Deliverable report

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Project Website:	www.creatorproject.eu

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CREATOR CONSORTIUM

PARTICIPANT NUMBER	ABBREVIATION	ORGANISATION
1	ICT	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung – Institut für Chemische Technologie
2	VLB	Volbas S.A.
3	MOS	Machinefabriek Otto Schouten BV
4	CLR	Coolrec BV
5	REL	Treee SRL
6	GKR	Fundacion Gaiker
7	TCK	Transfercenter fur Kunststofftechnik GmbH
8	RMA	Erema Engineering Recycling Maschinen und Anlagen Ges.m.b.H
9	CTB	Centre Scientifique & Technique De L'industrie Textile Belge
10	MAI	Maier S. Coop.
11	DAW	DAW SE
12	CYC	Cyclefibre S.L.
13	CID	Fundacion Cidaut
14	KLU	Kühne Logistics University GmbH
15	OVM	Openbare Vlaamse Afvalstoffenmaatschappij
16	ITB	ITRB Group LTD

Document history and contribution of the partners

Version management

Version nr	Reviser	Content
V1	DAW	First draft
V2	ICT	Revision
V3	DAW	Revision
V4	ICT	Final review and submission

Contribution of the partners

Partner	Short name	Role in the WP	Contribution to the deliverable
DAW SE	DAW	Insulation panel development	Author of deliverable 4.7
Fraunhofer Gesellschaft für angewandte Forschung e.V.	ICT	Foam bead development	Material development

Abbreviations

EPS	Expanded polystyrene
HBCD	Hexabromocyclododecane, a brominated flame retardant
PS	Polystyrene

1 INTRODUCTION

The objective of the work considered in this report was to realise a demonstrator showing the potential of CREAToR's material for an insulation application.

200 kg of polystyrene (PS) material was supplied by Fraunhofer ICT. The raw material was a polystyrene foam contaminated with the flame retardant hexabromocyclododecane (HBCD), which was purified in the CREAToR extractive extrusion process[1], readdivated, blended with virgin polystyrene and transferred to foamable beads for later use at DAW as expanded polypropylene (EPS). With this material, pre-foaming as well as blocking experiments were conducted. Finally thermal insulation boards were produced and installed on a building wall to demonstrate their applicability.

[1] Deliverables 3.1 Extractive extrusion process performed with all provided material classes and 3.3 Purification process using IL/(NA)DES performed **Publications – CREAToR (creatorproject.eu)**

2 PRODUCTION OF CREAToR EPS BLOCKS

2.1 PRE-FOAMING

Joint experiments of DAW and Fraunhofer ICT were conducted at the DAW facility in Hirschberg on 7th of February 2023.

In these experiments, the parameters of pre-foaming were investigated and optimised, aiming for a density of approx. 20 kg/m³. Figure 1 shows the polystyrene raw material and the nozzle intake of the pre-foaming process.

Figure 1: CREAToR polystyrene raw material (front) with nozzle intake for pre-foaming

To achieve the targeted density, after pre-foaming the density of the EPS beads was measured and the parameters of the pre-foaming process were optimised.

Figure 2 shows the measurement of the EPS density of the beads. Figure 3 shows the running pre-foaming process and the setting of the parameters.

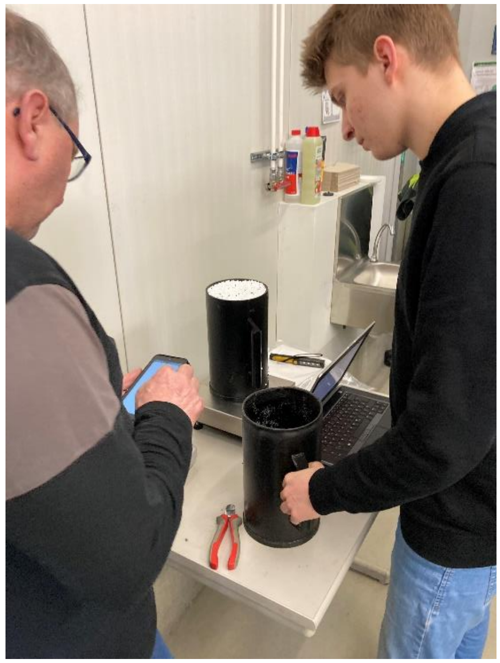

Figure 2: Measurement of the EPS density after pre-foaming for the purpose of optimising the process parameters

Figure 3: Setting of the parameters with running pre-foaming process (see right side)

As can be seen in Figure 4, the beads were expanded successfully by the process. The expanded PS beads were collected in a container where they were stirred up to prevent sticking.

Figure 4: Collection container for the expanded PS beads (material is stirred up to prevent sticking)

2.2 BLOCKING

After the pre-foaming experiments were completed, joint experiments for the blocking, and the manufacture of expanded polystyrene blocks, were conducted by DAW and Fraunhofer ICT at DAW facility in Hirschberg on 8th of February. After calculating the parameters for the blocking process (Figure 5), the blocking process was implemented and the CREAToR EPS blocks were made using the expanded PS beads manufactured previously. Figure 6 shows the CREAToR EPS block ejected by the block molding machine.

Figure 5: Calculating the parameters for blocking

Figure 6: CREAToR EPS block ejected by the block molding machine

Thus, the team of DAW and Fraunhofer ICT employees (Figure 7) succeeded in realising the pre-foaming and blocking processes.

Figure 7: Group photo in front of a freshly ejected EPS block

In the trials, three CREAToR EPS blocks were produced (Figure 8). To obtain applicable boards, the EPS blocks were cut into thermal insulation boards (Figure 9). The size of the boards was 500 cm x 1000 cm x 12 cm. For tracking and documentation purposes, the individual boards were labelled (Figure 10).

Figure 8: Three CREAToR EPS blocks produced during the trials

Figure 9: Cutting the EPS block into thermal insulation boards (500x1000x12 cm)

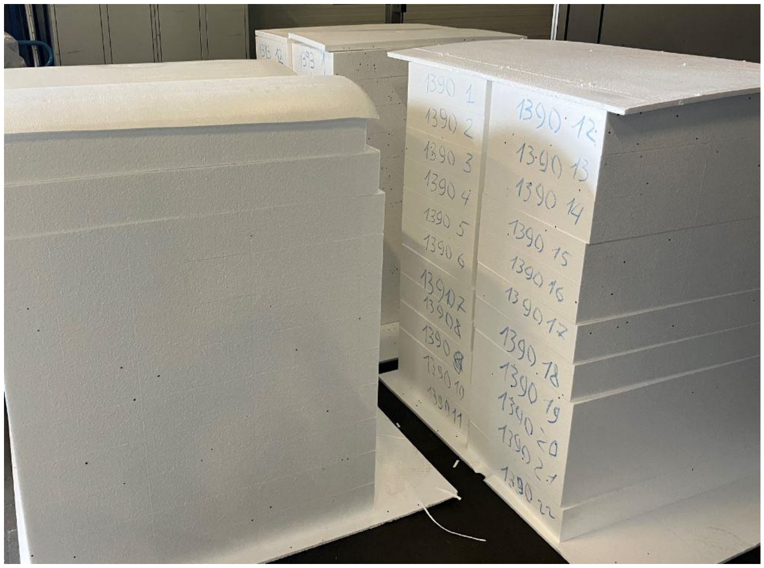

Figure 10: Labelled EPS insulation boards

2.3 CHARACTERISATION OF THE CREATOR EPS INSULATION BOARDS

In the next step, the properties of the insulation boards were investigated.

Thermal insulation:

Measurements of the thermal insulation properties were conducted (Figure 11). It was found that the thermal conductivity varied from 36.07 mW/(m K) (at a density of 21.7 kg/m³) to 37.10 mW/(m K) (at a density of 20.8 kg/m³, Table 1).

Table 1: Thermal conductivity

SPECIMEN	MASS [G]	THICKNESS[MM]	DENSITY [KG/(M3)]	THERMAL CONDUCTIVITY λ_{tr} (MEASURED) [MW/(M*K)]	THERMAL CONDUCTIVITY λ_{tr} (CALCULATED) [MW/(M*K)]
1390-9-1	1238,86	119,21	20,8	λ_{10} 37,10	λ_{10} 37,10
				λ_{23} 38,97	
				λ_{40} 41,40	
1390-9-2	1238,86	118,86	20,9	λ_{10} 36,31	λ_{10} 36,34
				λ_{23} 38,25	
				λ_{40} 40,61	

1392-9-1	1276,06	118,39	21,6	λ_{10} 36,17	λ_{10} 36,18
				λ_{23} 38,03	
				λ_{40} 40,41	
1392-9-2	1276,06	118,15	21,7	λ_{10} 36,08	λ_{10} 36,07
				λ_{23} 37,86	
				λ_{40} 40,25	
1392-10-1	1243,21	119,51	20,9	λ_{10} 37,03	λ_{10} 37,03
				λ_{23} 38,84	
				λ_{40} 41,23	
1392-10-2	1243,21	118,88	21,0	λ_{10} 37,09	λ_{10} 36,99
				λ_{23} 38,43	
				λ_{40} 40,79	
mean value			**21,2 ± 0,4**	**λ_{10} 36,63 ± 0,49**	

The thermal conductivity of the boards is within the expected range (for white EPS). Compared to the value stated in deliverable D1.2 of λ = 34 mW/(m K), these values seem fairly high. However, it should be noted that a purely white material was used here, compared to a mixture of grey and white material used in regular production. The grey material contains IR absorbers and is therefore beneficial for the thermal insulation properties.

Also the target value for a density of 20 kg/m³ as stated in D1.2 was slightly exceeded: Due to the relatively scarce availability of material, the density in the trials was set rather too high to increase the certainty of obtaining the requested mechanical properties.

Figure 11: Measurement of the thermal insulation properties

Mechanical stability:

The mechanical properties also had to be considered to ensure that the board had the required stability. Tensile tests were therefore conducted (Figure 12). An average tensile strength of 251 kPa was measured (Table 2).

Table 2: Tensile strength

SPECIMEN	TENSILE STRENGTH σ_m, [KPA]
1390-12-1	257
1390-12-2	239
1390-12-3	263
1391-1-4	237
1391-1-5	261
1391-1-6	247
mean value	**251 ± 11,2**

Figure 13 shows the fraction patterns of the test specimens.

The measured tensile strength is far higher than the legal requirement (as presented in D1.2, the mean value must be above 100 kPa). This can be explained by the relatively high density (see above). Thus, in terms of mechanical stability there is the potential to reduce the density. However, due to the lack of CREAToR material this could not be examined further.

Figure 12: Measuring the tensile strength

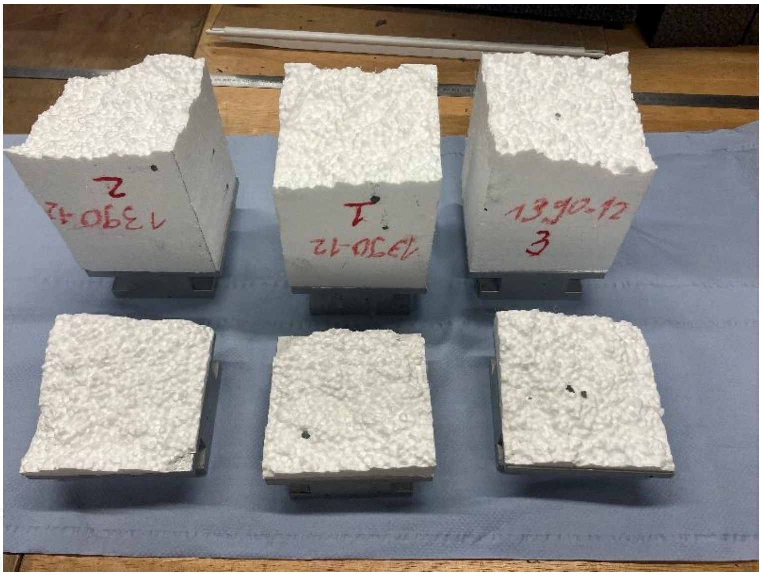

Figure 13: Fracture pattern of the test specimens

Reaction against fire

To evaluate reaction to fire, tests were performed according to the standard EN ISO 11925-2. The aim presented in D1.2 was to reach class E (DIN EN 13501-1) which is the standard for all EPS thermal insulation boards. After 30 seconds, there was no flame above the marked line 15 cm above the test flame (see Figure 14 and Figure 15). This behavoiur was found for all six specimens (Figure 16, Table 3). The class E-test was therefore passed successfully.

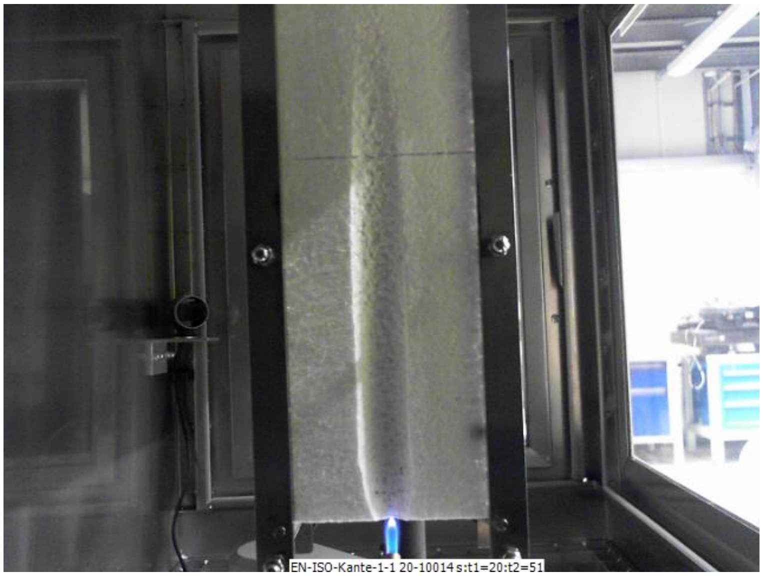

Figure 14: CREAToR EPS after 10 seconds of fire testing

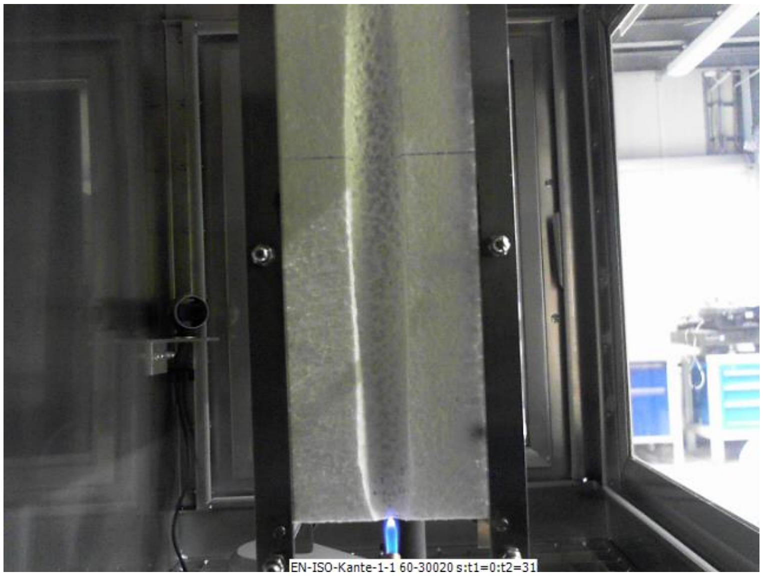

Figure 15: CREAToR EPS after 30 seconds of fire testing (end of test)

Figure 16: Every specimen passed the test for class E (DIN EN 13501-1)

Table 3: Reaction against fire

SPECIMEN	DENSITY [KG/(M3)]	MAX. FLAME TIP ≤ 150 MM	BURNING DRIPPING / FALLING OFF	REQUIREMENTS FULFILLED
1390-12_1	22,3	yes	no	yes
1390-12_2	22,2	yes	no	yes
1390-12_3	22,6	yes	no	yes
1391-1_1	22,0	yes	no	yes
1391-1_2	22,0	yes	no	yes
1391-1_3	22,8	yes	no	yes

To summarise, it has been shown that the CREAToR insulation boards were produced successfully and fulfill the requirements for thermal insulation boards. This allowed the application of the boards to the test façade.

3 Installation of the CREAToR insulation boards to the test facade

After it had been shown that the CREAToR insulation boards fulfill the requirements, the demonstrator was installed. For this purpose, a façade measuring 8 by 4 metres was constructed with a window in the middle to illustrate the layered structure of an ETICS and to provide a direct view of the CREAToR EPS. Figure 17 shows the CREAToR test façade provided by DAW in its original state.

Figure 17: CREAToR test façade in its original state

Figure 18 shows the application of adhesive on the CREAToR EPS thermal insulation board. Figure 19 shows the application of the EPS board to the wall.

Figure 18: Application of adhesive on CREAToR EPS thermal insulation board

Figure 19: Attaching the EPS board to the wall

In Figure 20 the test façade is shown after the boards were attached.

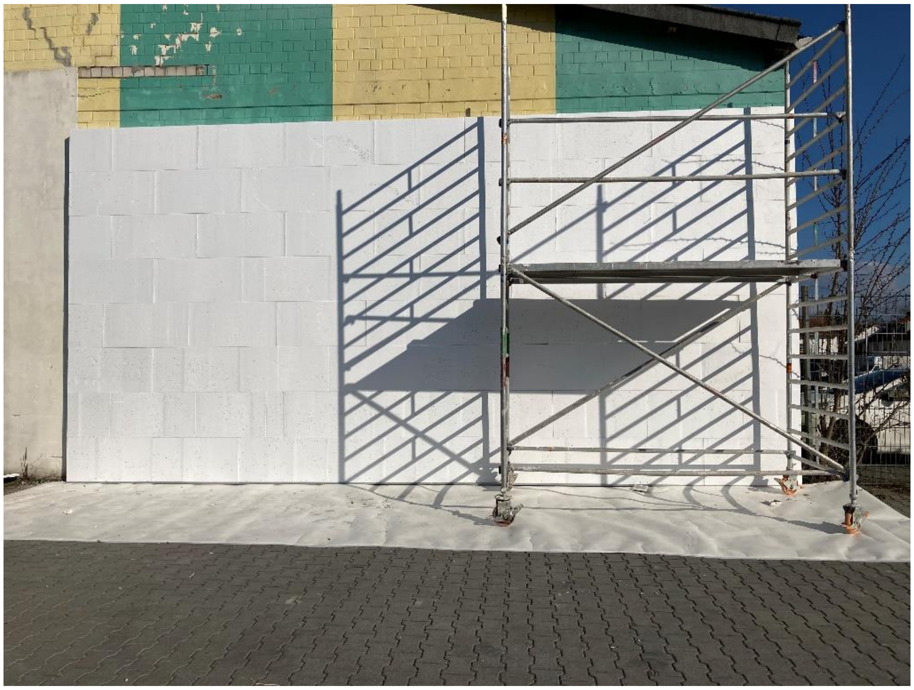

Figure 20: CREAToR test façade with attached EPS boards

In the next step, anchors were installed to fix the boards (Figure 21 and Figure 22).

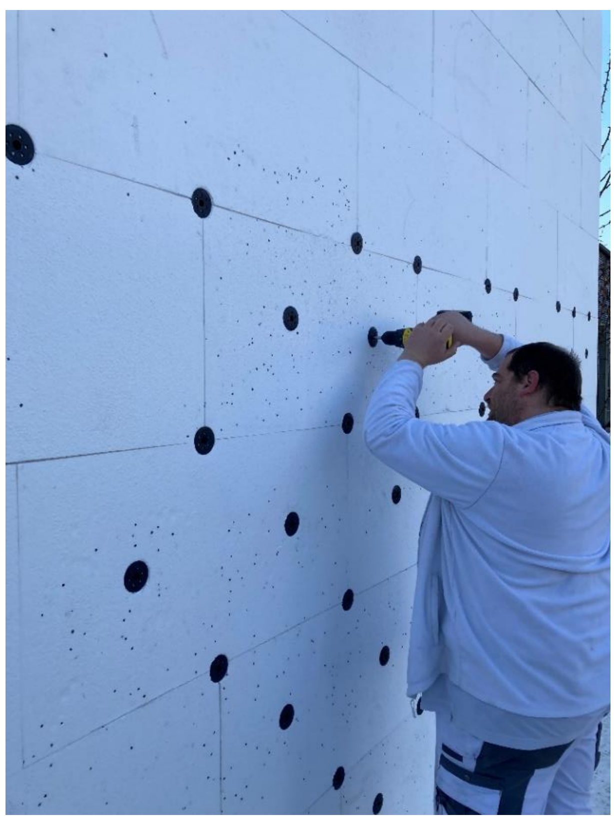

Figure 21: Fixing the EPS with anchors

Figure 22: Test façade fixed with anchors

For general stability of an ETICS, a base coat layer is applied and a mesh is incorporated into the material for reinforcement (Figure 23, Figure 24 and Figure 25).

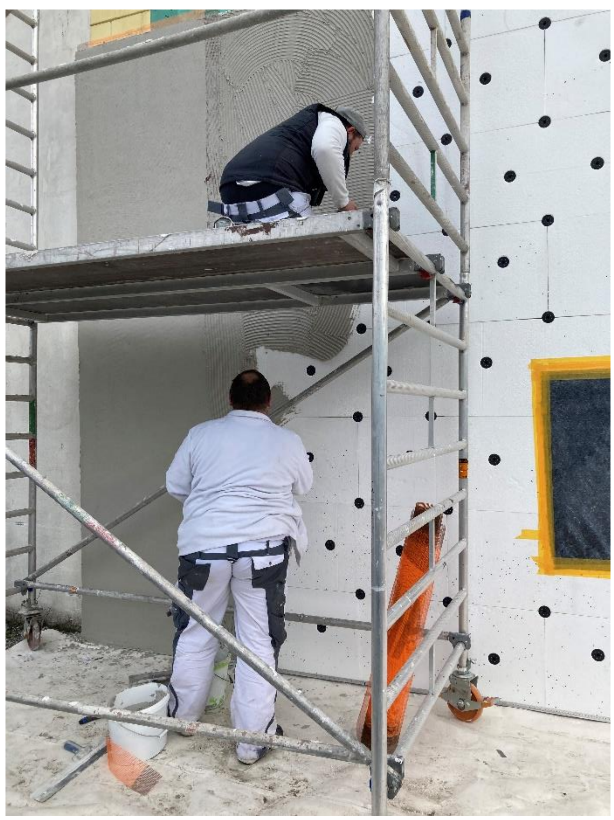

Figure 23: Application of the base coat layer

Figure 24: Reinforcement mesh is attached (left) and incorporated (right) into the base coat layer

Figure 25: Test façade with completed reinforcement layer (base coat) with block-out for an EPS window

For better adhesion of the top coat on the wall, a primer coat is applied to the base coat (Figure 26 and Figure 27)

Figure 26: Application of the primer coat

Figure 27: Application of the top coat

Figure 28 and Figure 29 show the completed test façade with a window to see the CREAToR EPS beneath the other layers.

Figure 28: Completed test façade with a window for the CREAToR EPS in the middle.

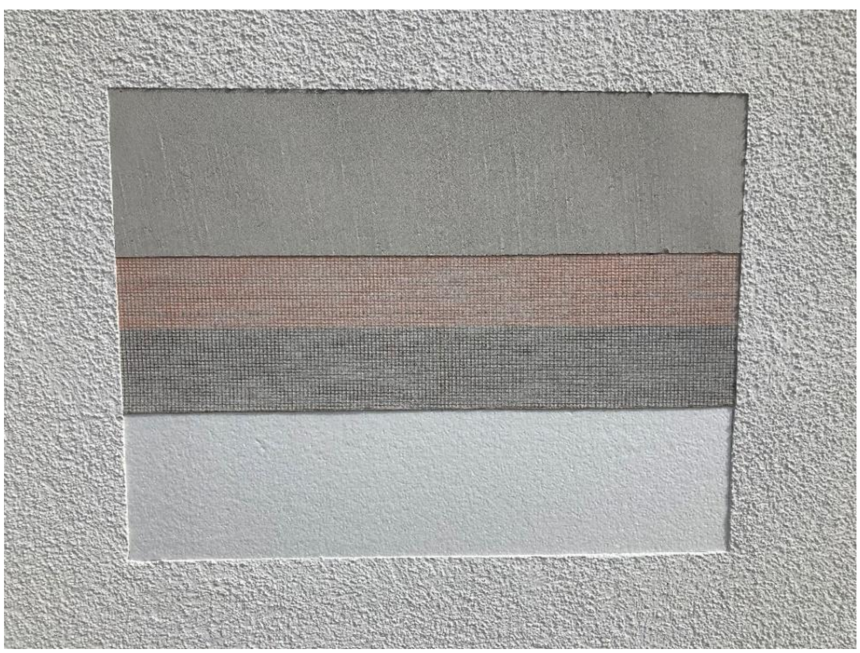

Figure 29: Close up of window for the CREAToR EPS including build-up of layers

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Thus, the CREAToR insulation boards were successfully applied within a demonstrator and the potential for insulation application was confirmed.

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4 Conclusion

From the polystyrene (PS) material obtained by Fraunhofer ICT, the CREAToR insulation boards were produced successfully by pre-foaming beads and the subsequent blocking process. It was shown that these boards fulfill the requirements regarding thermal insulation and mechanical stability as well as the reaction against fire.

Finally, the boards were attached to the test façade. Thus, the suitability of the CREAToR insulation boards for installation was demonstrated successfully. The potential for insulation application was confirmed.