IEA Annex 65: Long-Term Performance of Superinsulating Materials (SIM)

Christoph Sprengard – FIW München

Content

Energy in Buildings and Communities Programme

Factsheet

Long-Term Performance of Super-Insulating Materials in Building Components and Systems

ANNEX 65

http://www.iea-ebc.org/projects/ongoing-projects/ebc-annex-65/

VIP and APM

Photo: Porextherm

Photo: FIW München

Knudsen Effect

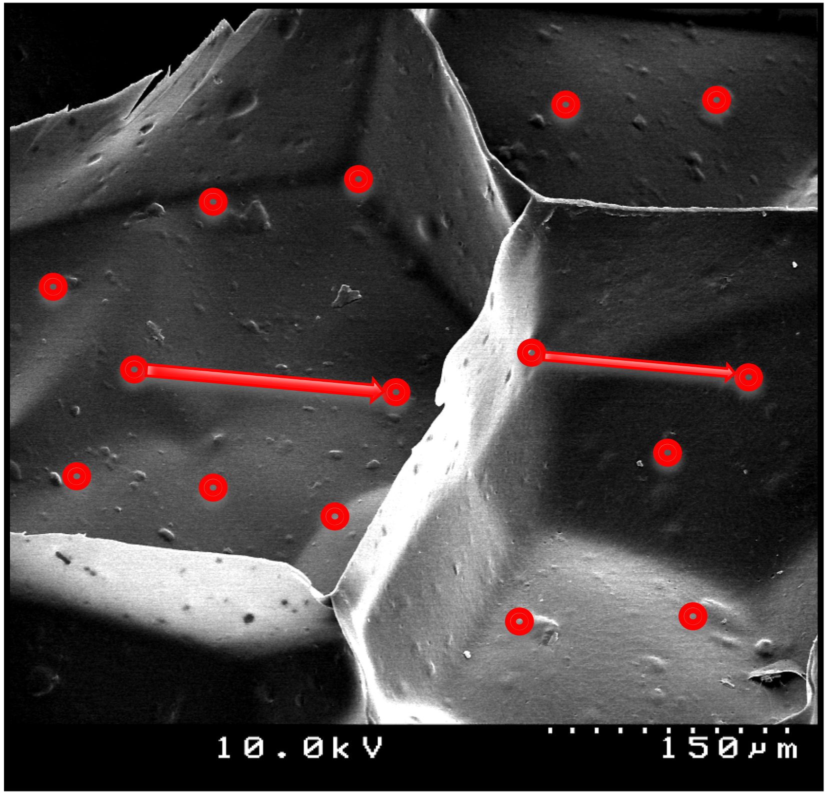
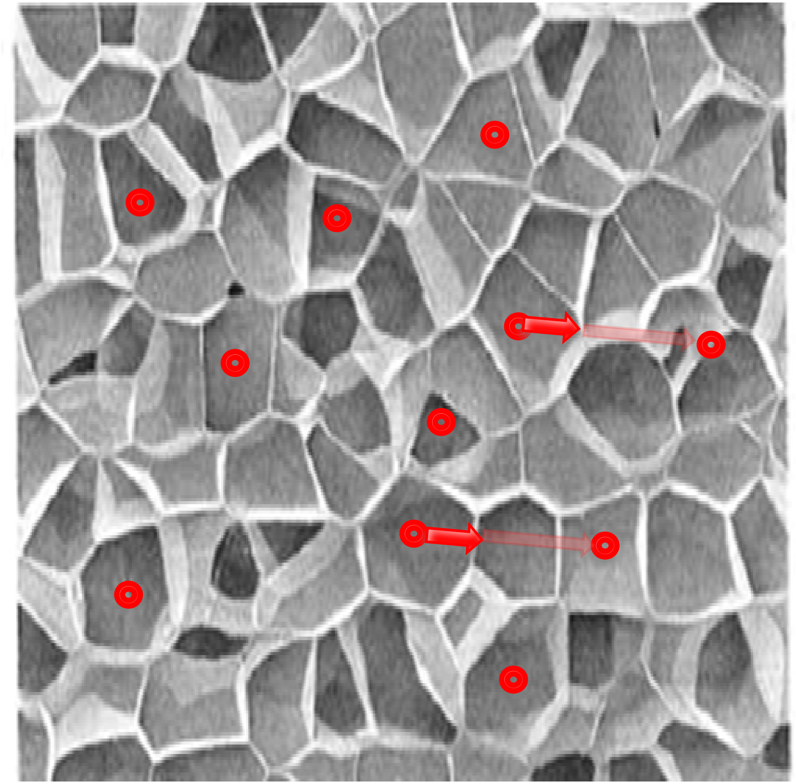


Photo: BASF; Grafic: FIW



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Knudsen Effect

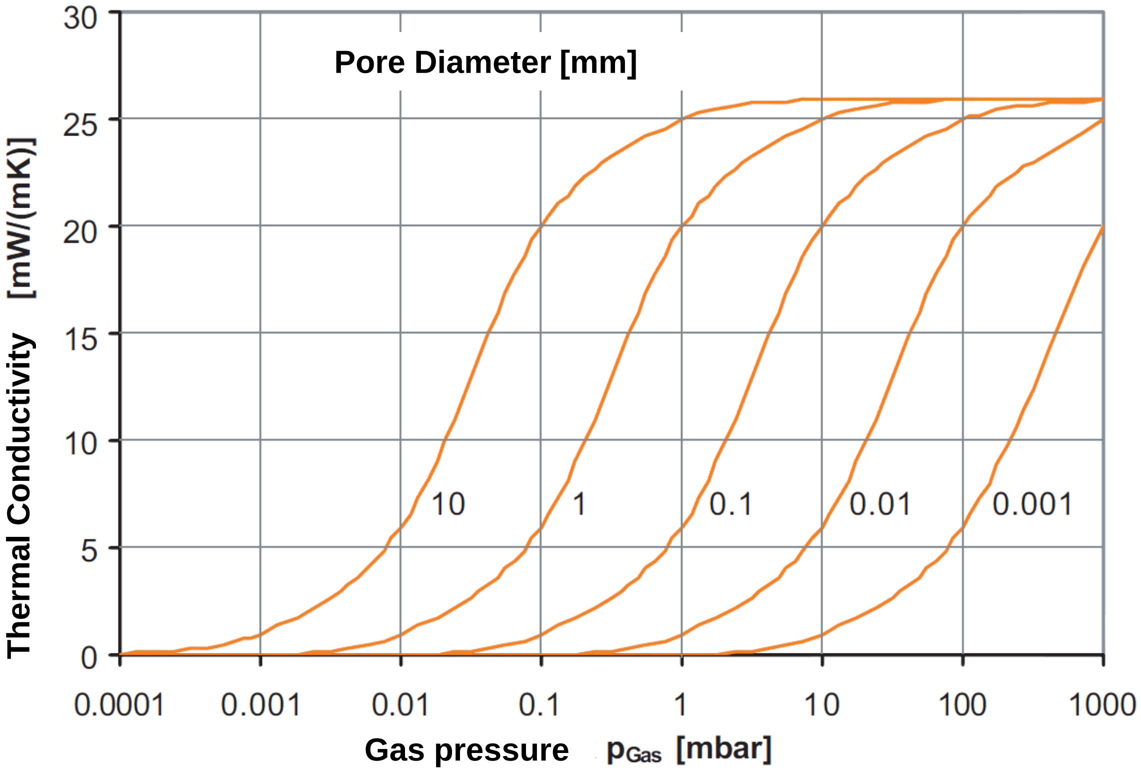


Diagram: Jan Cremers

IEA EBC Annex 65 „SIM“ - Goals

- Raise level of knowledge of decision makers and planners for new materials in the building sector
- Provide Reliable and Reproducible Data (and Methods) for
  - Thermal, Hygric and Mechanical Properties
  - Durability
  - Sustainability
- Clearly define artificial ageing methods and derive reliable performance calculations over time
- Raise confidence for SIM in different applications
- Set the basis for start of standardization work

IEA EBC Annex 65 „SIM“ – goals

- NO PRODUCT DEVELOPMENT!
- No research to widen the fields of application
- No research on new measurement methods
- No development of new apparatuses

- Alignement of the level of knowledge within the partners for
  - Measurements
  - Artificial Ageing
  - Calculations and Simulations
- Enhancing Scientific Collaboration of involved Countries (intercultural Task)
- Establishment of Networks for future Research

Annex 65 - Partners

- Institutes
  - CSTB; ZAE; FIW; BBRI; Fraunhofer IVV; DLR; EDF; EMPA; etc.
- Universities
  - Kyoto; Oxford Brookes; Chalmers; Brunel; Lyon; Stockholm; Athens; Nanjing; Milano; etc.
- Manufacturers
  - Aspen, Cabot, Creek, Evonik, Arcelor, Dow Corning, Hanita, Kingspan, LG Hausys, OCI, Panasonic, Porextherm, Recticel, Rockwool, St. Gobain, Separex, Siltherm, Tecnalia, Va-Q-Tec, Rexor, etc.

Annex 65 – Overview and Structure

FIW München

- Operating Agent: Daniel Quenard, CSTB
- Subtask I: State of the Art on Materials and Components: Ulrich Heinemann, ZAE Bayern
- Subtask II: Characterization of Materials and Components: Andreas Holm, FIW München
- Subtask III: Practical Applications – Retrofitting at the Building Scale: Bijan Adl-Zarrabi, Chalmers University (Göteborg)
- Subtask IV: Sustainability: LCC, LCA & Risk and Benefit: Holger Wallbaum, Chalmers University (Göteborg)

Goals and Tasks – Subtask I & II

- Subtask I
  - Characterization Methods
  - Materials, Components & Systems
  - Case Studies at the Building Scale
  - provide an up-to-date catalogue of commercially available materials & components
  - provide technical description of each product with technical data and information about the application domains and the implementation rules
- Subtask II
  - Materials Assessment & Ageing Procedures
  - Adaption of measurement methods for characterization of materials and barrier films
    - microstructural,
    - hygro-thermal and
    - mechanical
  - Adaption and Validation of modelling methods for
    - Heat-, Moisture- and
    - Air-Transfer

Goals and Tasks – Subtask III & IV

- Subtask III
  - Mapping of the Use Conditions
  - Performance at the Building Scale
  - Practical Applications focused on Retrofitting
  - define the application areas of SIM
  - requested performance of SIM will strongly depend on the temperature, humidity and load conditions.
  - For building applications, storage, handling and implementation requirements will be described

- Subtask IV
  - Life Cycle Assessment (LCA), including Embodied Energy (EE)
  - Life Cycle Cost Analysis (LCC)
  - assess the overall sustainability of SIM through the evaluation of LCA, and LCC of superinsulation materials over the entire life cycle (production, use and end-of-life)

Subtask II

Approach for Subtask II

1. Determination of the “State of the Art” (originally assigned to ST I)
   - Measurement Methods
   - Ageing Methods
   - Calculation and Simulation Methods

   Summary and Report of SoA

2. Further improvements in description of methods or modifications needed
3. Validation and Verification

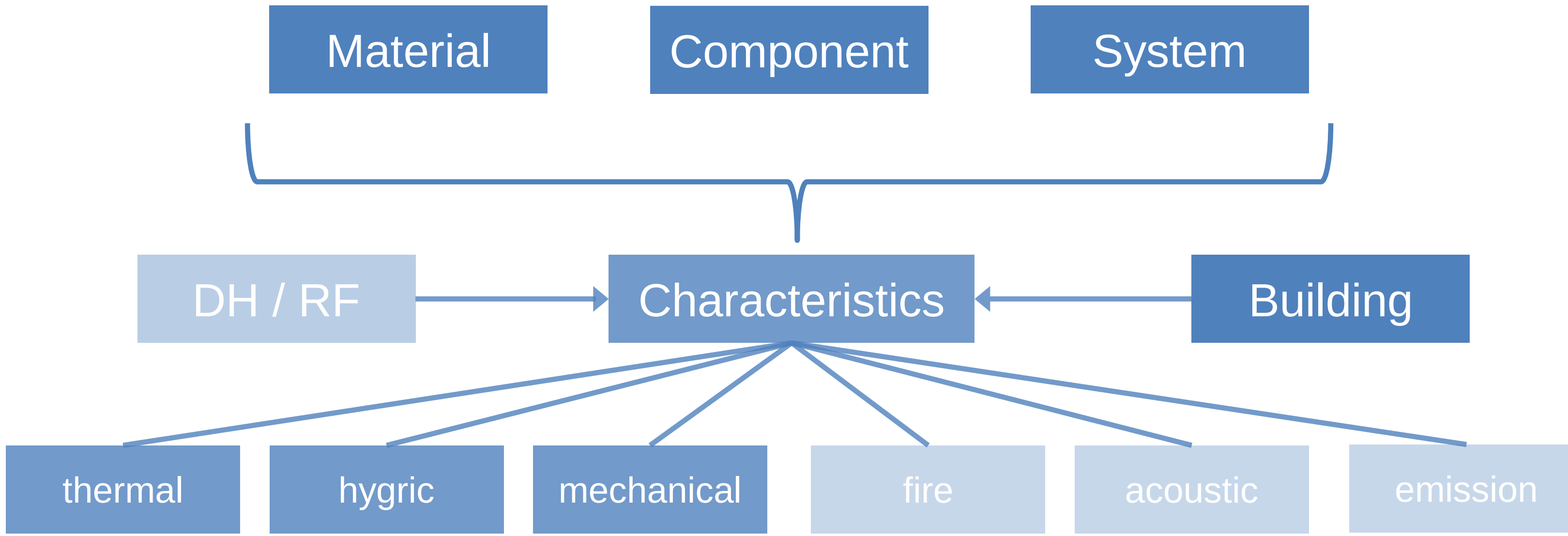
„Common Excercise“

4. Recommendations for Laboratories and production control by the manufacturers (deliverables: report for manufacturers and labs)

Approach

1. State of the art – Measurement Methods

“Type” of Material and characteristics to look at



Approach

1. State of the art – Measurement Methods

Questions:

- Which characteristics of SIM can be / need to be measured?
- Which measurement methods are used for SIM?
- Which measurement methods are used for components and systems?

State of the Art: Basic Material Properties

	Porosity Properties									
	Density			Porosity	Specific Area	Pore Size Distribution	Solid morphology and size distribution	Water sorption	VOC	
Participants	Skeleton	Granular	Apparent						Adsorption	Desorption
CHALMERS University										
CRMgroup										
CSTB										
EDF										
EMPA										
Evonik										
Hanita Coatings										
Isover Saint Gobain										
Kongju National University										
KTH										
LEPMI										
MATEIS, INSA Lyon										
MINES ParisTech										
NTUA										
Politecnico di Torino										
RECTICEL										
Université Paul Sabatier										
va-Q-tec										

State of the Art: Thermal Properties

	Thermal Propertis						
	Thermal Conductivity						Specific heat capacity
Participants	Guarded Hot Plate	Vacuum Guarded Hot Plate	Heat Flow Meter	Hot Disk	Hot Wire	Hot Strip	DSC
CHALMERS University							Support
CRMgroup			Support				
CSTB							Responsible
EDF							Support
EMPA	Responsible						
Evonik							
Hanita Coatings			Support				
Isover Saint Gobain	Support						
Kongju National University				Responsible	Responsible		
KTH		Responsible				Responsible	
LEPMI							
MATEIS, INSA Lyon		Support		Support			
MINES ParisTech				Support	Support		
NTUA	Support						
Politecnico di Torino			Responsible				
RECTICEL							Support
Université Paul Sabatier	Support						
va-Q-tec			Support				

Responsible (orange)
Support (grey)

State of the Art: Envelope Properties

	Envelope Properties				
	Permeance		Diffusion	Solubility	Activation Energies
Participants	Manometry	VIP in climatic chamber			
CHALMERS University					
CRMgroup					
CSTB					
EDF					
EMPA					
Evonik					
Hanita Coatings					
Isover Saint Gobain					
Kongju National University					
KTH					
LEPMI					
MATEIS, INSA Lyon					
MINES ParisTech					
NTUA					
Politecnico di Torino					
RECTICEL					
Université Paul Sabatier					
va-Q-tec					

Approach

1. State of the art – Ageing Methods

Questions:

- Which ageing mechanisms are relevant?
- Which are artificial ageing methods in use?
  - UV – Temperature and Temperature Cycles – Salt Spray – Moisture – Temperature AND Moisture - Chemicals etc.
- Which of these methods are used for SIM?
- What are the effects on SIM – understand ageing process?

Approach

1. State of the art– Calculation and Simulation

Calculations and Simulations can be applied to
Material / System / whole Building

Questions:

- Which level of detail is necessary?
- Which boundary conditions have to be concerned?
- Limits and uncertainty of calculations and simulations?
- How to verify calculation and simulation results by measurements?

Questionaire on methods in use

Annex 65 – Subtask 2

Guideline "State of the Art" – Test Methods

About the authors

Responsible Participant: FIW Munich, Christoph Sprengard, Christine Mayer

Supporting Participants: -

About the Test Method

Test Method: Guarded Hot Plate

This method defines the steady-state heat transfer through flat slab specimens and the calculation of its heat transfer properties. Thereby the heat transfer through radiation, conduction (solid and gas phase) and convection are considered. But there is no way to separate these heat transfer mechanism.

Measured characteristic: thermal resistance **Unit:** m²K/W

Basic characteristics: U and I (Power); temperature and temperature difference (Delta T); thickness d; Area A; …

Functionality

Description of functional principle

According to ISO 8302:

Experiences measuring SIM with these meth.?

Experiences with SIM

Limitations of this test method to SIM

Example what we mean in this section:

SIM have a high thermal resistance for a low thickness. The method is applicable to SIM, but needs some adjustments and precautions to improve accuracy. At FIW VIP is tested up to a thickness of 50mm representing a thermal resistance of 0,05/0,0035=14 m²*K/W. the limitations of the method in the standard EN 12667 or EN 12939 is stated to a minimum of 0,02 m²W/K with accepting reduced accuracy. Minimum thickness should be at least 8 mm to be able to handle this properly. (50 mm is not a big thickness for a GHP, but the thermal resistance is hard to handle! Although the thermal resistance of a 10mm VIP is perfect for measurement, but the thickness measurement is becoming more and more critical…)

For APM the limitations (thickness (10<d<160mm) and resistance 0.02 < R < 12) are easier to handle, although especially for APM with a very low density the weight of the heating and cooling plates might get too big to be carried by the material. A more rigid material has to be used (usually PU-foam or XPS) to guarantee the nominal thickness of the specimens

Application and conduction of test method to SIM

Standard test method is used in accordance with the measurement procedure guideline in FIW lab. Additional precautions for SIM as follows:

Approach

2. Modification – Measurement-, Ageing- and Cal. + Sim-methods

- Which adjustments are necessary?
- Special precautions or sets of boundary conditions?
- Influence of measurement uncertainty
  - SIM have up to 10 times lower thermal conductivity
    - Lower heat flows in measurement
    - Higher influence from thickness measurement
    - Special treatments due to sample characteristics (uneven surfaces for fiber-glass VIPs, densitiy and particle size variations for APMs (esp. when „loose fill“) etc.

Step 3: Validation and Verification

Common Exercise on Thermal Conductivity, ψ-values, internal pressure

Common Exercises - Objectives

- Validation and Verification
- Indication and reduction of possible sources of errors and their order of magnitude
- Improvement through detailed process instructions/advices especially adapted for SIM!
- Reliable and reproducible characteristics for long term performance of SIM

→ increase the level of confidence for these new materials

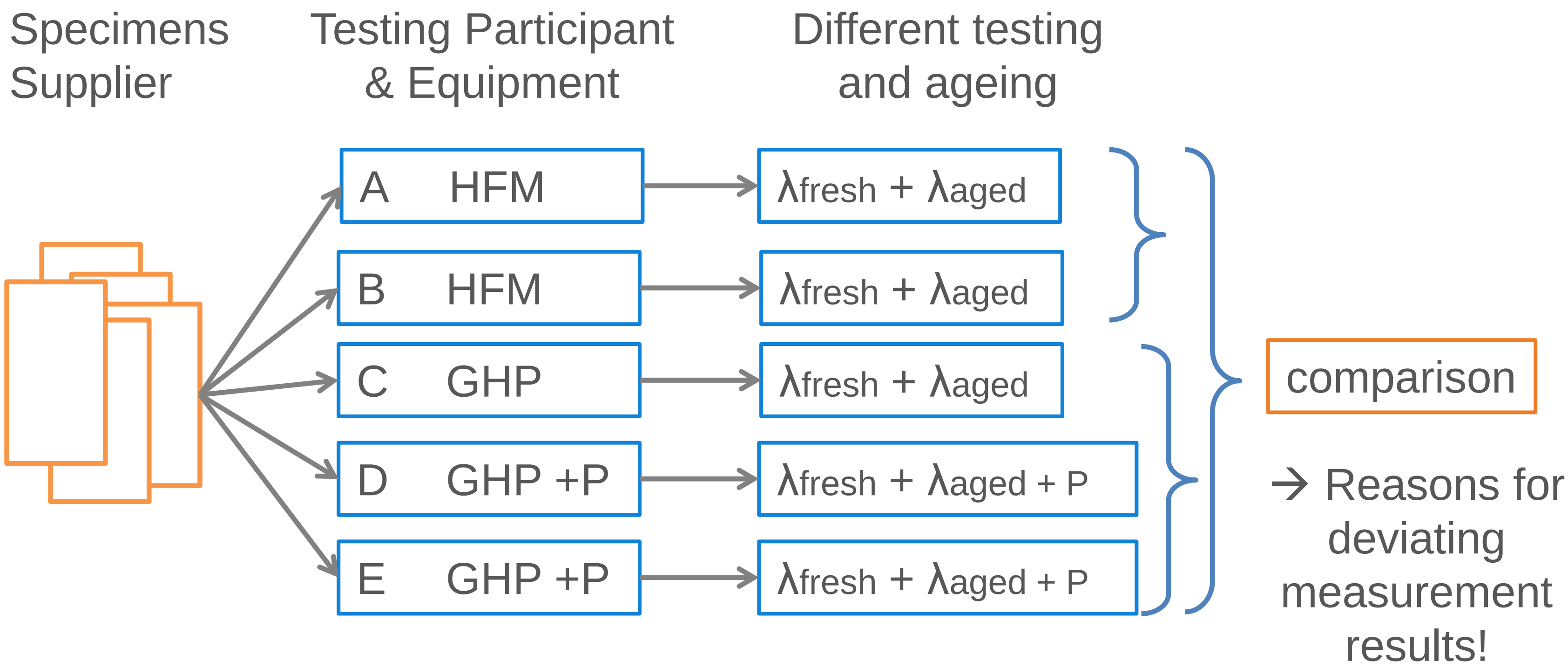
→ Increase the level of knowledge among all partners

Planned outcome

- List of adjustments and boundary conditions for the thermal conductivity testing for SIM (Report)
- Recommendations (guideline SIM measurements; scientific articles)
- ***For customers:***
  Reproducible and comparable results and better transparency
- ***For all Partners in the Annex 65:***
  Achieve same level of knowledge

Important: It's all about methods!
It´s not about comparing specimen characteristics!!!

Common Exercises - Approach



Common Exercises - Participants

VIP Testing		λ_{COP}		ψ		P
		HFM	GHP	HFM	GHP	
1.	Hanita	x				
2.	KTH	x				
3.	Kongju National Univ.	x				
4.	Super Tech	x		x		
5.	CSTB	x		x		
6.	POLITO	x		x		
7.	Isover - Saint Gobain		x		x	
8.	INRiM		x		x	
8.	NTUA		x		x	
9.	FIW		x		x	x
10.	va-Q-tec	x		x		x
11.	EDF	x		x		x
12.	Empa		x		x	x
13.	Chalmers		x			x

Common Exercises - Participants

APM Testing		λ_{APM}	
		HFM	GHP
1.	CSTB	x	
2.	POLITO	x	
3.	INRiM		x
4.	FIW		x
5.	EDF	x	
6.	Empa		x
7.	University of Perugia	x	
8.	CRM Group	x	
9.	MINES Paritech	x	
10.	Recticel	x	
11.	Evonik		x
12.	DLR	x	

Common Exercises – ageing procedure

	VIP	APM	
Climate	50°C / 70%	50°C / 70%	80°C / 60%
Step 1	30 d	30 d	30 d
Step 2	150 d	150 d	150 d

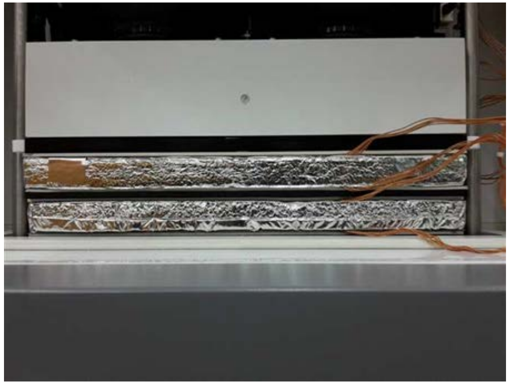
Common Exercises – Time schedule

	2015						2016											
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Logistics																		
Specimens delivered to FiW																		
Anonymous distribution of test specimens																		
Development of data template																		
Measurement - Fresh																		
λ + P (VIP) & λ (APM)				λ_{fresh}														
Forward data Template to FIW					Data													
Measurement - Aged 1																		
Ageing Step 1 - Duration 2 Months					Ageing Step 1													
λ + P (VIP) & λ (APM)							λ_{aged1}											
Forward data Template to FIW								Data										
Measurements - Aged 2																		
Ageing Step 2 - Duration 4 Months									Ageing Step 2									
λ + P (VIP) & λ (APM)														λ_{aged2}				
Forward data Template to FIW															Data			

Conduction of measurements and first results

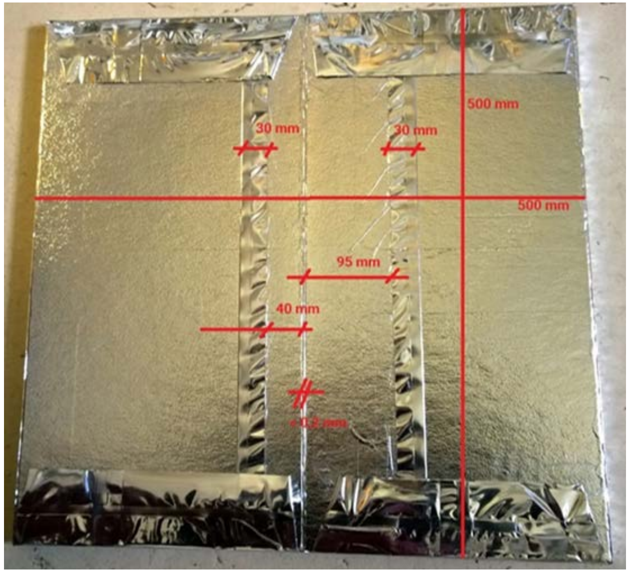
Common Exercises - conduction

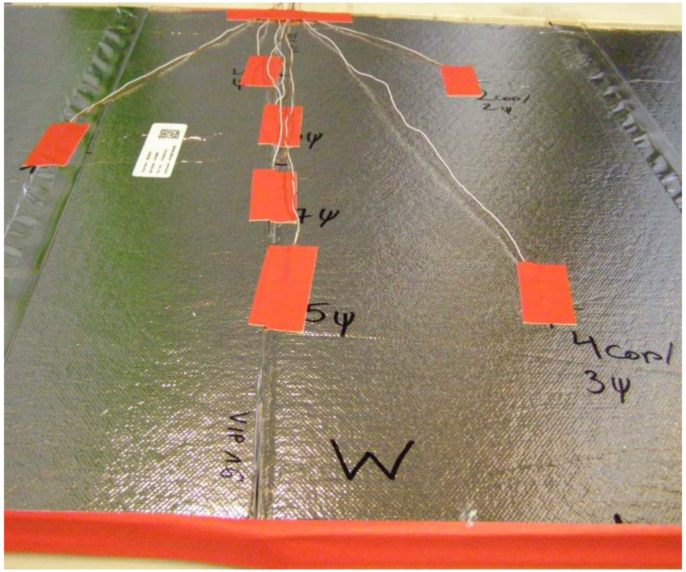
VIP – Center of panel

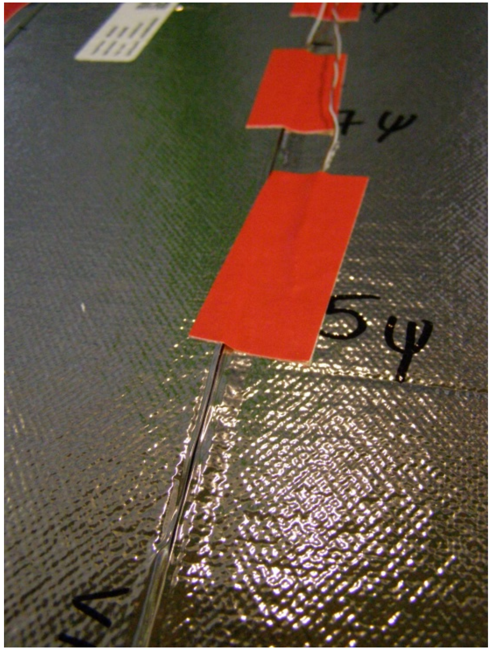


Common Exercises - conduction

VIP – ψ measurements

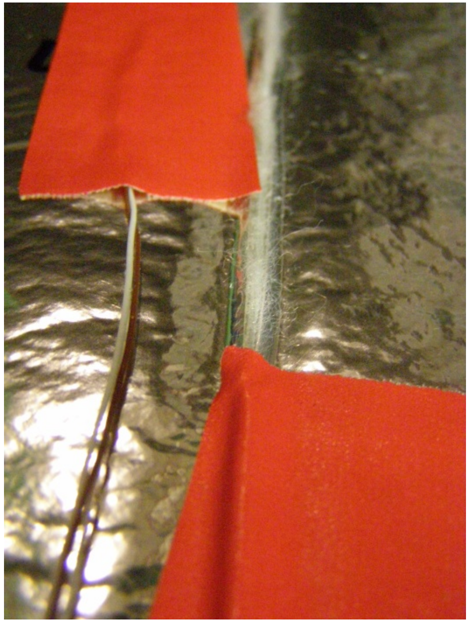


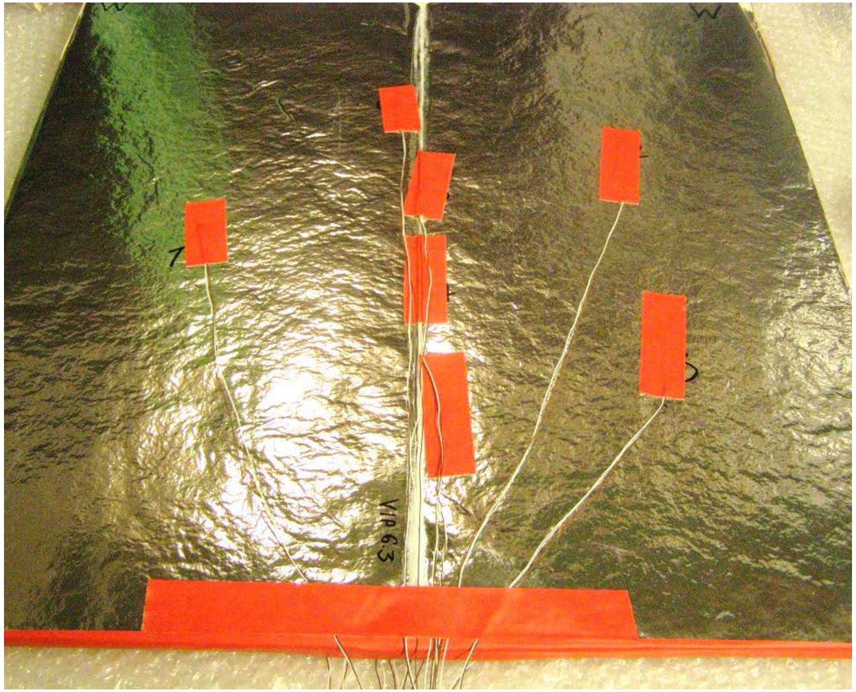




Common Exercises - conduction

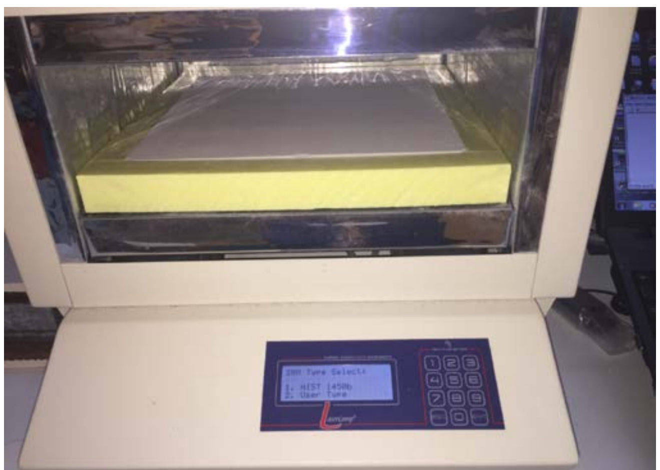
VIP – ψ measurements





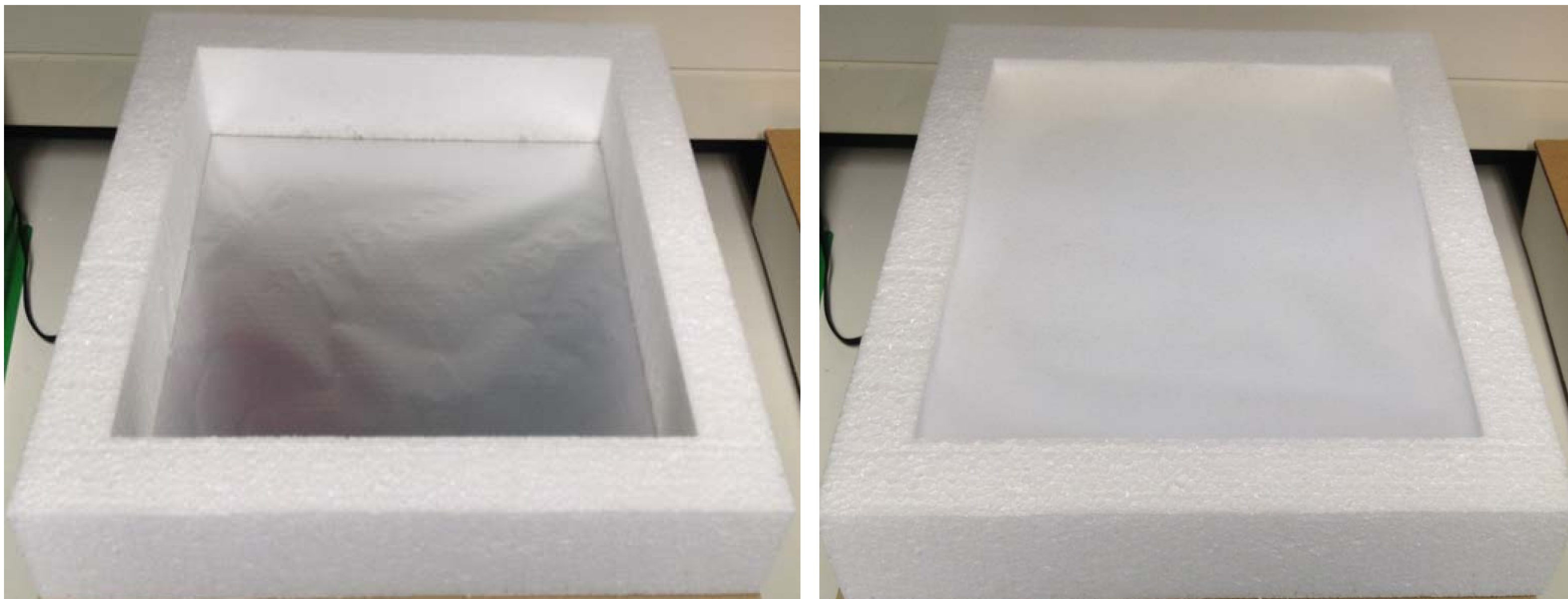
Common Exercises - conduction

APM – Thermal conductivity measurements



Common Exercises - conduction

APM – Thermal conductivity measurements



Common Exercises - conduction

APM – Thermal conductivity measurements

First findings

- Characteristics of same product can vary a lot – or to be more precise: the measurement results vary a lot…
- Basic properties, such as density, thickness, flatness, parallel surfaces etc. have large influence
- Thickness measurements are very important and lead to high uncertainties
- Characterization oft granular samples difficult
  - How to install?
  - Compression? Density?
  - Influences thickness (usually given by the frame thickness) and density (difficult to apply pressure on loose fill to compress particles).

Results after Ageing

Agreed measurement procedure

	VIP	APM	
Fresh values	X	X	
Ageing @	50°C / 70%	50°C / 70%	80°C / 60%
Step 1	30 d	30 d	30 d
New step 2 (Turino)	60 d	60 d	60 d
Step 3	180 d	180 d	180 d

In total 105 COP measurements

COP	Ageing time [d]													∑
	0	30	40	53	75	87	90	130	132	150	170	180	196	
APM 1	4	4	-	-	1	-	-	1	-	-	-	2	-	12
APM 2	10	6	1	-	-	-	1	-	1	1	-	1	1	22
VIP 1	5	3	-	1	-	1	2	-	-	-	1	1	-	14
VIP 3	5	4	-	-	1	-	1	1	-	1	-	2	-	15
VIP 4	5	3	-	-	-	-	2	-	-	-	-	2	-	12
VIP 5	5	3	-	1	-	1	2	-	-	-	1	1	-	14
VIP 6	7	5	-	-	-	-	2	-	-	-	-	2	-	16
∑	41	28	1	2	2	2	10	2	1	2	2	11	1	**105**

…26 PSI measurements

PSI	Ageing time [d]													∑
	0	30	40	53	75	87	90	130	132	150	170	180	196	
APM 1	-	-	-	-	-	-	-	-	-	-	-	-	-	0
APM 2	-	-	-	-	-	-	-	-	-	-	-	-	-	0
VIP 1	3	1	-	-	-	-	-	-	-	-	-	1	-	5
VIP 3	2	1	-	-	1	-	-	1	-	-	-	2	-	7
VIP 4	3	-	-	-	-	-	-	-	-	-	-	1	-	4
VIP 5	5	1	-	-	-	-	-	-	-	-	-	1	-	7
VIP 6	1	-	-	-	-	-	-	-	-	-	-	2	-	3
∑	14	3	0	0	1	0	0	1	0	0	0	7	0	**26**

…28 internal pressure measurements

p_i	Ageing time [d]													∑
	0	30	40	53	75	87	90	130	132	150	170	180	196	
APM 1	-	-	-	-	-	-	-	-	-	-	-	-	-	0
APM 2	-	-	-	-	-	-	-	-	-	-	-	-	-	0
VIP 1	2	1	-	-	-	-	1	-	-	-	-	1	-	5
VIP 3	3	3	-	-	1	-	1	1	-	1	-	2	-	12
VIP 4	2	2	-	-	-	-	2	-	-	-	-	2	-	8
VIP 5	3	-	-	-	-	-	-	-	-	-	-	-	-	3
VIP 6	-	-	-	-	-	-	-	-	-	-	-	-	-	0
∑	10	6	0	0	1	0	4	1	0	1	0	5	0	**28**

Conclusion on λ mesurement

- With exception to VIP 6 reproducible values (inter-laboratory)
- Deviations become higher for the aged panels
- Ageing rates are different (e.g. for VIP 4)

Conclusion on ψ mesurement

- Partly reproducible values (for fresh panels)
- High deviations for aged panels
- Partly negative PSI values:
  - Ageing of panel sizes used for COP measurement may be significantly different to these used for PSI measurement
    - Production process with variabilities (defects, etc.)
    - Panel size itself
    - Ageing parameters (deviation in climate chamber, etc.)
- COP measurement shall be performed on the same panels (and on both of them!) used for PSI measurement
- So far only partly sufficient for fresh values

Conclusion on pressure mesurement

- good reproducible values
- Rather small deviations for aged panels
- Pressure increase in good accordance with lambda increase
- Pressure measurment not suitable for fiber core panels (up to now – subject for investigation)

Approach

4. Recommendations

Based on results oft steps 1, 2 and 3 recommendations for future measurements, ageing procedures and calculations are defined, for example:

- Recommendation which methods should be used with SIM
- Necessary adjustments to these measurement methods
- Estimations of uncertainty in measuring SIM
- Hints for Labs and forum for discussion
- Summary Report

Thank You!

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