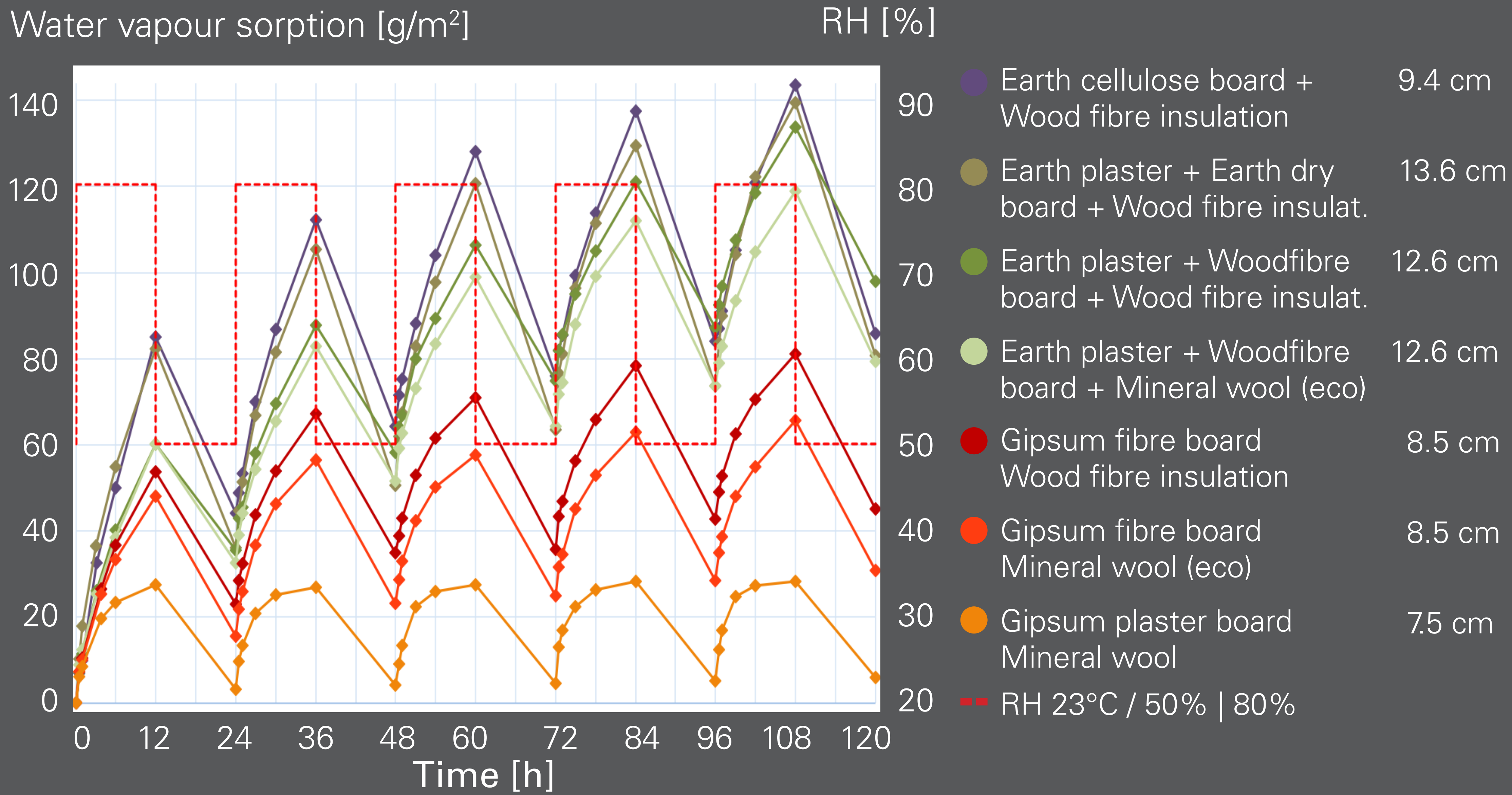
Material investigation - Water vapour sorption test (based on DIN 18947)



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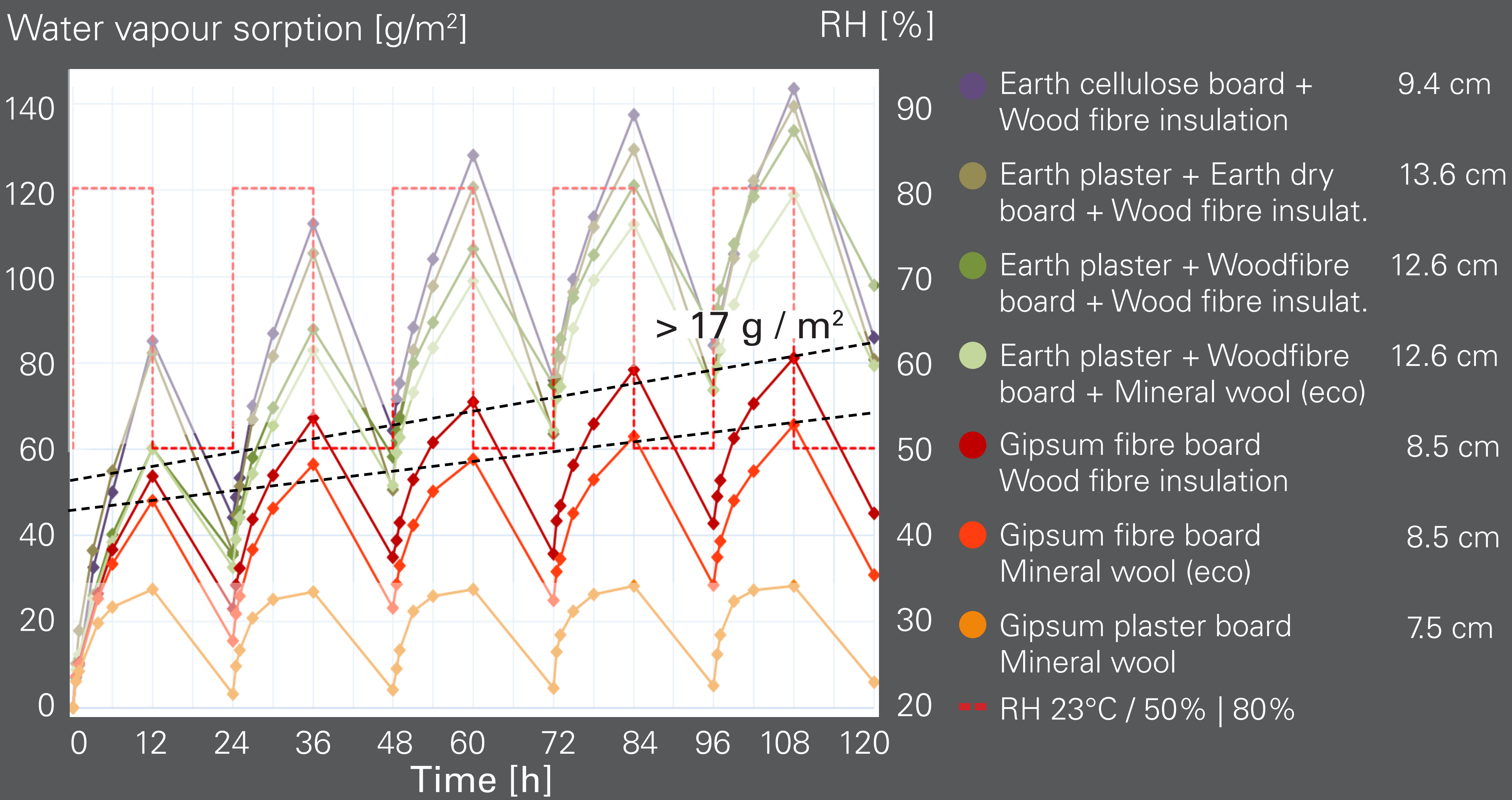
Material investigation - Water vapour sorption test (based on DIN 18947)



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Material emissions and reduction of airborne pollutants

1. Emissions testing
   - Emissions of formaldehyde, VOCs, SVOCs and radon by sampling at days 3, 7, 10 and 28 days after loading
   - Evaluation against German AgBB testing scheme

2. Testing for adsorption capacity
   - Sorption behaviour towards 5 VOCs representing important indoor air pollutants (1-pentanol, hexanal, butyl acetate, α-pinene and n-decane)
   - Concentrations ranging from 200 to 500 µg/m³

3. Testing parameters for both types of testing
   - T = 23 °C / RH = 50%
   - $n = 1.0\ h^{-1}$ / $L = 2.0\ m^2/m^3 \rightarrow q = 0.5\ m^3/(m^2h)$
   - corresponds to a reference room of 30 m^3 (3 m x 4 m x 2,5 m) with a wall surface area of 31.4 m^2 (European reference room)

Preparation of test samples and testing

1. Installation into modular sample intakes

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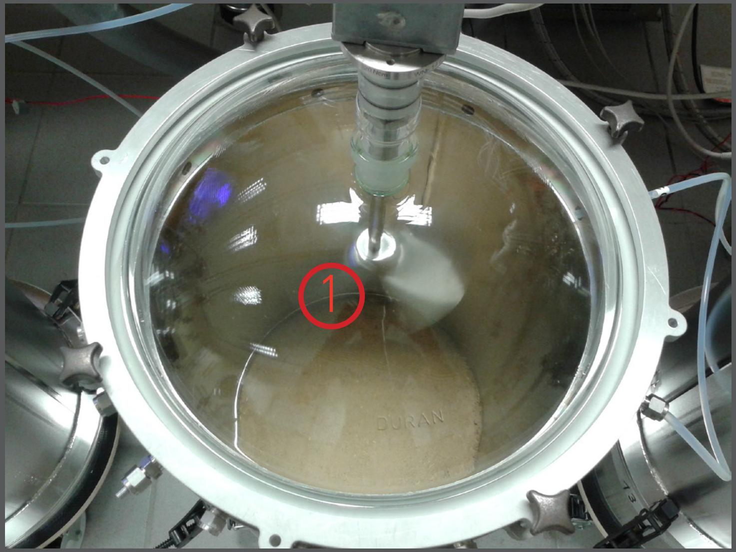
Material emissions and reduction of airborne pollutants

Preparation of test samples and testing

2. Pre-conditioning of test samples, if necessary

   n = 1,0 h^{-1}, RH = 50 %

3. Assembling emission test chamber



1 Glass lid with agitator
2 Connection ring
3 Hollow cylinder
4 Sample intake

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Material emissions and reduction of airborne pollutants

Evaluation of (S)VOC emissions

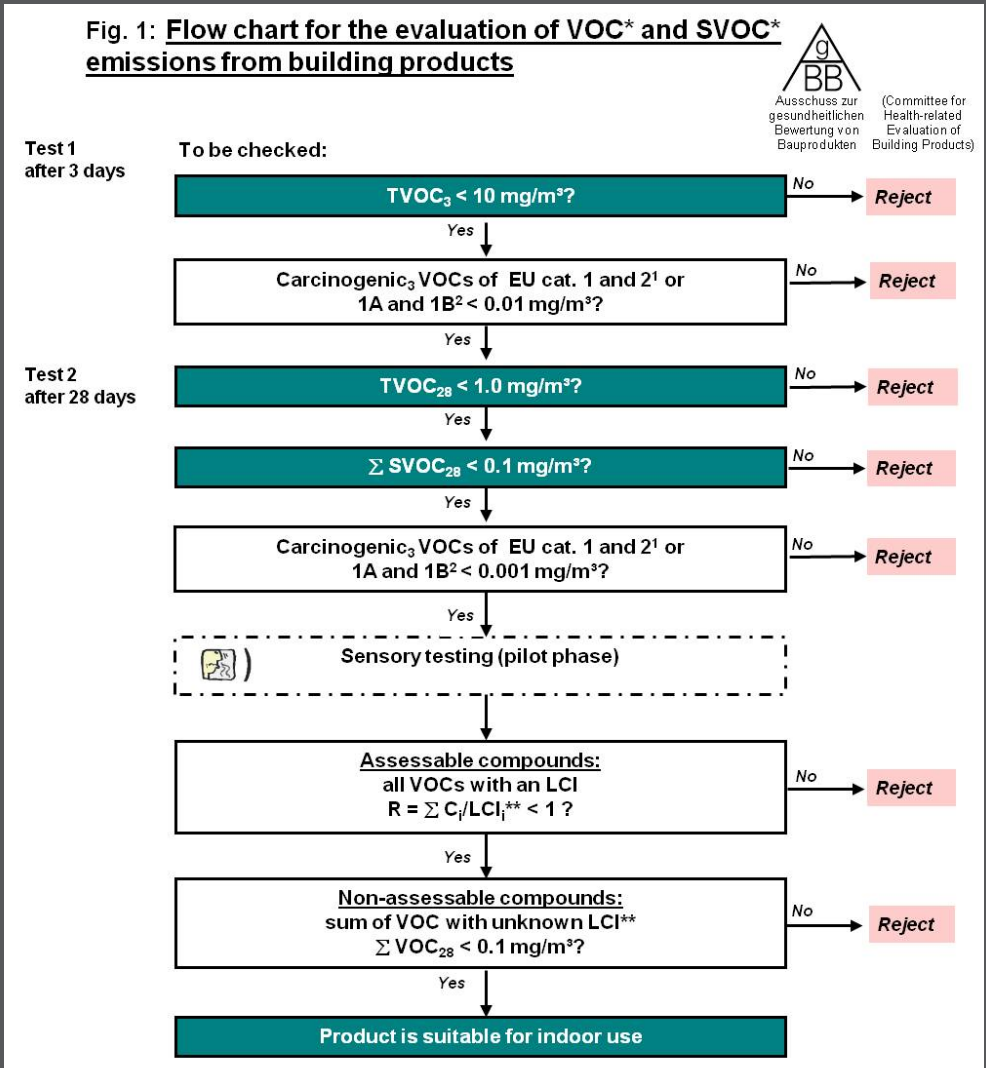

Fig. 1: **Flow chart for the evaluation of VOC* and SVOC* emissions from building products**

- Evaluation of suitability for indoor use
- In Germany mandatory for flooring materials and decorative wall coverings
- Developed for evaluation of VOC emissions from single building materials

→ In the H-House project used to assess emissions into indoor air

Material emissions and reduction of airborne pollutants

Evaluation of VOC reduction (ISO 16000-24:2009)

1. Determination of sorption flux F_m [µg/(m²h)]
   Mass of VOC (except formaldehyde) sorbed per time per area at the specified elapsed time from the test start.

2. Calculation of sorption mass ρ_{Aa} [µg/m²]
   Theoretical maximum mass of VOC (except formaldehyde) that could be removed per area of the sorptive material.

3. Test stopped when half-lifetime was reached for each compound
   Time elapsed from the start of the test until the VOC decreases to one-half of the initial concentration.

4. Measurement of re-release of VOCs for at least 7 days

Results of emissions tests

VOC

- TVOC in all cases below 1000 µg/m³
- AgBB criteria fulfilled in 18 from 19 cases

Limitation: Evaluation scheme developed for single materials! For application on composite materials criteria would need to be adjusted.

Radon

- Radon exhalation from all tested materials fell below the recommended contribution to the overall indoor radon concentration of 20 Bq/m³ (*recommendation German Committee for Radiation Protection*)
- In most cases near or below limit of detection

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Material emissions and reduction of airborne pollutants

Results of VOC reduction tests (ISO 16000-24:2009)

No.	1-pentanol (mg/m²)	Hexanal (mg/m²)	Butyl acetate (mg/m²)	α-pinene (mg/m²)	n-decane (mg/m²)	$\Sigma\rho_{Aa}$ (mg/m²)
1	7.9	6.0	12.6	0.0	0.0	26.5
2	8.7	7.9	18.0	0.0	0.0	34.6
3	38	21.9	27.3	0.0	0.9	88.1
4	30.4	24.0	32.6	0.0	1.0	> 88.0
5	3.2	3.0	5.1	0.0	0.0	11.3
6	6.6	4.2	11.0	0.0	0.0	21.8
7	6.0	1.9	1.8	0.0	0.8	10.5
8	36.3	32.2	57.1	0.0	0.9	> 126.5
9	9	2.3	11.9	0.0	1.7	24.9

- Earth plaster materials generally show good adsorption capacity
- Significant increase of adsorption when ND *Aerogel powder hydrophilic* (ND_{PI}) or CMS *Aerogel Granulate hydrophilic* (CMS_{GI}) was added
- Adsorption generally favourable to the polar VOCs and n-decane in low amounts; α-pinene was not attached
- Plaster thickness important – best performance at 5-10 mm

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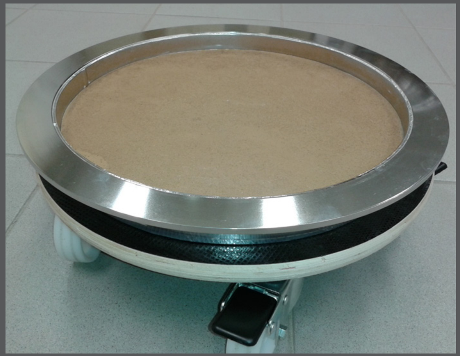
Material emissions and reduction of airborne pollutants

Sorption mass at different thicknesses and RH at half-lifetime

Earth plaster with straw, final coat (EPRF)	3 parts
Aerogel CMS_{GI}	1 part
Clay powder	1 part

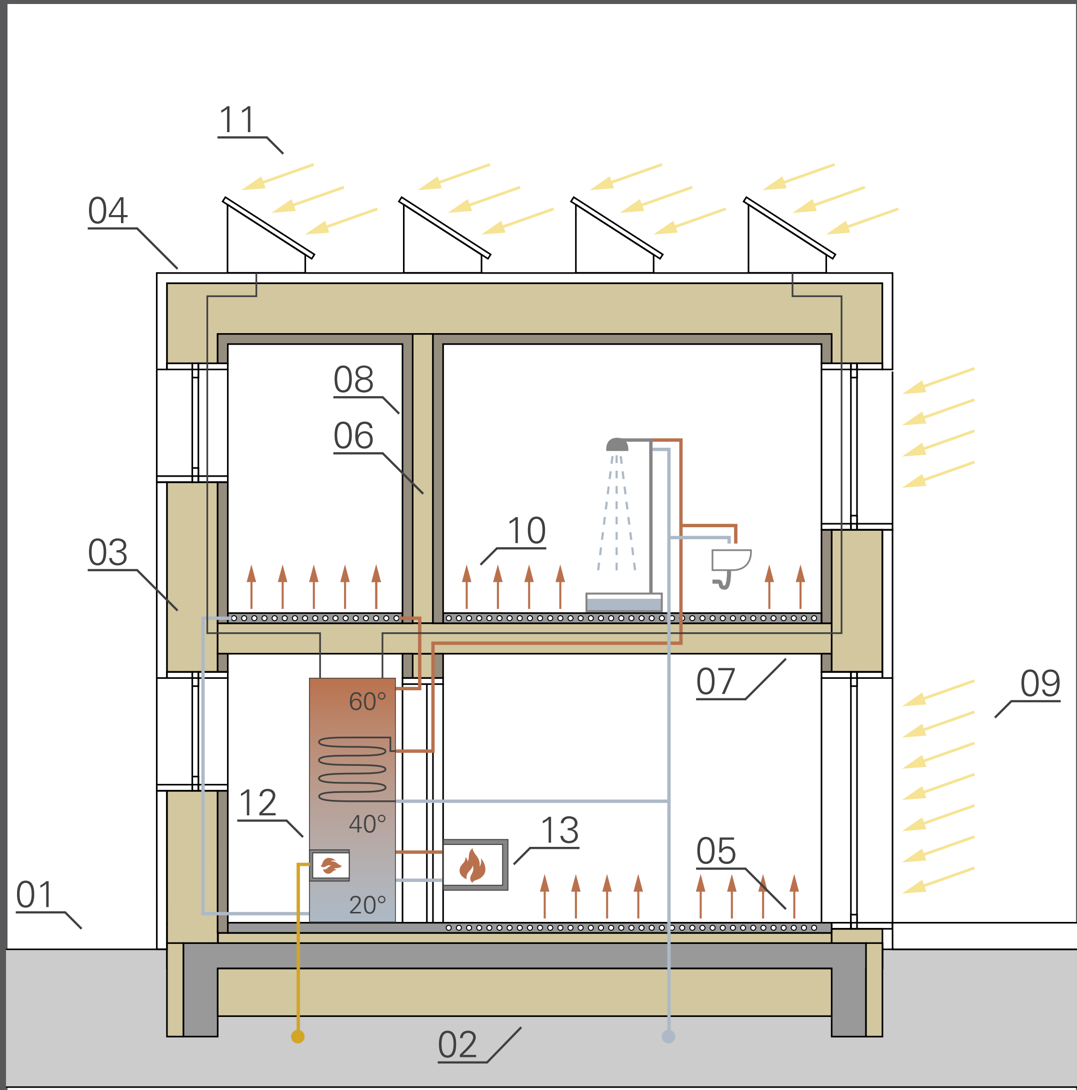


[a] after 82 days; half-lifetime not reached

RH (%)	Thickness (mm)	1-pentanol (mg/m²)	Hexanal (mg/m²)	Butyl acetate (mg/m²)	α-pinene (mg/m²)	n-decane (mg/m²)	$\Sigma\rho_{Aa}$ (mg/m²)
50	5	21	14	63	0.4	2	100
	10	39	29	184[a]	1	4	257
	15	56[a]	42	138[a]	1	3	240
70	5	6	4	11	0	0	21
	10	8	6	15	0	1	30
	15	20	14	27	0	0	61

TIMBER - EARTH BUILDING SYSTEM

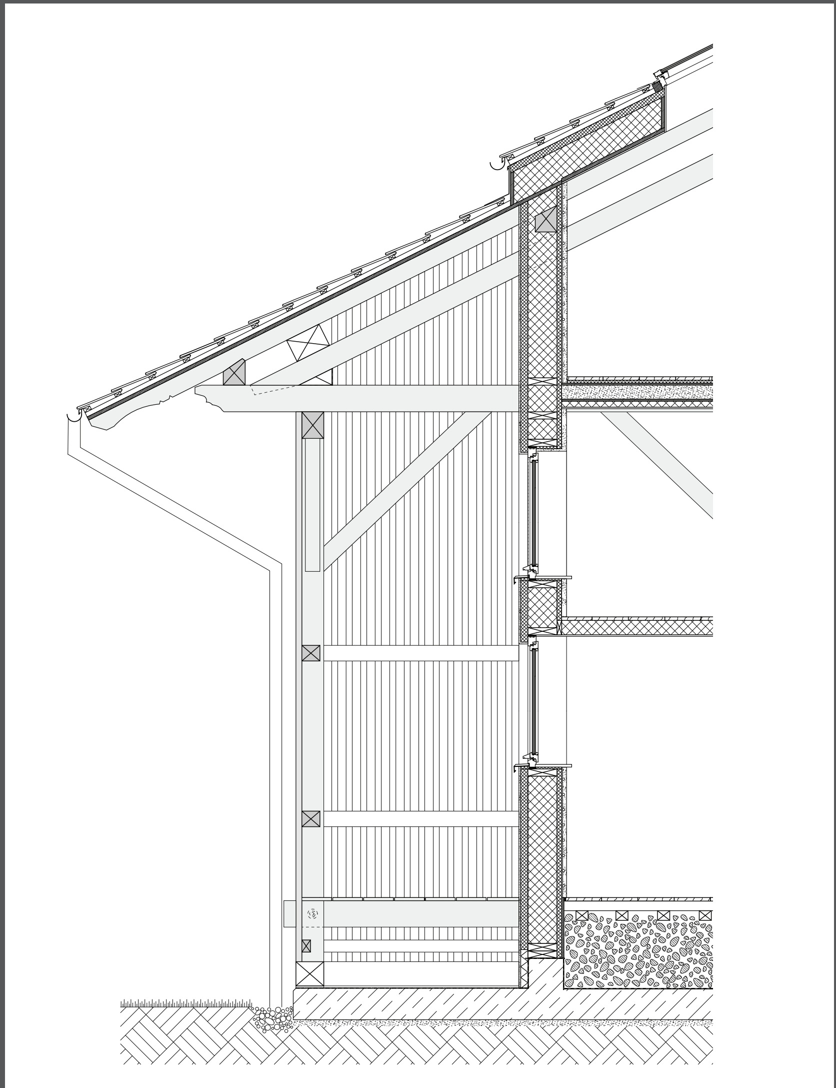
Energy efficient without mech. ventilation



01 Building Ground
02 Concrete Floor Slab
03 Timber Construction, Wood Fibre Insulation
04 Timber Construction, Wood Fibre Insulation
05 Wood Fibre Insulation, Floor Heating
06 Timber - Earth Walls
07 Solid Timber Ceiling
08 Earth Cladding to condition room climate
09 Passive Sun Use
10 Floor Heating
11 Solar Hot Water Collector
12 Hot Water Storage, Additional Gas Heating
13 Passive Fireplace (Heat Exchanger)

LIVING AND WORKING IN THE HISTORIC "TORFREMISE" SCHECHEN , BAVARIA

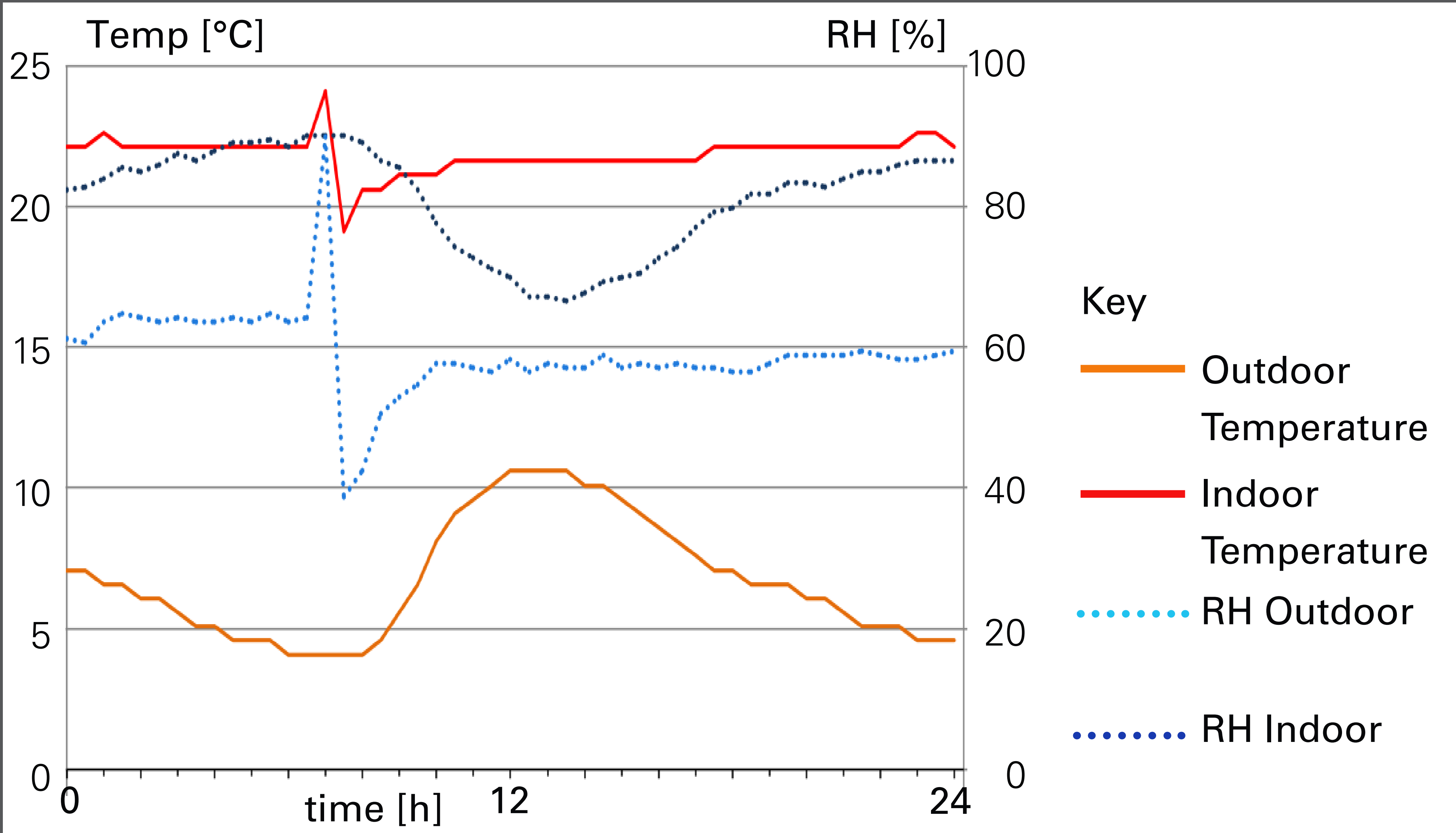
Timber, wood fibres, earth blocks, earthen plasters



Torfremise, Living Groundfloor

MONITORING RESULTS OF FLATS FITTED OUT WITH EARTH PLASTERS

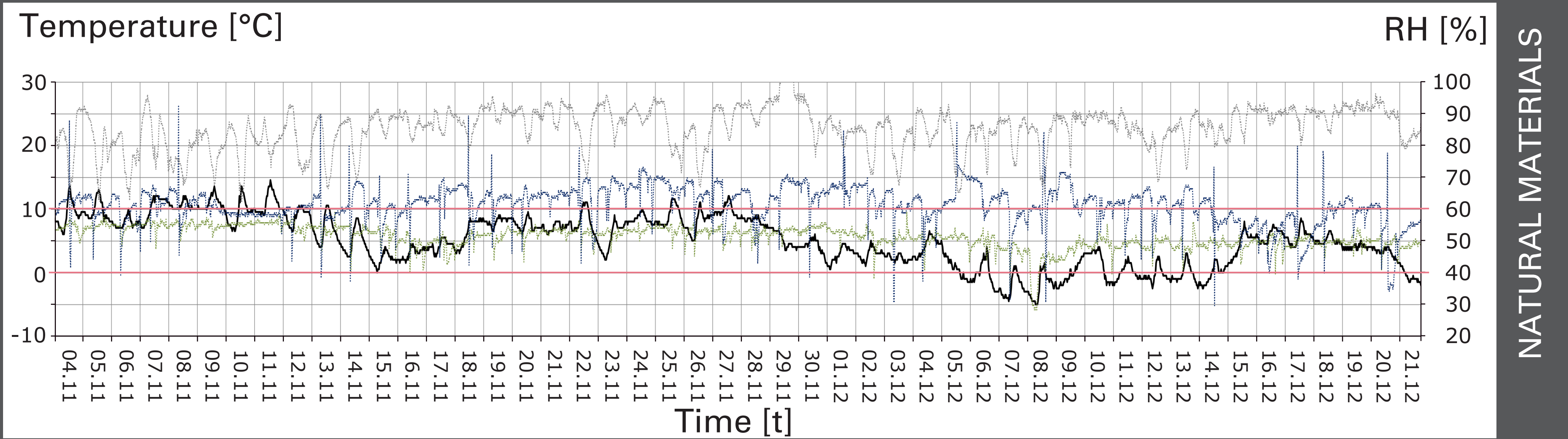
Bathroom in wintertime

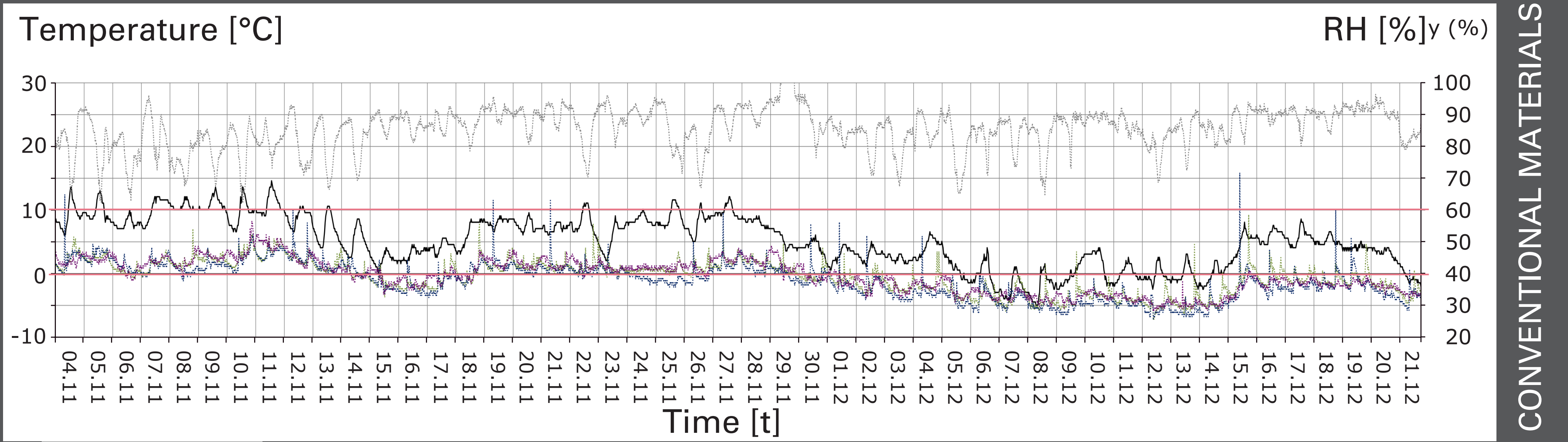


MONITORING RESULTS

Natural building materials versus conventional building materials

Temp. outdoor
RH outdoor





Material emissions and reduction of airborne pollutants

Conclusions

- Earth, timber, wood- and other natural fibres are vapour active and able control the indoor climate / humidity and temperature
- These natural building materials demonstrate very low emissions and earthen plasters are able to absorb VOC from the indoor air
- The addition of aerogels the moisture adsorption and air purifying capacity of earthen plaster was enhanced
- Energy efficient, airtight buildings, naturally ventilated twice a day demonstrate healthy RH between 40% - 60%
- In the moderate central climate (Europe) Low-Tech zero carbon buildings can be constructed without or significantly reduced mechanical ventilation
- This Low-Tech approach can also be applied for the usually high mechanical ventilated and conditioned office building sector and production buildings
- In hot dry climatic zones specially earth has a huge cooling and low-cost potential
- Based on further R&D natural materials are based for Low-Tech pioneers of the post fossil society

Thank you