Project Title: Lightweight prefabricated panels for energy renovation of buildings

Mid-term Report: October 2025

Kanton Zürich
Baudirektion
Amt für Abfall, Wasser,
Energie und Luft

aeroskin|tech

ETH zürich

Executive Summary

Project Title: *Lightweight prefabricated panels for energy renovation of buildings*

Reporting Period: Project Start – October 2025

This mid-term report summarizes the progress achieved across the first four work packages (WP1–WP4) of the project. The project aims to develop a prefabricated ETICS façade system, integrating digital tools (3D scanning and robotic fabrication) with glass wool as main insulation material, complemented with aerogel insulation for specific façade details. The project is structured in six work packages; the remaining activities in **WP5 (on-site application)** and **WP6 (cost/time/LCA assessment)** will be addressed in the next project phase.

WP1 – Project Management

The project has been successfully managed in line with the planned timeline, scope, budget, and quality metrics. Key activities include stakeholder coordination, procurement, and reporting. The building permit and subsidy have been already requested. A project progress was presented to the **Partnership Council for Sustainable and Digital Construction at ETH Zurich** on May 13, 2025.

WP2 – ETICS panel prototypes

- A small-scale **hybrid ETICS demonstrator prototype** (1.10 × 0.80 m) was constructed using traditional methods, combining mineral wool and Aeroskin Tech aerogel boards for enhanced insulation in constrained architectural details (e.g., window reveals).
- **KK71 lightweight adhesive mortar** (Weber Marmoran) was successfully modified using a **PCE superplasticizer (2%)** to enable **Digital Casting** workflows without compromising flexural, compressive, or bonding strength.
- **Thermal conductivity** of KK71 was reduced by ~40% vs. the declared reference, improving the system's energy performance. The bonding strength and vapor diffusion properties of the casted system remained consistent with requirements.

WP3 – Robotic Prefabrication Setup

A fully functional robotic manufacturing setup was developed and validated for the off-site production of prefabricated ETICS panels:

- **Digital Casting:** Parameters for robotic deposition, filament width, toolpaths, and casting window (up to 100 minutes) were established for KK71 mortar. Surface finish and mechanical properties were verified.
- **Robotic Cutting:** A cutting robotic tool head was developed and adapted for robotic operation. Complex insulation geometries (e.g., window reveals) were successfully cut on two insulating materials.
- **Robotic Spraying:** A robotic sprayer was designed and tested. While surface quality was high, limitations in robot movement speed introduced excess material deposition, indicating the need for future refinement.

WP4 – Customization of the façade system

- A **3D scan and BIM model** of the demonstrator building was created with sub-millimetre accuracy (≤0.5 mm), supporting the development of **customized panel geometries**.

Multiple design iterations were tested:

- **First iteration: Z-cut** transitions proved technically feasible but were rejected by the insulation manufacturer for cost reasons with their current manufacture setup.
- **Second iteration**: **Straight cuts** transitions demonstrated comparable thermal and mechanical performance, enabling simpler fabrication.

    - **10 m² of prefabricated panels** were produced, tested on-site for fitting accuracy.
    - The panels were also installed on a mock-up wooden structure at ETH to further validate fit, tolerances, and workflow feasibility.
        - On-site workflow testing showed a **20% reduction in application time** for KK71 + mesh using prefabricated elements. However, **partial pre-spraying of the rough cast** was found inefficient and has been discarded for future iterations.
- **Third and final iteration:** Developed to optimize system manufacturability and on-site installation:
    - **Panel sizes were standardized**, and glueing was restricted to specific locations, improving logistics and reducing material waste. The transitions are made by **straight cuts** and tolerances are solved with a 140x10mm glass wool roll from Isover.
    - **A new prefabricated aerogel-based modular window reveal element** was developed to drastically reduce installation time around windows — historically the most labor-intensive detail. The element offers commercial potential also as a standalone retrofit solution, besides full prefabricated façades.
    - **Rough cast spraying was moved fully on-site** to ensure higher surface quality and reduce robotic processing complexity.
    - This iteration represents the final prefabricated system to be tested in WP5 (on-site application) and forms the basis for the full performance and cost assessment in WP6.

Next Steps

- **WP5 – Demonstrator Building:**

The final prefabricated system will be produced and installed at the renovation site in spring 2026. Full integration of all panel types, including window reveals, will be tested under real conditions.

- **WP6 – Cost calculation, energy consumption and LCA assessment:**

The time efficiency and cost-effectiveness of the prefabricated approach will be quantitatively assessed in comparison to conventional on-site ETICS application. Additionally, the production system will be assessed from the perspective of energy consumption, carbon footprint and production capacity (m^2/year).

Conclusion

The project has reached key technical milestones in robotic prefabrication, material optimization, and digital workflow integration. Laboratory and pilot-scale tests confirm the feasibility and robustness of the proposed system. The remaining work will validate the system in full-scale on-site application and provide quantitative assessment of its cost and time advantages, as well as a preliminary LCA.

Mid-Term Report

WP1: Project Management

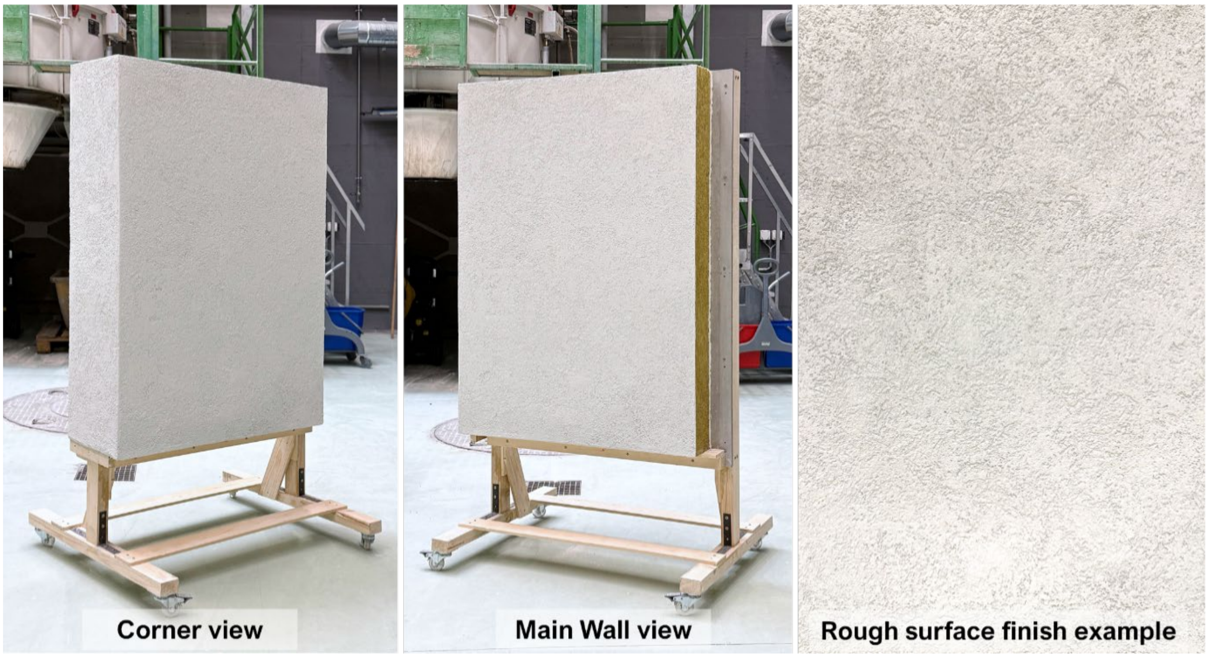
The project management included activities related to keep the project in time, scope, budget and quality. Additionally, the project required meetings with stakeholders, purchasing, reporting and other management activities. The building permit and subsidy have been already requested. Finally, a presentation regarding the project progress was done at the Partnership Council for Sustainable and Digital Construction from ETH Zurich, on the 13th of May, at the Hönggerberg Campus, HIB Building.

WP2: ETICS panel prototypes

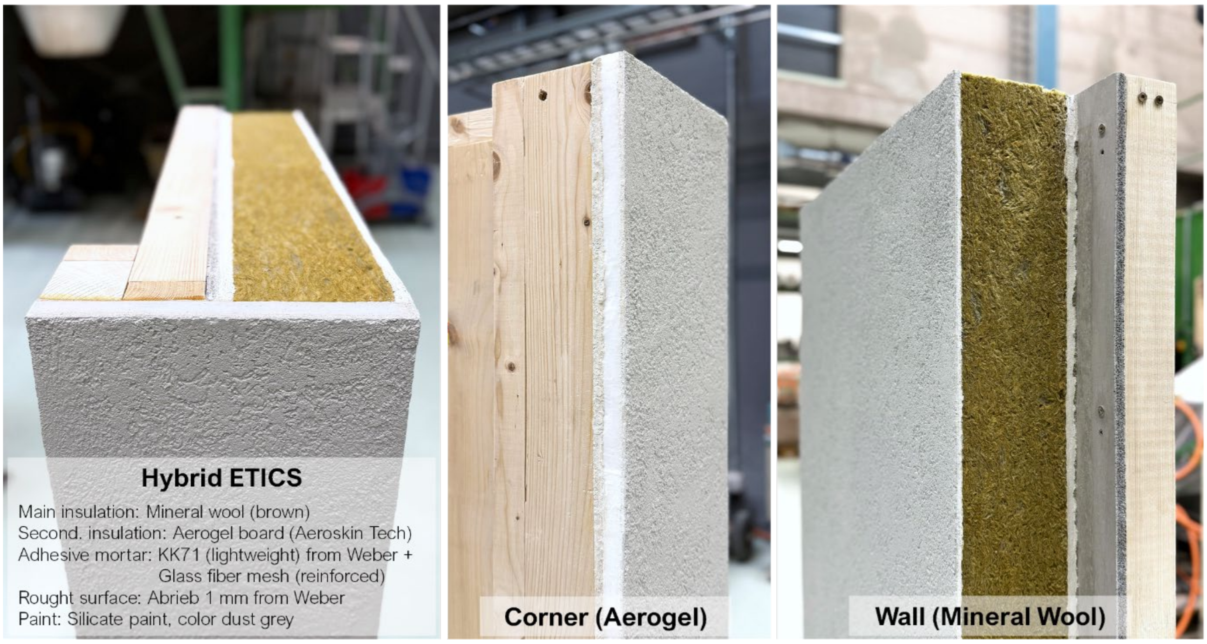
The WP2 consisted in testing the different materials and the ETICS system. The main goal was to adapt a standard ETICS system to be used in digital fabrication processes. In this particular case, the main focus is on the insulation, the adhesive reinforced mortar (KK71) and the mechanical properties of the materials individually and integrated as a system.

Prototype: Hybrid ETICS – Traditional application

A small demonstrator of 1.10 x 0.80m was successfully built, adapting a standard ETICS system based on mineral insulation to a hybrid insulation system. The prototype was performed using traditional application methods (as on-site).



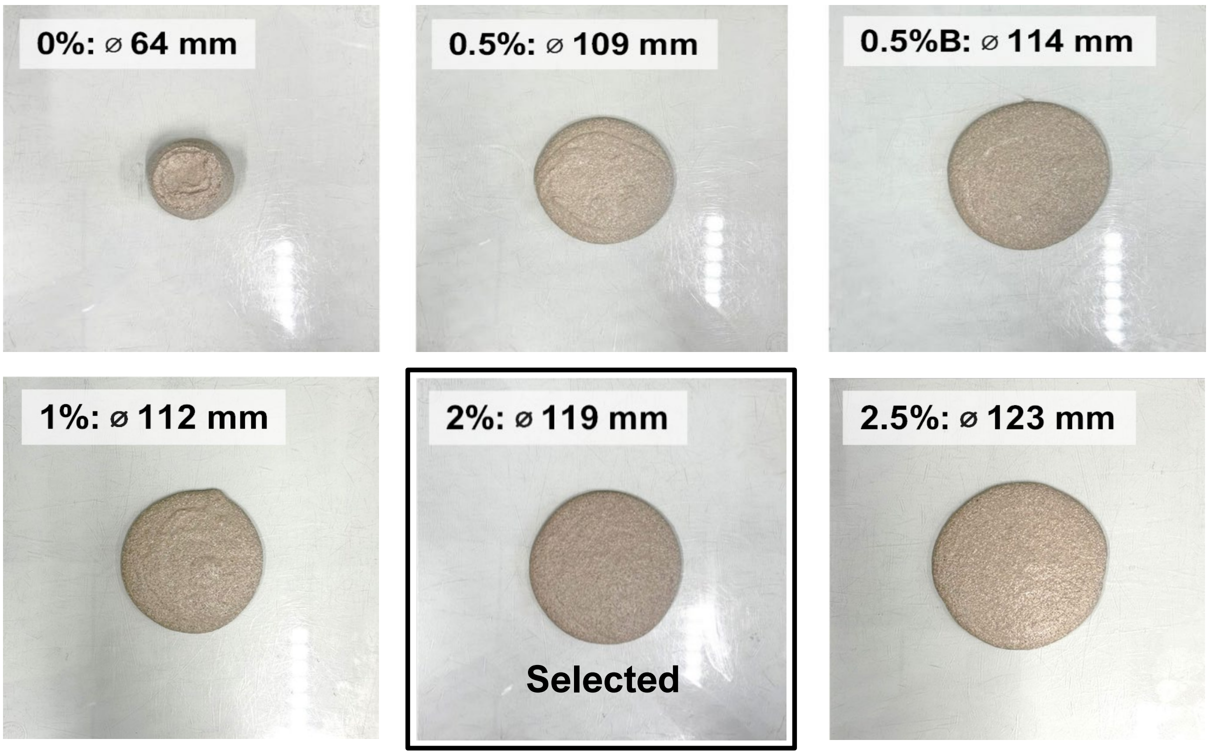
The integration of Aeroskin Tech boards was achieved, in order to include the material in space restricted areas of the building, such as window reveals or other façade details, due to its much higher thermal insulation performance.



The system is the basis of a new prefabricated constructive system for renovation of buildings, consisting in using digital fabrication and robotic manufacture processes.

Rheology optimization of KK71 towards Digital Casting

The first step for implementing Digital Casting processes was to optimize the adhesive mortar (Weber Iso-Leicht-Combimörtel KK71), by increasing its flowability without decreasing its mechanical properties. The increase and desired flowability was successfully achieved by the addition of PCE superplasticizer (Glenium ACE 30) to the KK71 during the mixing process with water. The method for systematic testing used was Mini-Slump tests. Its principle is to pour the mix in a small cylinder on top of a glass plate, then release the cylinder and measure the spread flow diameter in two perpendicular directions:

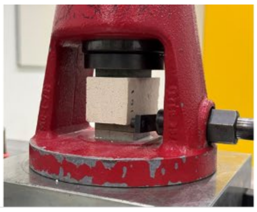


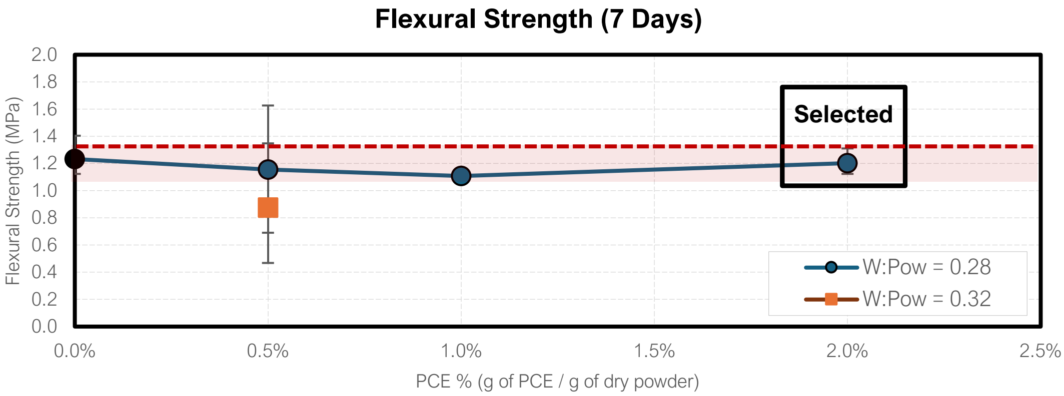
The reference sample (0.0% of PCE), used the water proportion recommended by the manufacturer (Water:Powder = 0.28). The PCE was added in different proportions to assess the increase of flowability. In order to test the addition of extra water in parallel, an extra sample of 0.5% PCE (0.5%B) but with slightly higher water:powder ratio (0.32) was also prepared. Such sample was found to be unstable (segregation of the components), therefore, discarding any increase in the water dosage. The tests were successful for enabling the capabilities for digital casting. The **2%** was considered the most suitable.

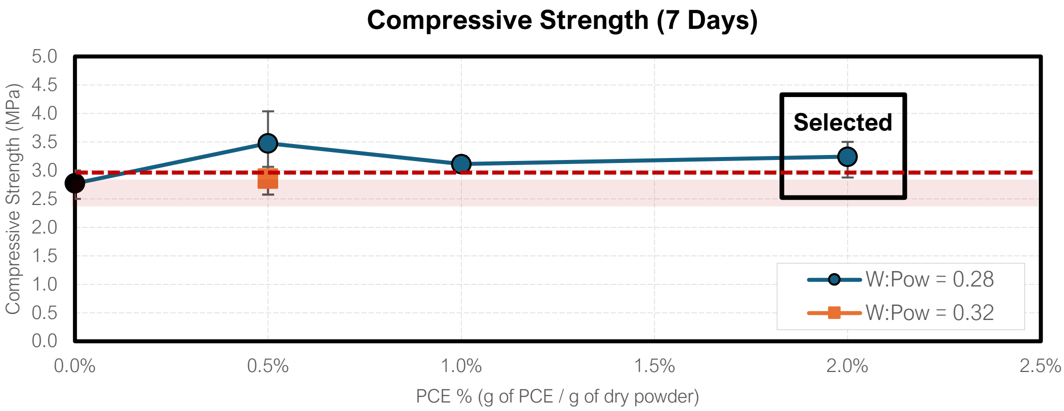
Mechanical properties of KK71 + PCE (7 Days)

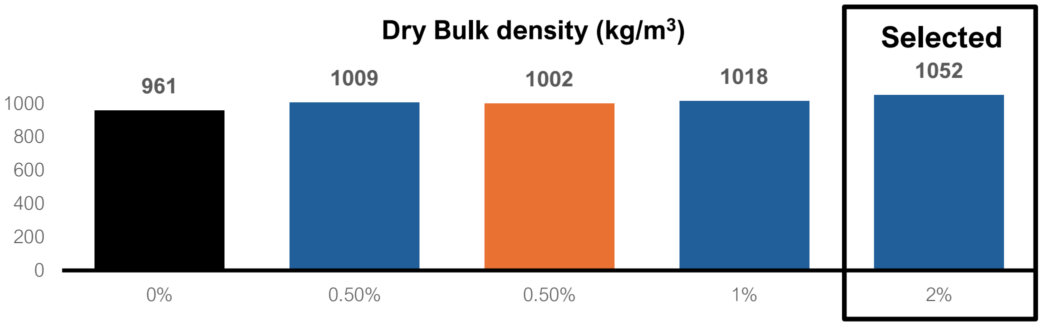
Flexural and compressive strength:

The assessment of the impact of adding PCE to the reference in the mechanical properties started by producing samples (4x4x16cm) with the same dosing as in the rheology tests (left image below). The samples were tested for flexural (central image below) and compressive strength (right image below). Bulk density was also measured.





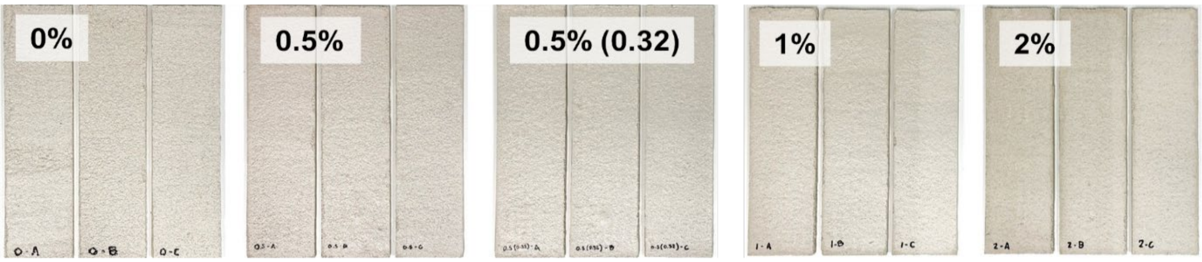


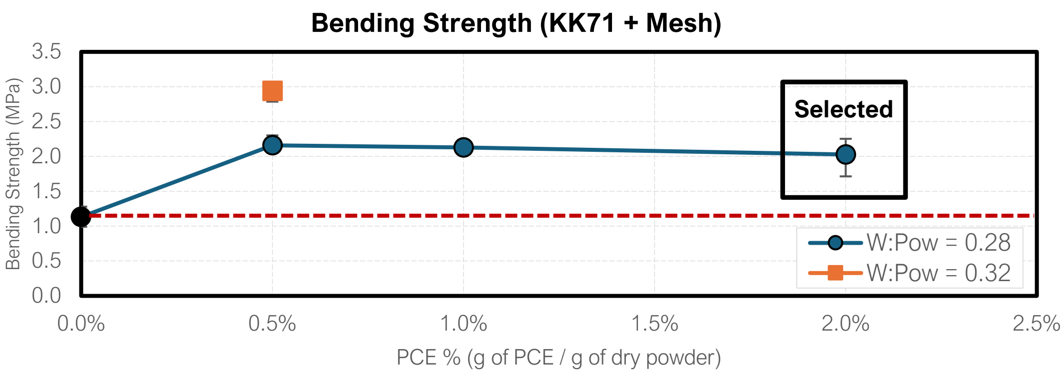


The modification of the KK71 mortar was successful in regards to the flexural and compressive strength, basic material parameters for the stability of the ETICS façade system. In particular, no decrease on these mechanical properties was achieved for highly flowable mixes. In fact, even a small increase was achieved. Only a decrease in the mechanical properties for the sample with slightly higher water amount (0.5%B) was observed. The bulk density (dry) increased slightly, due to a more efficient packing density.

Bending Strength of KK71 + PCE + Glass fiber reinforcing mesh (7 Days)

The next test to assess the modification of the KK71 mortar + PCE, was to test for bending strength, in a setup that reproduces its application. In this sense, plates of 210 x 70 x 8mm were prepared (image below). The same proportions testes above were used, but with an embedded glass fiber mesh (as applied in the ETICS system)

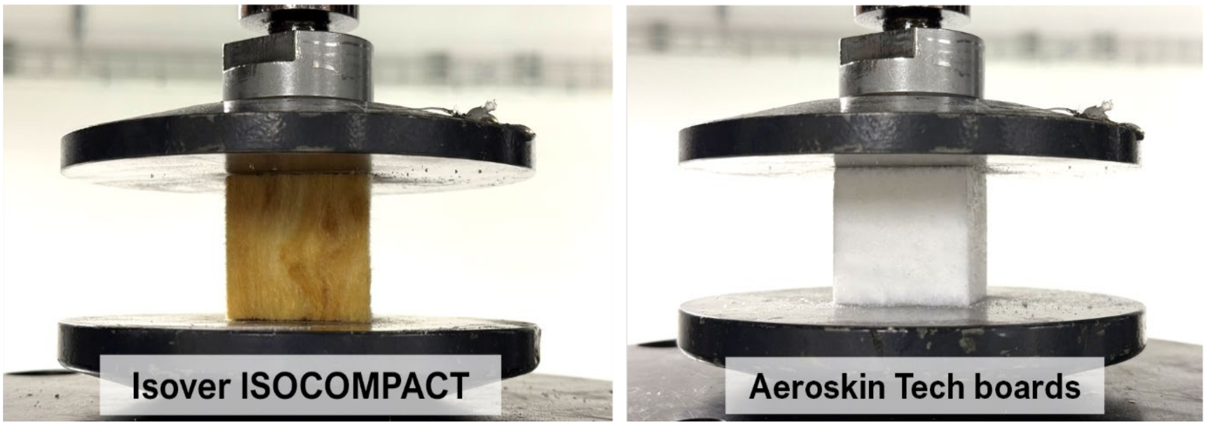


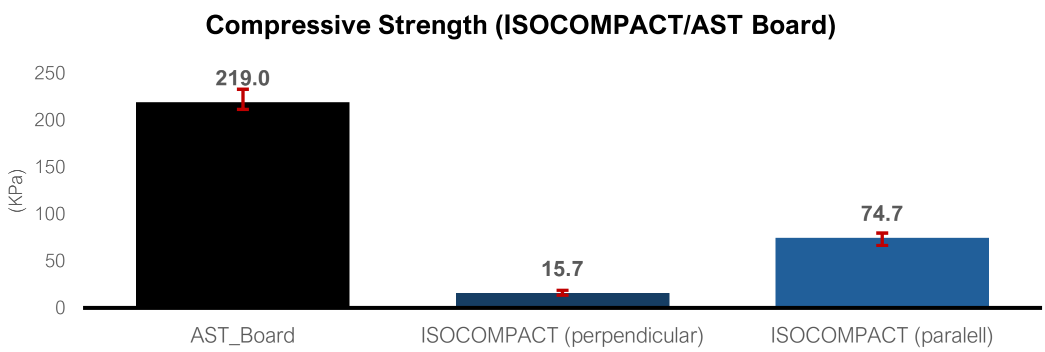


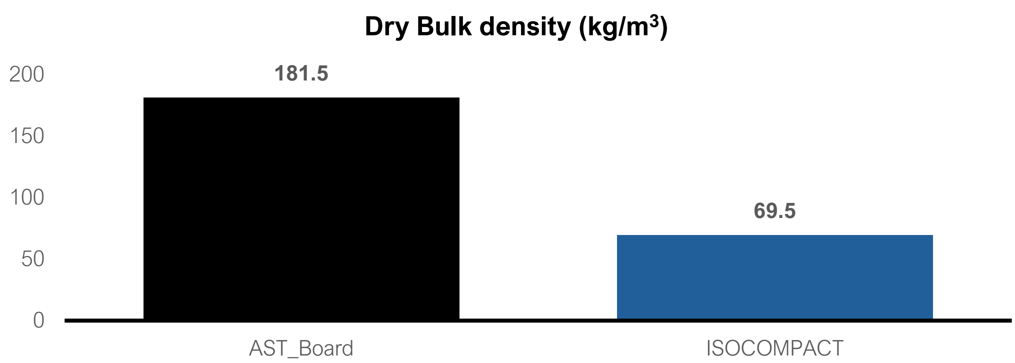
Compared to the reference sample (0.0), the addition of PCE has no negative impact on bending strength of the system, even improving the behaviour. Therefore, the modification was also successful in regards to the bending strength, another basic material parameters for the stability of the ETICS façade system. In particular, no decrease on these mechanical properties was achieved for highly flowable mixes. In fact, even an important increase was achieved (>80%).

Compressive Strength of ISOCOMPACT and Aeroskin Tech boards

Before testing the interaction of the KK71 with the insulating materials to be used in the project, a characterization to the compressive strength and bulk density of ISOCOMPACT (Isover) and Aeroskin Tech boards was also performed.



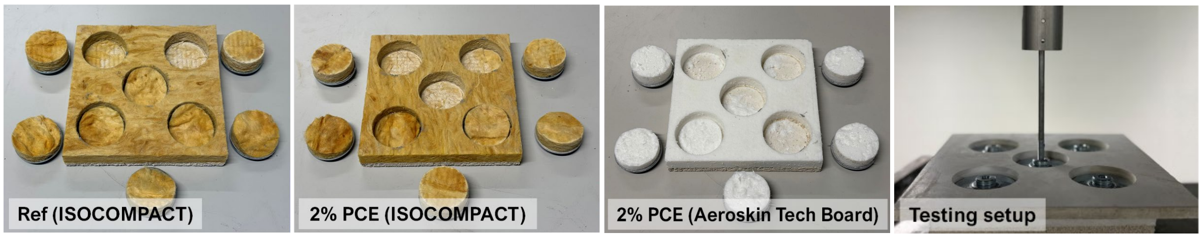


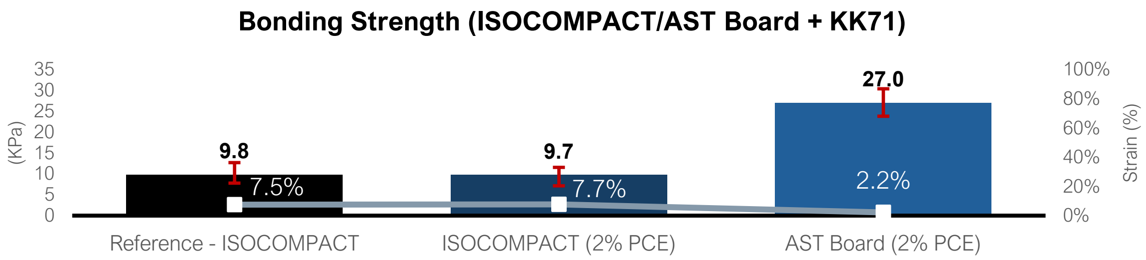


The compressive strength of the insulation was as expected. Aeroskin Tech boards (219 Kpa) are around 3 times denser vs. ISOCOMPACT (15.7 to 74.7 KPa). Moreover, in contrast to Aeroskin Tech boards, ISOCOMPACT showed anisotropic behaviour, whereas the highest compressive strength is achieved when compressing the material perpendicular to the insulation board, the relevant orientation for the ETICS system.

Bonding Strength of KK71 + PCE to the insulation materials (7 Days)

Once the basic mechanical properties of base materials are measured, the next test was to assess their interaction. In this sense, the stability of the ETICS also depends on the bonding between the layer. For this purpose, samples with KK71 (Reference) and KK71 + 2% PCE were prepared. The reference was casted on ISOCOMPACT to assess possible changes in the bonding strength. The KK71 mortar was therefore applied with a thickness of 8 mm and reinforced with a glass fiber mesh (as applied on-site to the ETICS system).

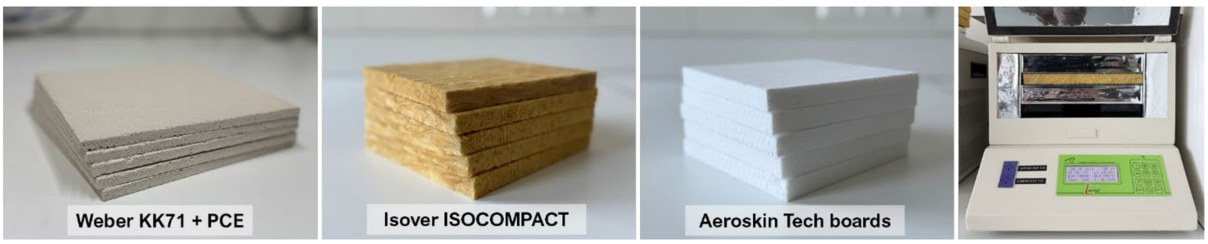


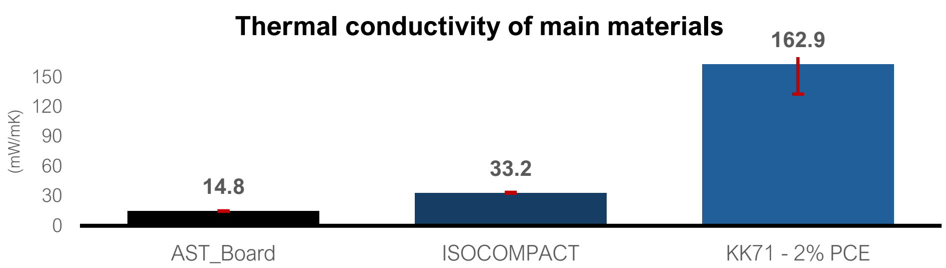


Compared to the reference sample, the addition of PCE has no negative impact on bonding strength of the system. The samples mostly broke at the insulation material in all cases, whereas, samples that broke at the interface showed very similar bonding strength vs. the latter case.

Thermal conductivity measurements

The thermal insulation capacity of the base materials through thermal conductivity was successfully measured: Glass wool and Aeroskin Tech insulation, as well as the modified KK71 was tested.





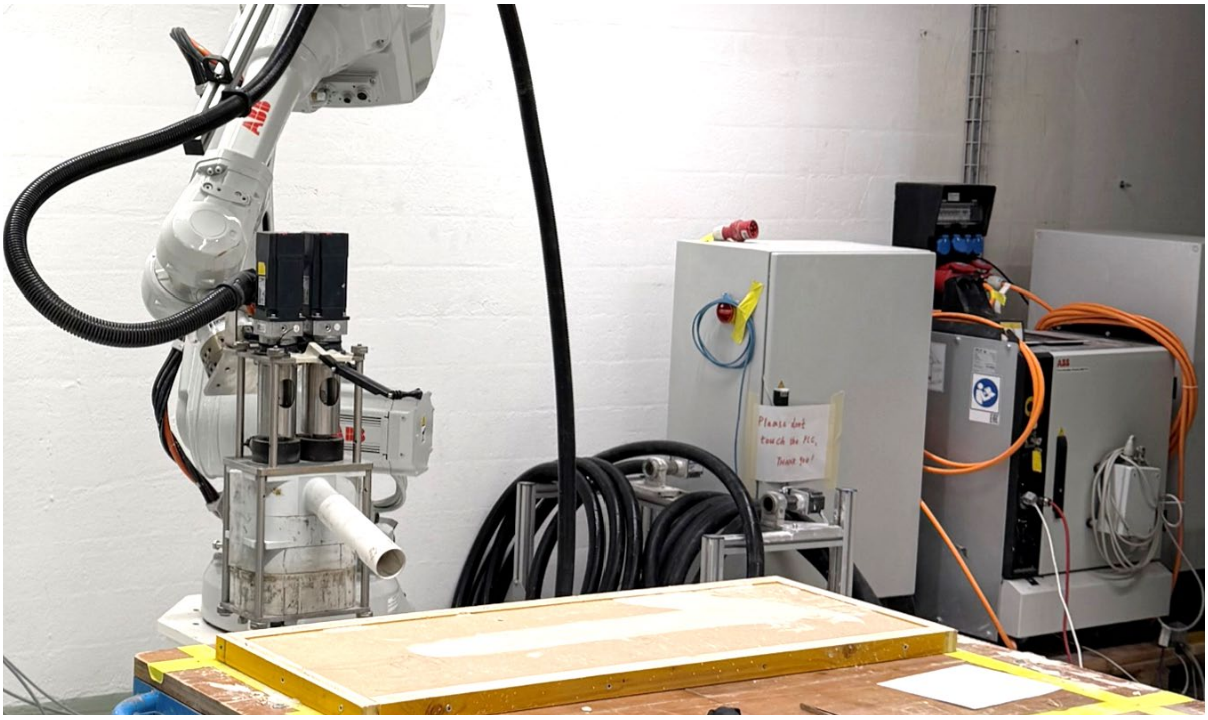
The thermal conductivity of the thermal insulation materials is within the declared values: <34 mW/mK for ISOCOMPACT, and <15 mW/mK for Aeroskin Tech boards. For the modified lightweight mortar KK71 + PCE, the thermal conductivity was significantly lower compared to the raw material's declared value. In particular, 40% lower compared to the declared value of 270 mW/mK. These parameters are required to assess the overall thermal performance of the prefabricated façade system. Therefore, the objective was successfully achieved.

WP3: Robotic setup for prefabrication

The WP3 consisted integrating a robotic setup for the semi-automated off-site manufacture of the prefabricated panels, and also test for the reliability of the processes. Robotic cutting and robotic spraying toolheads were developed from scratch, using existing parts from previous setups in the case of the spraying.

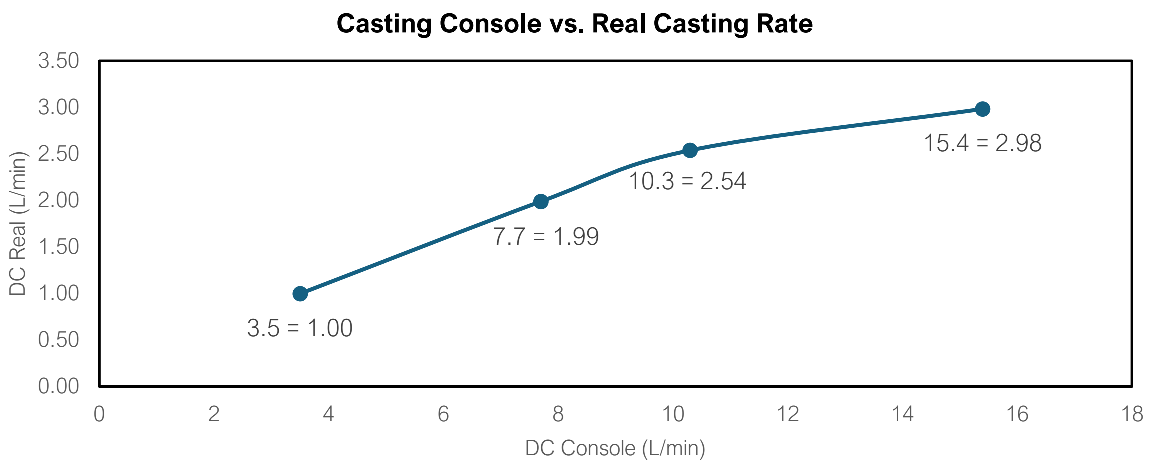
Robotic Digital Casting

The robotic casting system, provided by ETH Zurich, PCBM Group (IfB-DBAUG), was brought from and industry partner's facility (from a previous project). Therefore, the integration started by installing the whole system, making safety checks and training the involved personnel. The system also required to adjust for KK71 mix, test the open window for the casting, the rheology as well as the related mechanical properties of the adhesive mortar KK71.

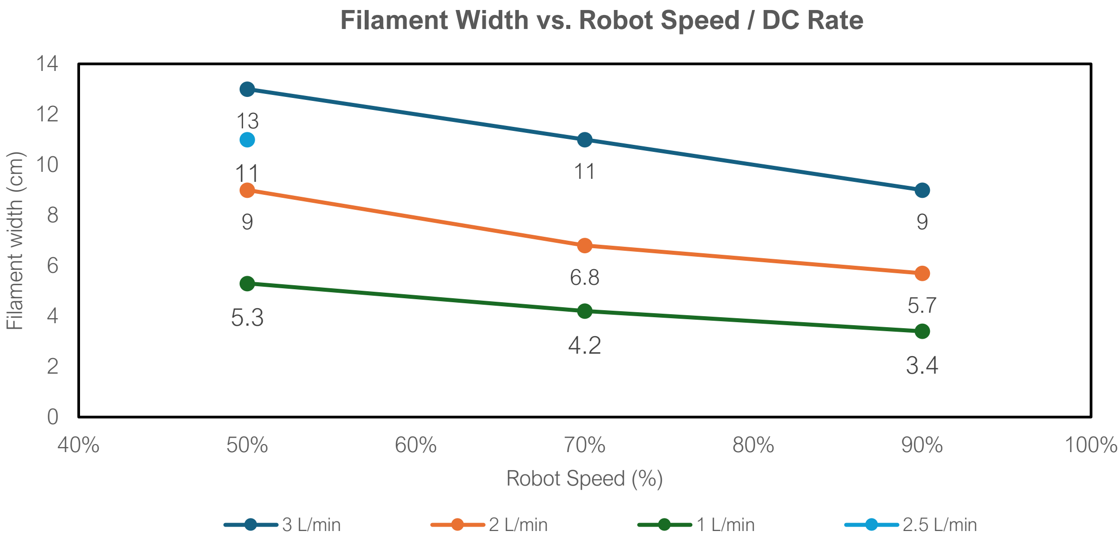


Casting Rate and filament width

The Digital Casting system parameters were originally built based on a different mix design; therefore, we adjusted the casting parameters to the KK71 mix, in order to validate the casting rate. The procedure started by measuring the amount of casted material vs time (L/min). For this, we casted during 10 seconds into a beaker at different casting rates on the console. After several tests, the final correlation of parameters obtained were as follows:

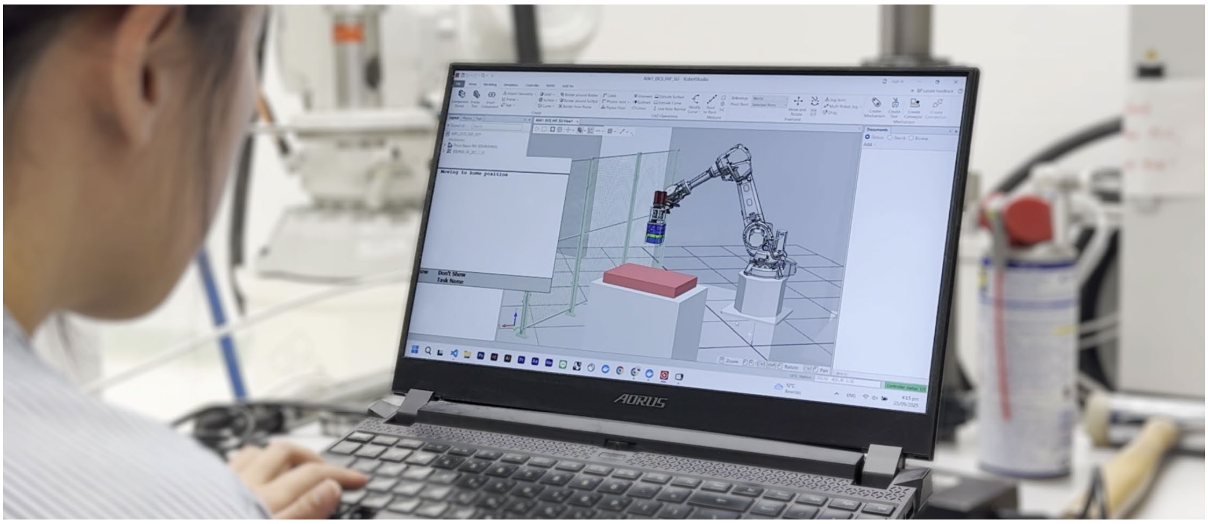


Once the real casting rates were obtained, we started to calibrate the filament width, defined as the width of the casted material at different casting rates and robot speed. Some examples below.

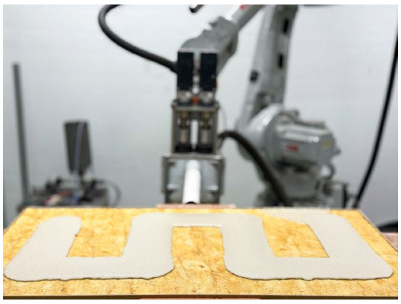
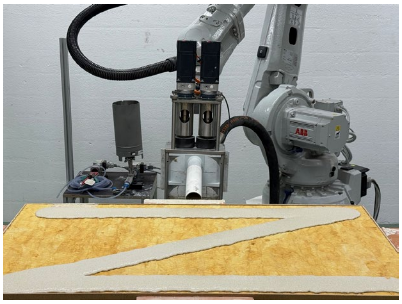
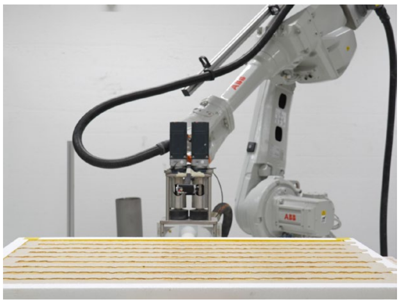


Tool path and material distribution

The information obtained sets the overall parameters to start casting the material at a given surface. The panel requires to cast a specific volume, given by the surface area and the target material thickness (i.e. 3 – 8 mm). The modified KK71 is self levelling, however, up to a certain extend. The minimum height that can be obtained during casting is 8-10mm, meaning, that for casting a 3mm or 5mm layer still requires to distribute the material within the surface. This was done by integrating an electric vibrating tool (used in casting concrete screeds), into the workflow. As we only have one robot, the vibrating tool was operated manually. Moreover, finding the right setup up required programming and testing different tool paths.

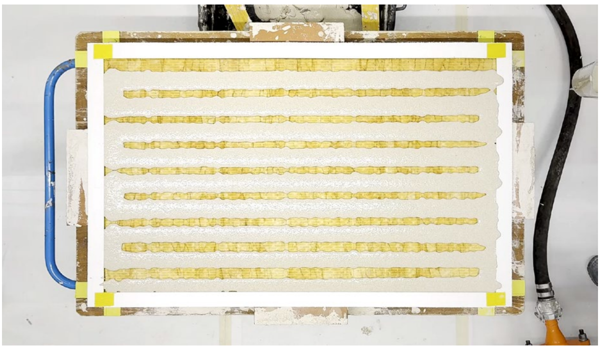


The following images show some examples of the casted toolpaths:

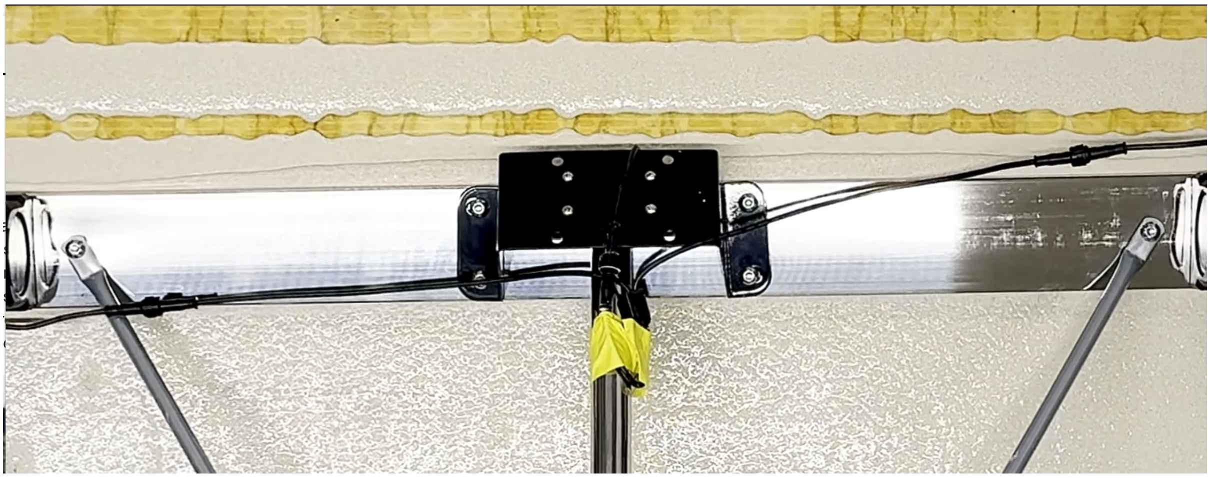




After several tests, the most efficient combination of casting rate, toolpath and vibrating step was found to be the one that make the lines closer to each other (right image above), therefore, the distribution of material is more localized, avoiding to move the material too far from the casted zone. The following images shows that the efficient combination of parameters obtained, translated to a homogeneous distribution of the KK71 mortar on top of the panel, as well as very high surface quality after the vibration tool step.

The first two images show a top view of the most efficient setup, during and after casting:

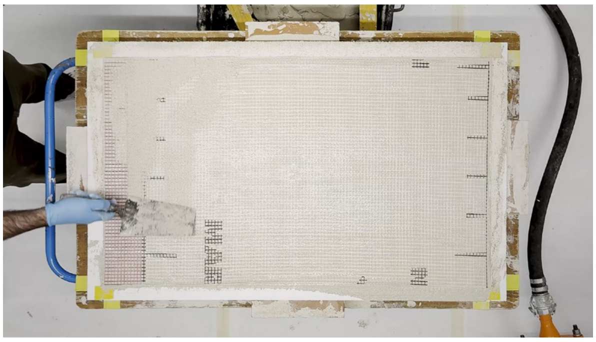



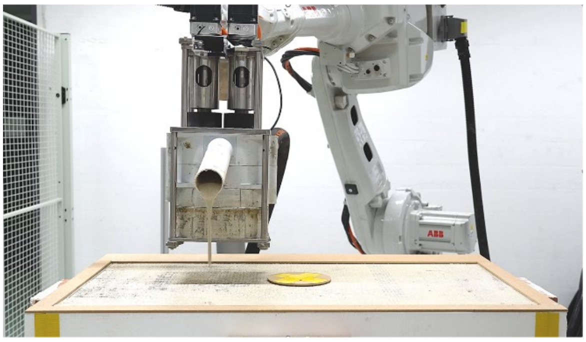
After the casting is finished, the vibrating tool is applied, to evenly distribute the material on the surface:



The panels are casted both sides and require the integration of the reinforcing mesh, however, each side has a different target thickness. In particular, the back side is casted with a thickness of 3 mm and the mesh is embedded once the vibrating tool is applied. The front side requires a total of 8 mm, but is casted in two steps. First, 3 mm followed by vibration and mesh application and finally another 5 mm followed by the vibration tool (no extra mesh).

The second layer is applied on a smaller surface, leaving a perimetral step for overlapping on-site. The following images show the step of applying the mesh (left image) and the application of the second layer with the step setup (right image).





Casting window and derived mechanical properties

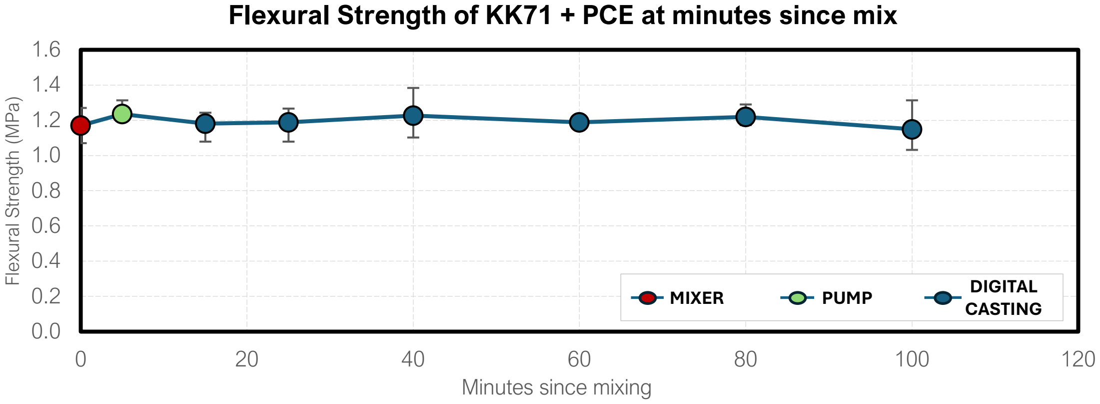
Once we have the correct parameters, it was necessary to assess the casting window time. This translates in how long the material stays flowable since the time of mixing without affecting the mechanical properties of the hardened material. The tests consisted in taking samples at different times, measuring the spread flow, and casting 3 prisms (4x4x16 cm) at each stage.

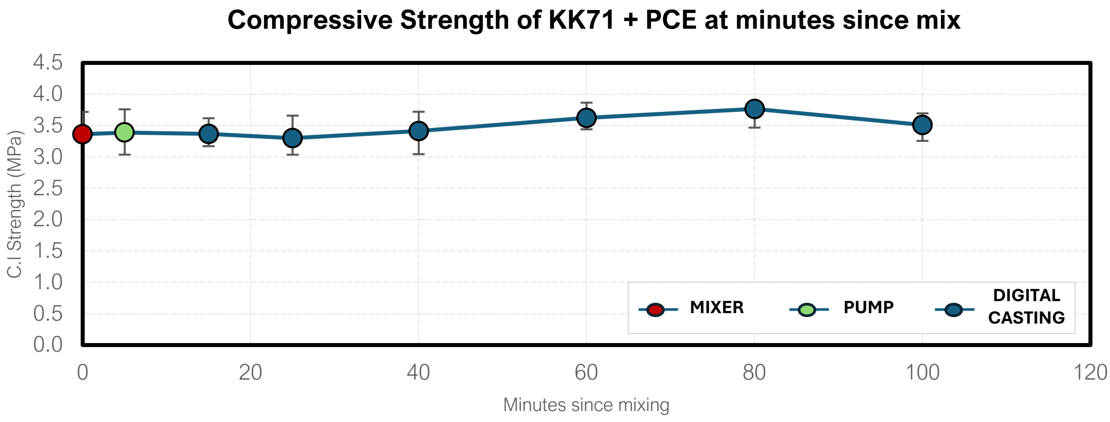
- Right after finishing the mixing procedure,
- Directly from the exit of the pump (10 min later)
- Directly from the robotic casting (15 min later), repeated every 15-20 minutes during 1.5 hours, and the casting rate was measured for every case.

It was found that the processing of the robotic system tool head increased the flowability by 15% compared to lab spread flow, allowing better spread flow during the robotic casting, therefore, better distribution of the paste on the surface of the panel. The casting window stayed open during the duration of the test since the mixing process 1.5 hours.

Mechanical test of the Casted KK71

The results on the mechanical properties showed that casting window of 1.5 hours did not impact the mechanical properties. The following graphs shows the mechanical properties obtained at every step:





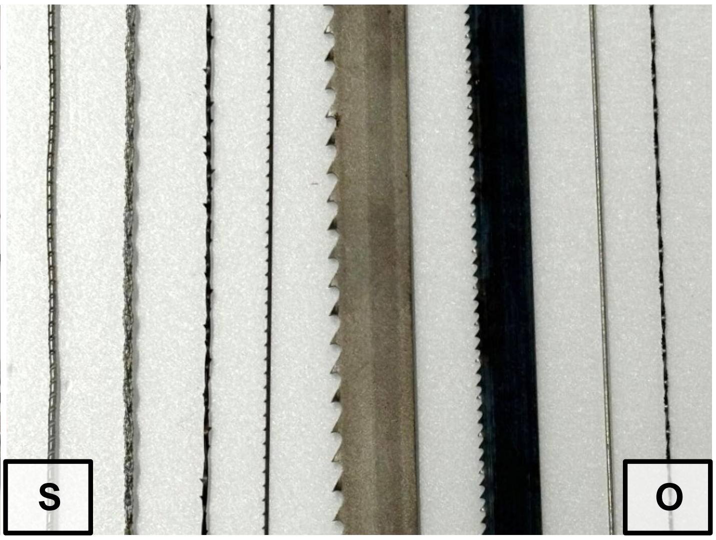
The mechanical properties derived from the processing of the KK71 mortar by the pump and the Digital Casting system are unchanged during at least an open window of 100 minutes. The tests show that in an open window of 100 minutes, no modification of the final material properties occur. The Digital Casting system is now validated and robust.

Robotic Digital Cutting

The cutting was divided in two setups. A first manual/electric cutting setup for generic cuts, and for testing different cutting saws. It serves as a basis for the robotic cutting in terms of setup and mechanism., but also easily available for fast straight cuts for the production phase. The second setup is the robotic cutter, useful for highly complex shapes that can be programmed and executed.

Manual/electric cutter

The setup up is based on a commercially available insulation cutter (left image below). The model had some size limitations for longer cross-sectional cutting. For this reason, the cutter frame was enlarged and a table for standing larger blocks of insulation was also integrated. Nevertheless, the saw is only available in two specific lengths (for each cutter model). Therefore, other commercially available saws (without length limitations) were tested (right image below). The original saw (O) and the selected saw (S) from the cutter is show in the image.

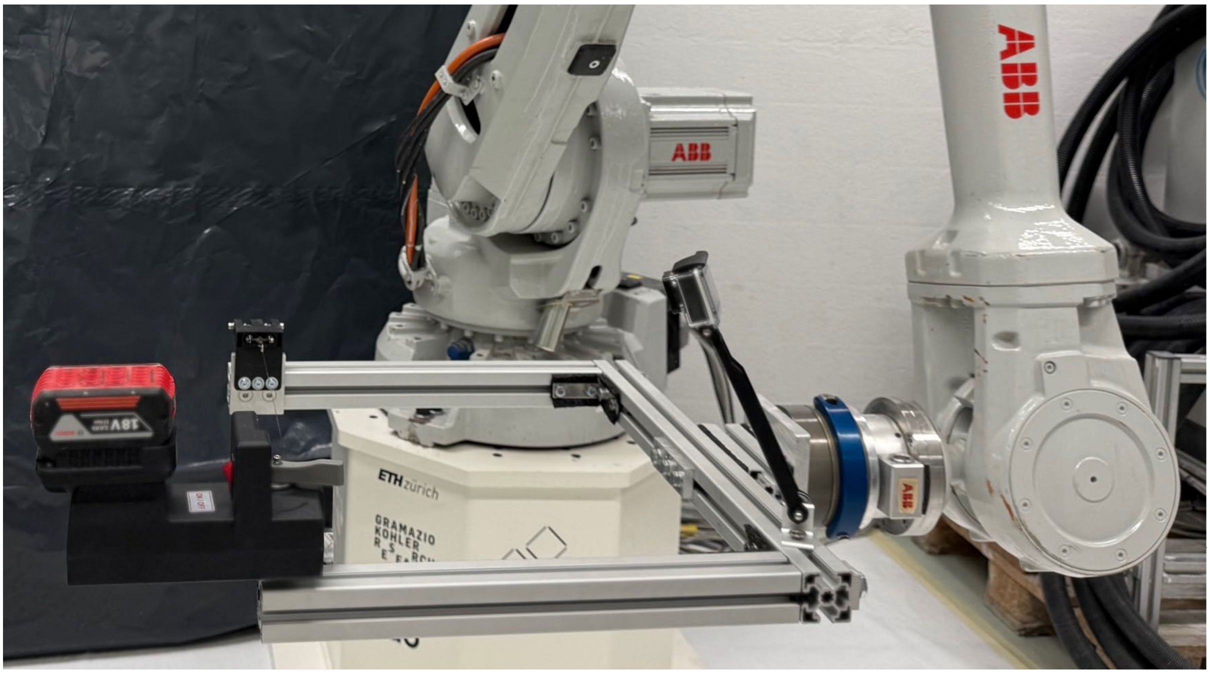


After trying several saws, the most suitable one is the 48" Dual Blade Rope Saw (from Spyral Saw), using a single filament. This saw provides the best combination of precision and robustness. Larger and heavier saws generate too much inertia, therefore, not suitable for the setup. Smaller saws tend to break much easier. Diamond cable saws (second from right lo left in the image above) are fine for soft materials, but not suitable for denser insulation, such as aerogel, particularly by cutting the material longitudinally.

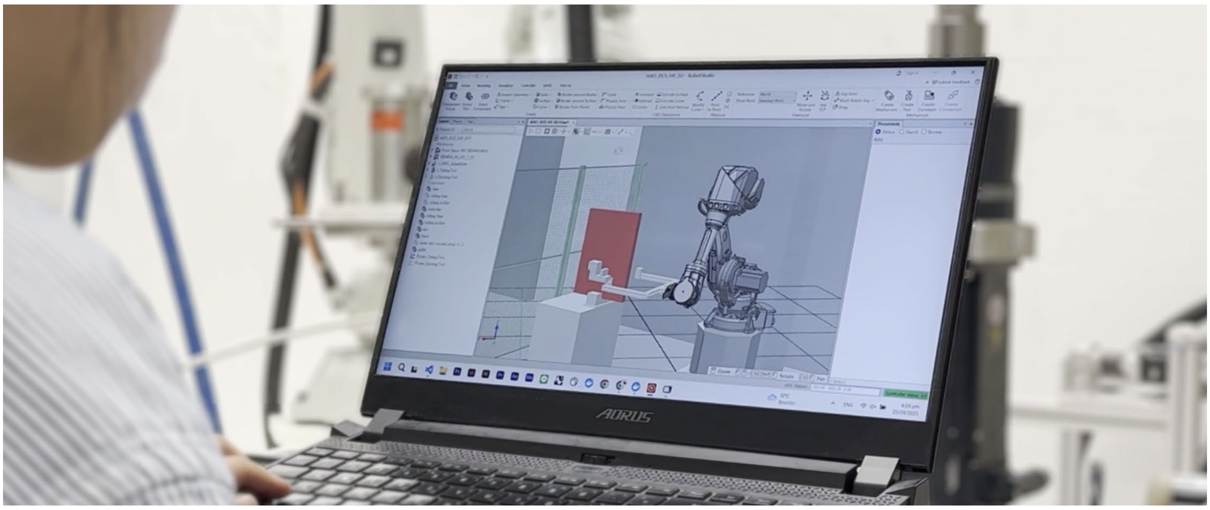
Robotic cutter

The cutting mechanism from the cutter above served as the starting point for the robotic cutter. It is based on short front and back moves at very high speeds, instead of a circular band that turns on one direction. This allows to have a compact setup for the robotic cutting, avoiding large loops that would not provide the flexibility needed by the robot to move around the sample during cutting.

The cutting setup consisted by building an aluminium support that can hold the mechanisms but also hold the flange to the robot. The aluminium frame also required dampening of the vibrations of the cutting mechanism, therefore, every profile connexion included a high-density rubber in between.



The next step was to program the robot and performing cutting tests. The final validation consisted in programming tool paths to replicate a complex façade detail (around a window with architectural details of classic style) were tested on different insulation materials, achieving a successful cut, therefore, ready for panel customization.



The results from cutting a specific façade detail, with two different insulating materials is shown below. The tool path replicates a specific complex shape from a Swiss building. The same example was shown in the project proposal document.

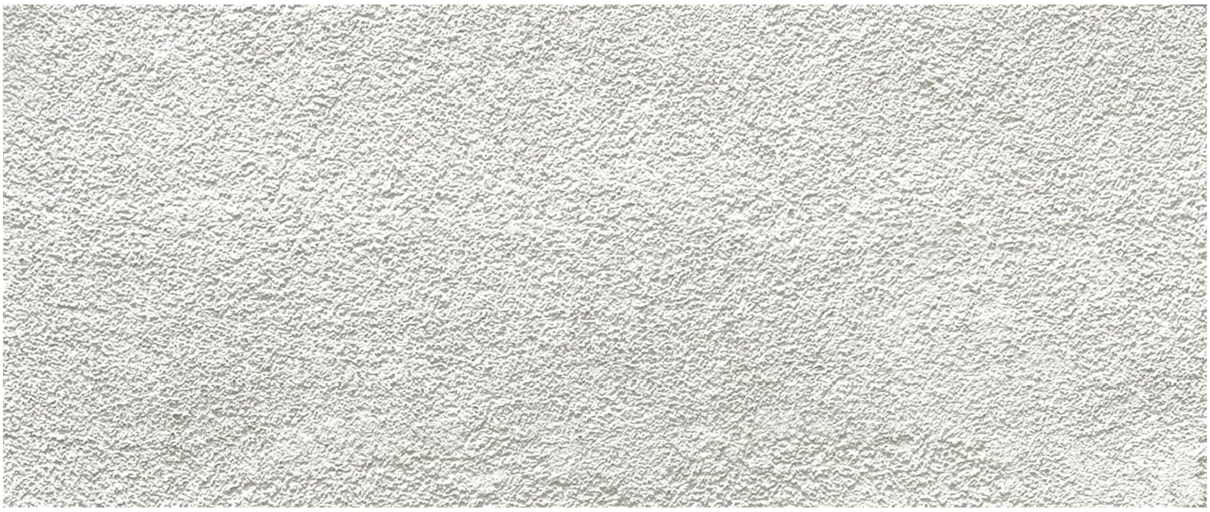
The robotic digital cutter obtained was fully validated and robust for cutting the insulation for complex façade details.

Robotic Digital Spraying

The robotic spraying started by selecting a setup for large surfaces, adapted to the material to spray. First, we used a commercially available manual sprayer for construction site, which is based on a reservoir for the paste, 4 nozzles and an inlet to connect the air pressure hose. The material used is Weber Silicon Vollabrieb aussen C210. For better sprayability, water was added to the material and tested for different dosages. An addition of 57g of water/1000g of paint was found the best for spraying and material distribution. Images from the tests are shown below.

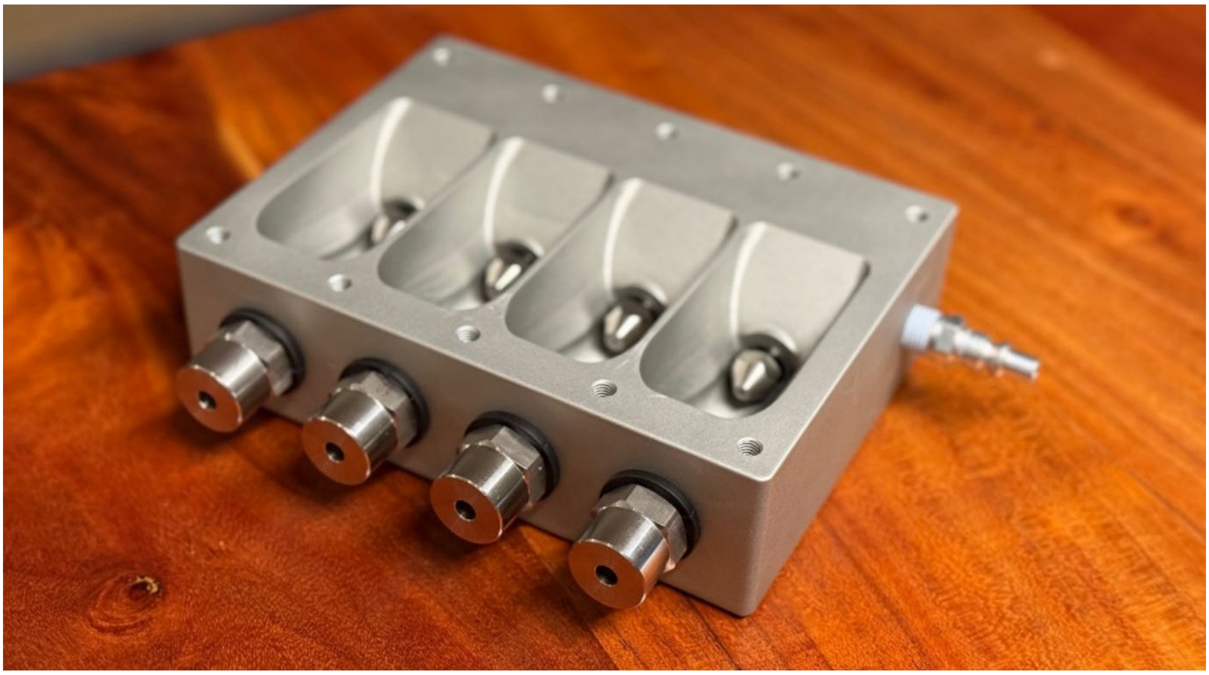

The tests included different strategies for overlapping new and old rough casts, in order to study the feasibility of including the rough cast in the prefabricated panels.


Final quality achieved was successfully obtain, at least for straight transitions. The image below shows the result of overlapping two rough casts, with a light grey color paint applied on top next day.



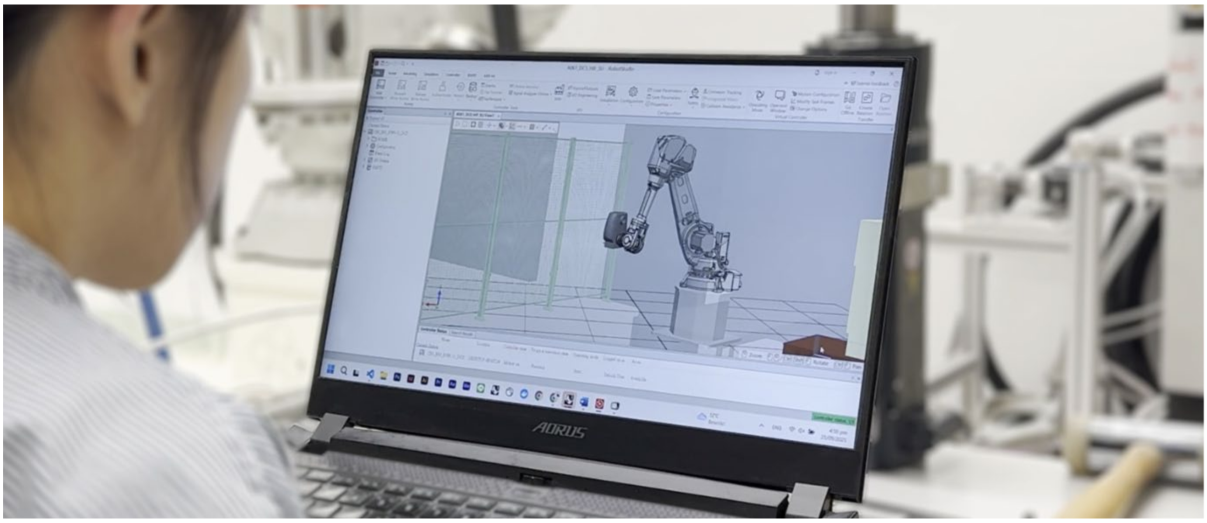
The setup served as a basis for developing a robust and high-quality setup up, giving already some parameters of possible moving speed ranges. The next step was to develop the robotic sprayer.

The robotic setup consisted in two main bodies. A first body (first image below), made from anodized aluminium, manufactured with 5-axis CNC machining (externally). It contains standard screwable and interchangeable nozzles, for both air (internal) and paste (external). It also includes a screwable inlet for the standard air pressure connectors.



The second body consists in a reservoir for the paste. It can be standalone (8-10L) or in combination with the digitally controlled pump used in the digital casting setup. The latter was not yet integrated. Two version of the reservoir were 3D printed and tested. The first one (black, left image below), made from PLA filament 3D printing (internally at ETH) was not suitable, due to the PLA layering. The second one (white, right image below), made from single body resin 3D printing (externally), worked much better, and was also much easier to clean.


Additionally, test with different nozzle openings, internal (air nozzles) and external (paste nozzles) were tested, optimizing the spraying quality. The tests robotic testing included programming of tool paths.



Despite the high spraying quality, the spraying is limited by the current maximum speed of the robot (software restricted), and deeper modification would be needed. Due to this limitation, the material is spraying material in slightly higher quantities than required. Faster robot movement would allow to potentially avoid any post-processing after the spraying (man labour shown in the video). A second strategy would consist in a secondary tool head to generate the circular moves to obtain the desired surface, nevertheless, due to time and budget limitations, no further development was planned for this project.

This work package also included the production of 3 videos (one per digital process). Links in the annex.

WP4: Customization of the façade system

The WP4 consisted in customizing the façade system: The 3D scanning of the demonstrator building, the generation of a BIM model, and the development of specific solutions for the prefabricated panels according to the requirements of the façade and architectural details. Prototypes of panel overlapping were developed and systematically assessed by lambda measurements. Final bending and bonding tests on the digitally casted composites were performed, as well as vapour diffusion coefficient of the final mortar and Aeroskin Tech Boards.

The WP included the planning and production of around 10m^2 of façade panels that were brought on-site, in order to assess the tolerances and precision, before the full manufacture of all the panels for the renovation.

Drone and 3D Scanning

The 3D scanning of the building including a drone inspection of the area of the building to be renovated.

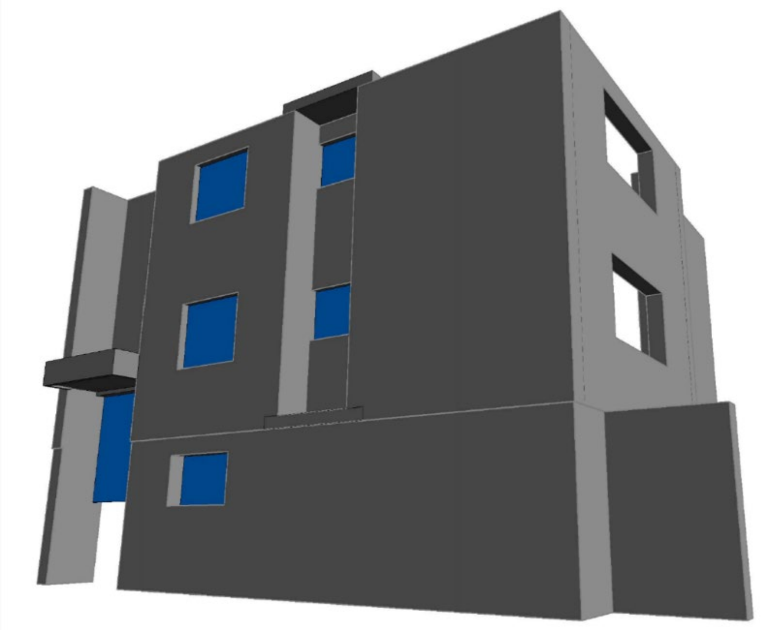



Besides the drone inspection, several spots where selected to make the high precision 3D scanning.

Point Cloud and BIM Model

The files were downloaded from the 3D scanning device (Leica RTC360) and the point cloud was processed using Cyclone Register 360 software. The process merged and cleaned all the generated scanned point clouds.

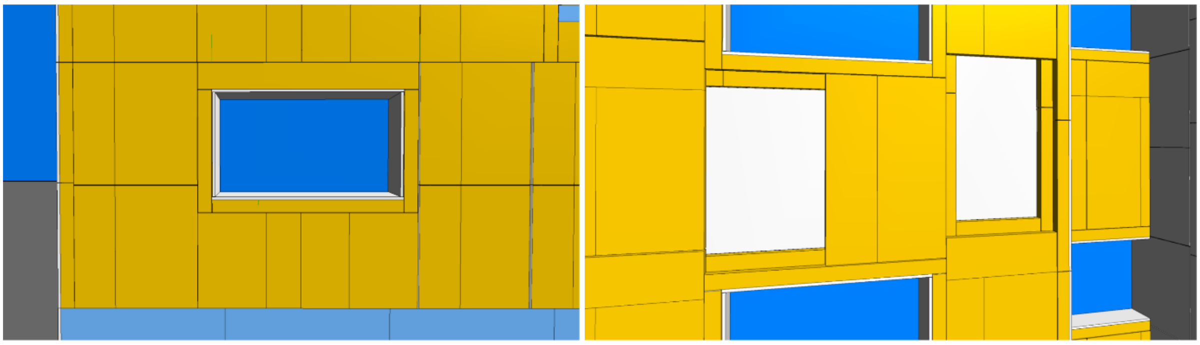
Once the point cloud is ready, it is imported in to Autodesk Revit and use it as reference for creating a BIM model.



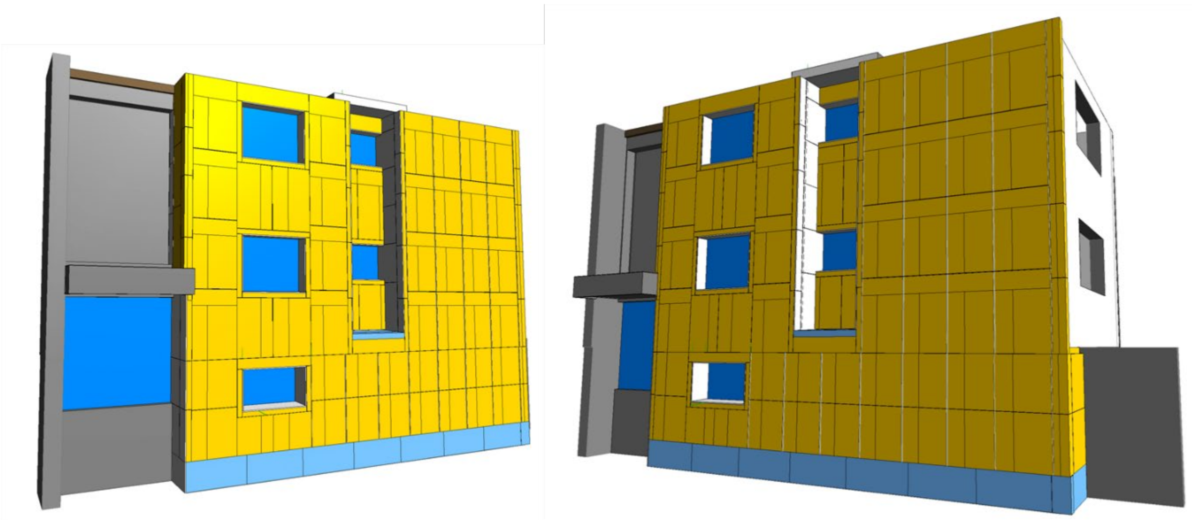
A second site visit was done, in order to audit the generated 3D model from the point cloud. It was confirmed that the 3D scanned generated point cloud and derived 3D model was very precise. In fact, on-site verifications showed precision up to 0.5 mm.

First Iteration: Stepped panel cut

The verified 3D model served as the starting point to generate the first iteration of façade modulation. The principle followed was the original Z cut overlapping, as well as window and corner panels as originally planned.



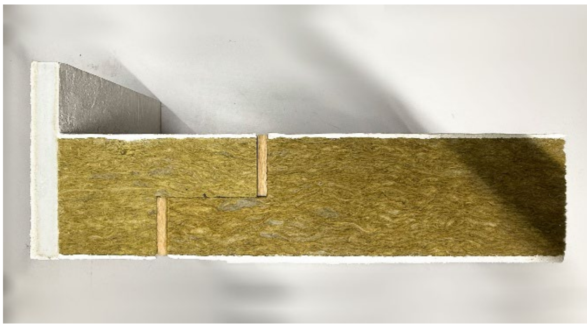
The modulation was based on Z cuts (stepped) at every transition, including internally between submodules.



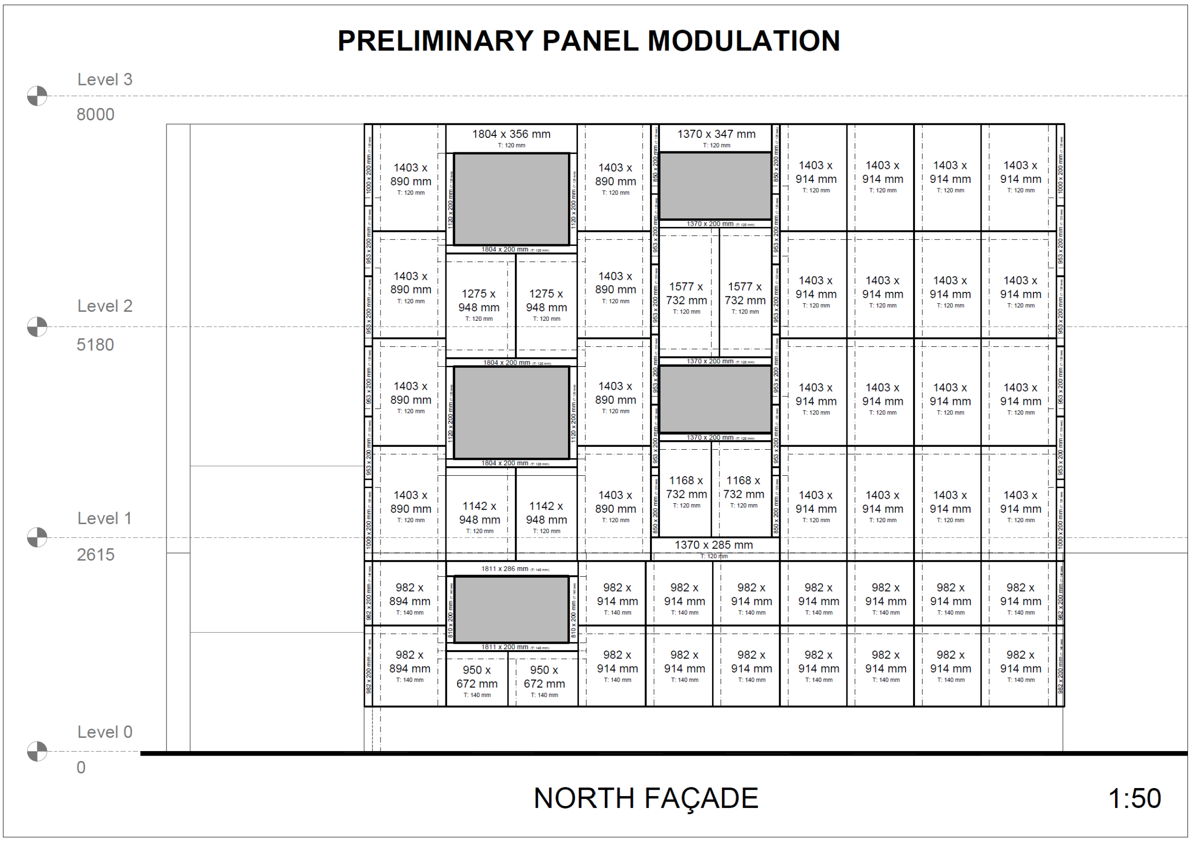
The first iteration was done only to the North façade, in order to obtain feedback from the manufacturer of mineral wool, as well as checking the feasibility of the cutting as proposed.

First prefabricated system prototype

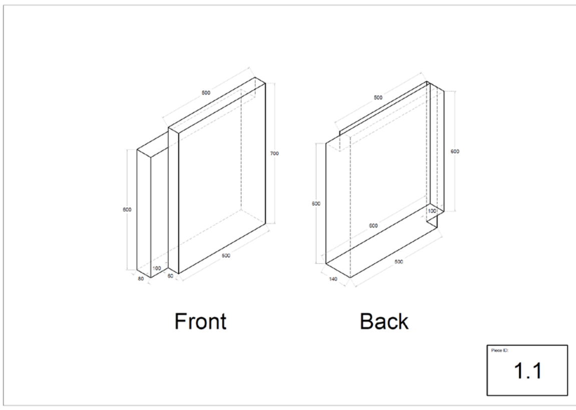
From the proposed modulation, a first small prototype was built, keeping same thickness of initial traditional prototype (as the building's requirements), in order to have a first approach to the prefabricated system.

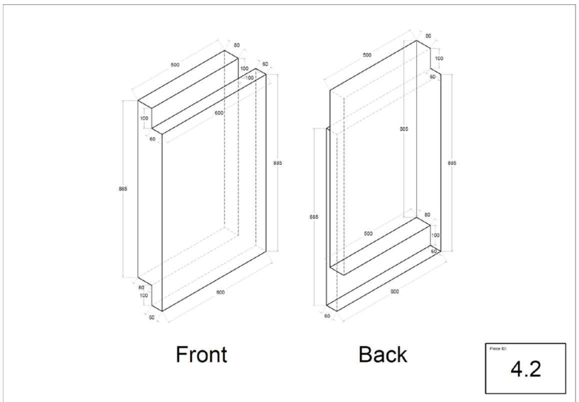


The prototype reproduced the initial concept of overlapping in Z shape, as well as a main panel (mineral wool) and a corner panel (aerogel + mineral wool transition). This prototype and the proposed modulation CAD drawing below, were presented to Isover Switzerland, as well as details of the panels of the 10m^2 to produce first.



Example of isometric views of two panel sent to Isover:





The feedback was that such cuts could be implemented in the future in their production, however, for this project, such cuts must be done by an external company, therefore, they were discarded by Isover.

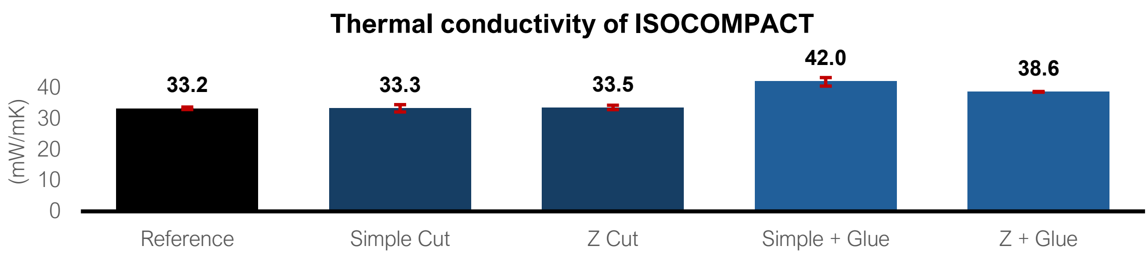
As a follow up for the project, easier cuts were requested (straight if possible). All cuts that do not adjust to current manufacturer automated setup, have to be processed manually (with electric band saws), which can increase the costs substantially.

Second Iteration: Stepped panel cut

The second iteration started by assessing the possible impact on the thermal conductivity and bending strength of the different options for cutting and glueing.

Thermal conductivity measurements

Samples were prepared in order to compare the different transitions, compared to a continuous panel. They are divided in non-glued and glued samples. Both groups included a straight cut and a Z shape cut.

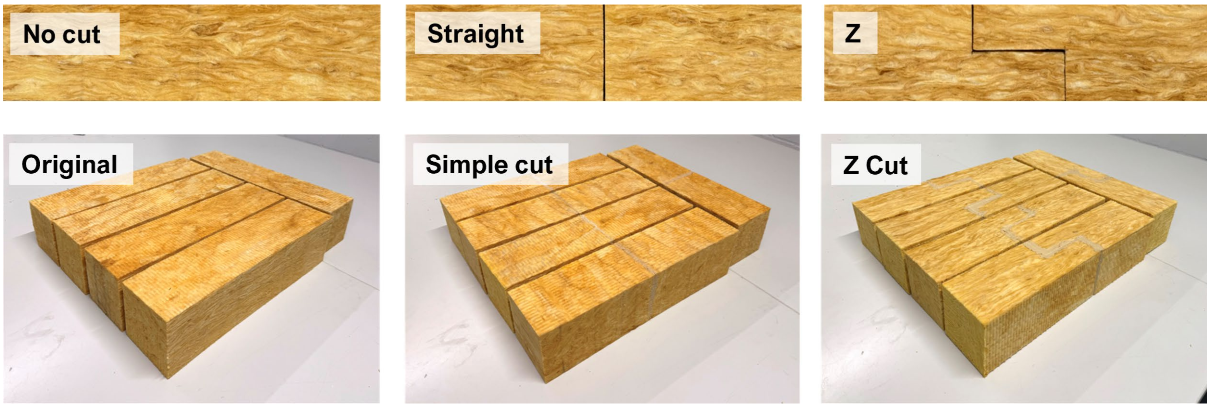


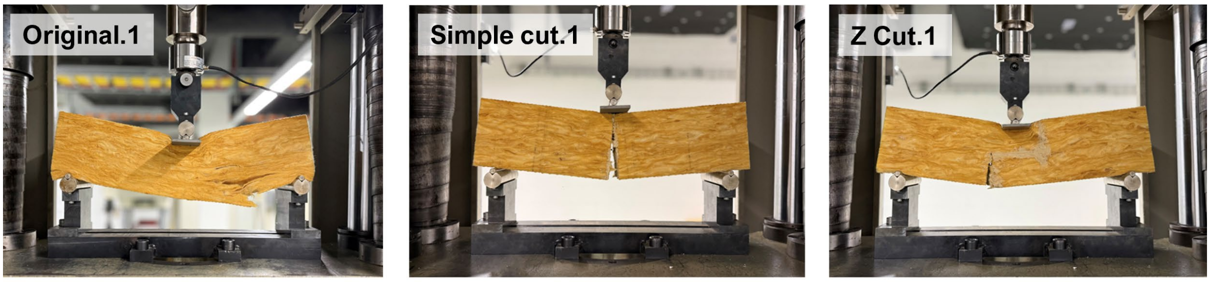
The impact of cutting and overlapping, plus the glueing of the samples in both cases showed mixed results. In first place, both cut samples (straight cut and Z cut) presented no impact on the thermal conductivity vs. the reference (continuous panel) and the declared values: <34 mW/mK for ISOCOMPACT. Therefore, the on-site placement of the panels next to each other does not generate thermal bridges, as long as the transition leaves no gap between panels.

Second, the addition of glue (glueing standard sizes to make bigger prefab panels have slightly higher impact. The Simple cut + glue increased the thermal conductivity to around 42 mW/mK, whereas Z cut, up to 38.6 mW/mK. To note is that the increase is only applicable to panel transitions areas of 10 cm wide (5 cm + 5 cm of each panel internally), therefore, no real thermal bridges are generated even with glueing.

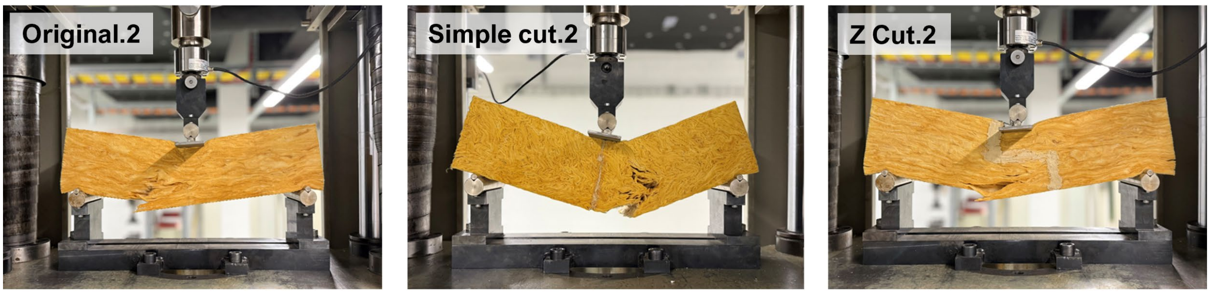
Mechanical tests on glueing

Besides the thermal conductivity audits, it was necessary to test the bonding of the glass wool, comparing the two types of cuts, vs no cuts. The mineral glue used (proposed by Isover) was **Silacoll 100.** Five samples for each setup were prepared and tested.



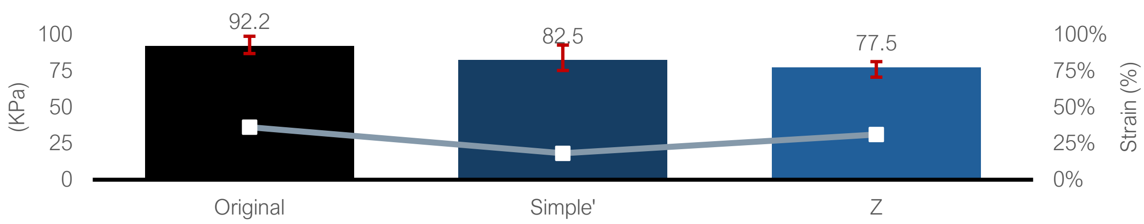


Characteristic fracture point | Fracture point at glue interface | Fracture point at glue interface



Characteristic fracture point | Fracture point at insulation | Fracture point at insulation

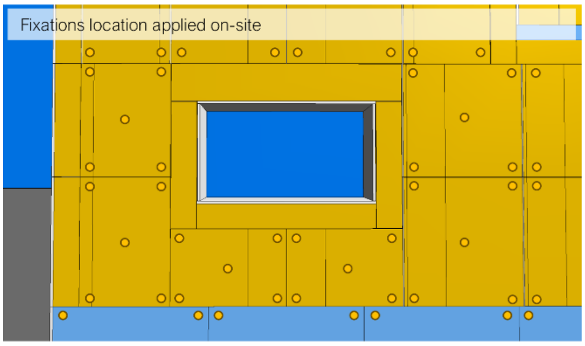
Bending Strength (ISOCOMPACT + Silacoll 100)

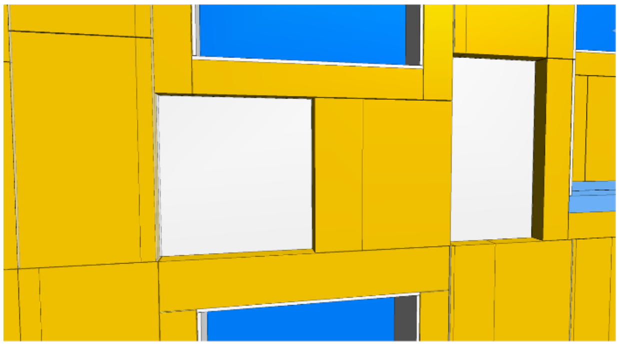


The mechanical tests also confirmed that straight cut, glued with Silacol 100 is provides the required robustness for the panels. The material behaves as an entity. Glueing the samples does not reduce overall bending strength.

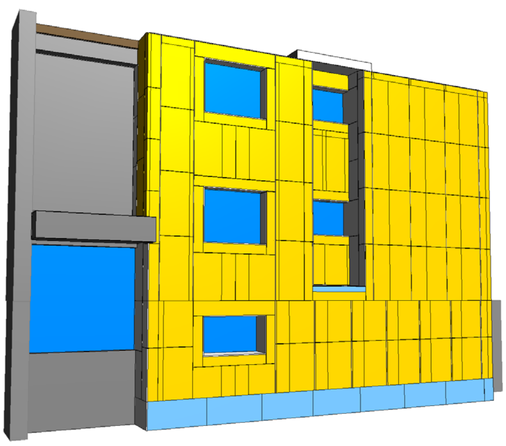
Façade modulation with straight cut transition

The second iteration changed the Z transitions to straight cuts. In order to avoid any gaps, a roll of glass wool of 140x10mm cross section from Isover was proposed (commercially available). The material offers an easy solution to apply on site where needed to adjust to required tolerances.



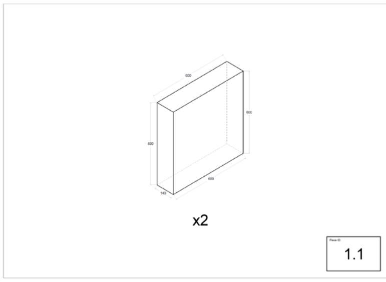


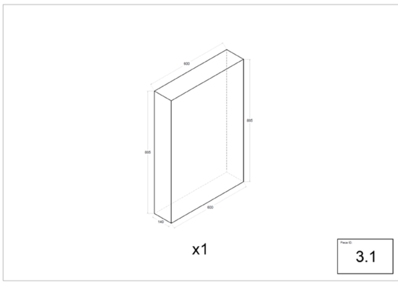
The previous image (left) shows the area to be produced (around 10m^2 of façade), checked for fitting assessed.

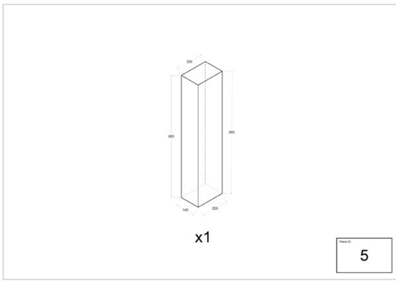


Prototypes production and on-site fitting check

The 3D model of the second iteration modulation was used to provide the sizes of the different panels to Isover.

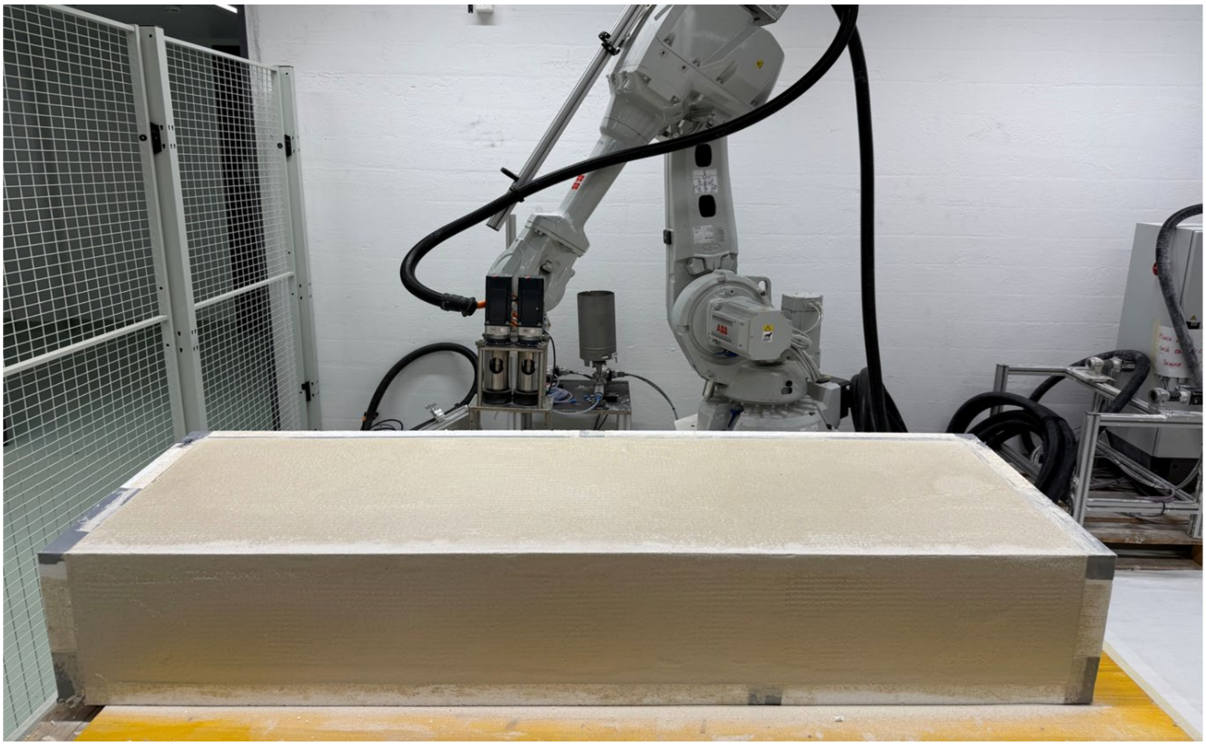




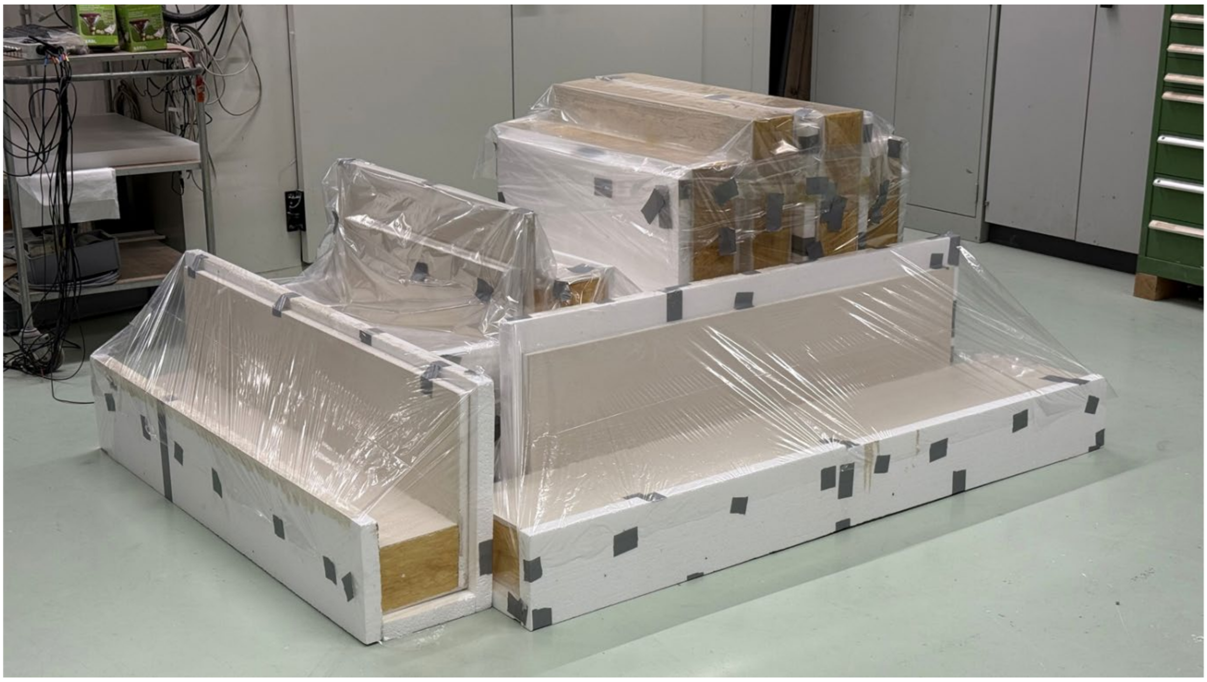


Once the panels from Isover were delivered, the production started. The first step was to glue the different pieces to generate the different panels.

The next step was to cast the KK71 + mesh on both sides. The image below shows a corner sample.



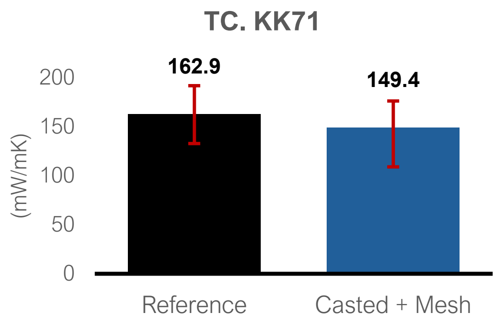
Once all the panels were produced, the next step was to pack them and to bring them on-site for fitting verification.



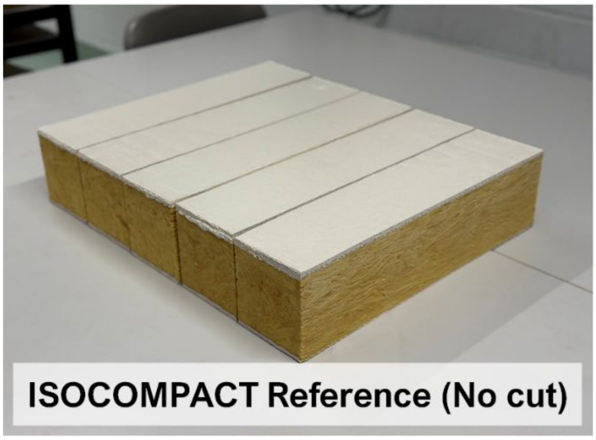
The prototype version of the second iteration produced panels that perfectly fit the existing building. The lower element of the window bank didn't fit all the way, because there is an aluminium profile (5 cm width) that increases the slope, and needs to be removed. However, as the construction will happen next year. The profile was kept in place. Moreover, the panels were brought back to ETH and spraying of the rough coating was done (final aspect is shown later below).

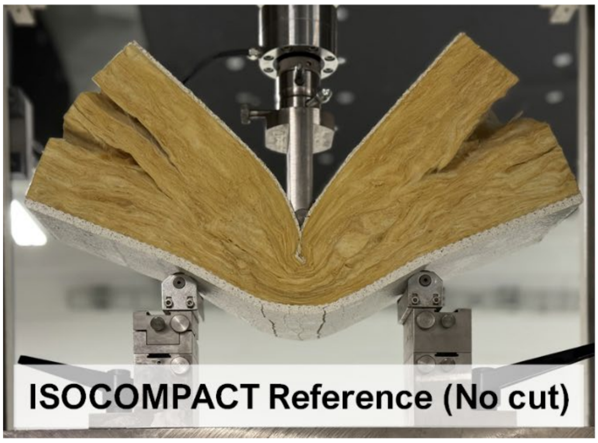
Composite system final testing

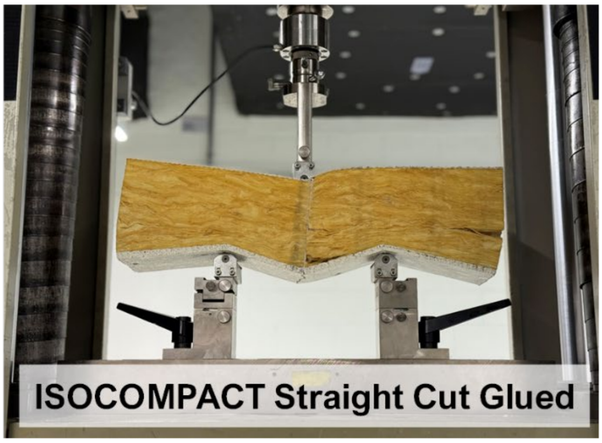
The prefabricated system still required final complementary tests. The first test was to measure the thermal conductivity of the KK7 Digitally casted.

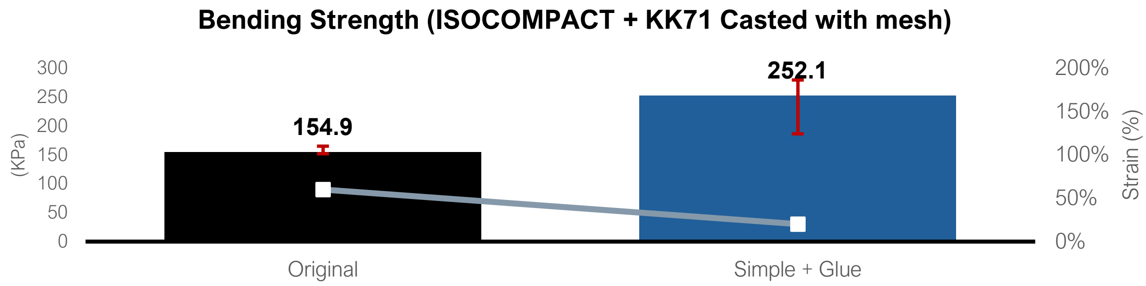


For the modified lightweight mortar KK71 + PCE + Mesh (Digitally Casted), the thermal conductivity was even lower compared to the reference (without mesh). The next test was to test the bending strength of the composite system, including the digital casting of the KK71. For this test, glued and non-glues glass wool was compared:



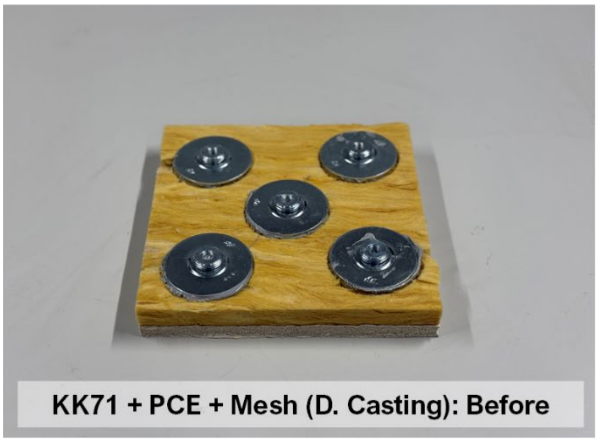


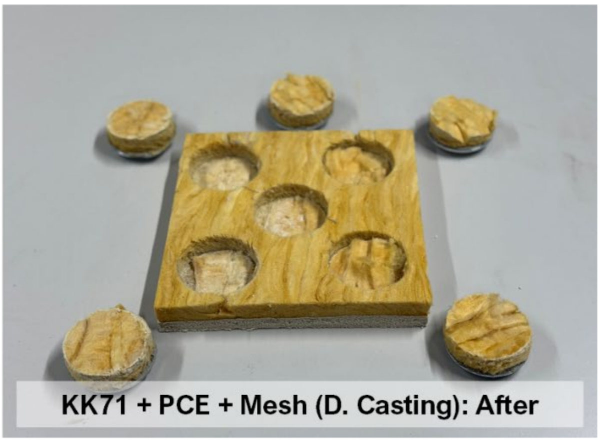




The bending strength of the composite ISOCOMPACT + KK71 mortar with mesh (3mm one side + 8mm on the other side) showed that the glue increases the overall rigidity. It fails at earlier deformation (20% vs 50% tested). Nevertheless, it increases the overall strength by 62%. Further compression of the reference (no cut, no glue) increase the strength up to 197.7 kPa (100% deformation), still below the achieve by the glued sample. Therefore, glued samples are robust as composite system.

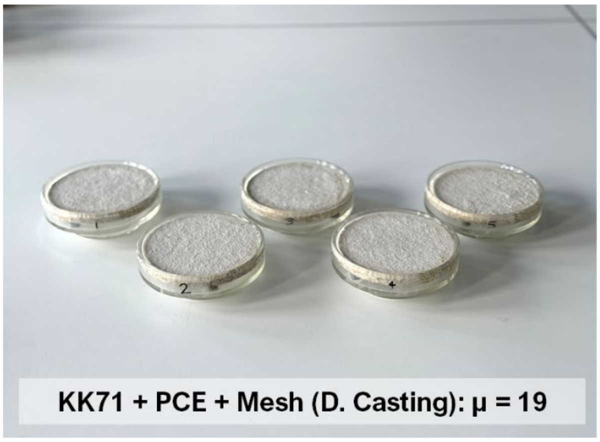
The mechanical tests were also complemented with bonding tests of the digitally casted KK71 on the glass wool:


KK71 + PCE + Mesh (D. Casting): Before


KK71 + PCE + Mesh (D. Casting): After

The bonding strength of KK71 mortar (Digitally Casted), with a thickness of 8 mm and reinforced with a glass fiber mesh, applied to ISOCOMPACT, presented no difference at 28 days vs. reference samples **9.6 kPa** vs. **9.7 kPa** of the reference. Therefore, the Digital Casting process kept the same bonding strength vs. non casted.

Finally, vapour diffusion coefficient (μ) tests were done for the KK71 (digitally casted) and Aeroskin Tech boards.

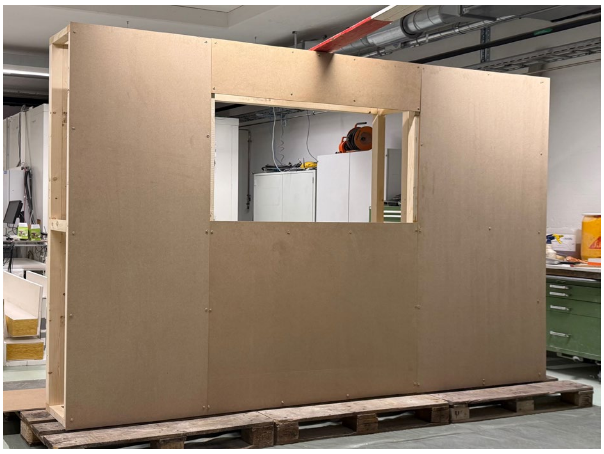

KK71 + PCE + Mesh (D. Casting): μ = 19


Aeroskin Tech Boards: μ = 9

The vapour diffusion coefficient (μ) of KK71 + PCE + Mesh (D. Casting) was measured at μ = <19, this is similar to vapour diffusion vs. KK71 (as declared μ <20). Therefore, no negative impact on possible condensations. For Aeroskin Tech Boards, the μ<9 also presented very good vapor diffusivity (open to vapor diffusion). Glass wools have μ=1 (as air).

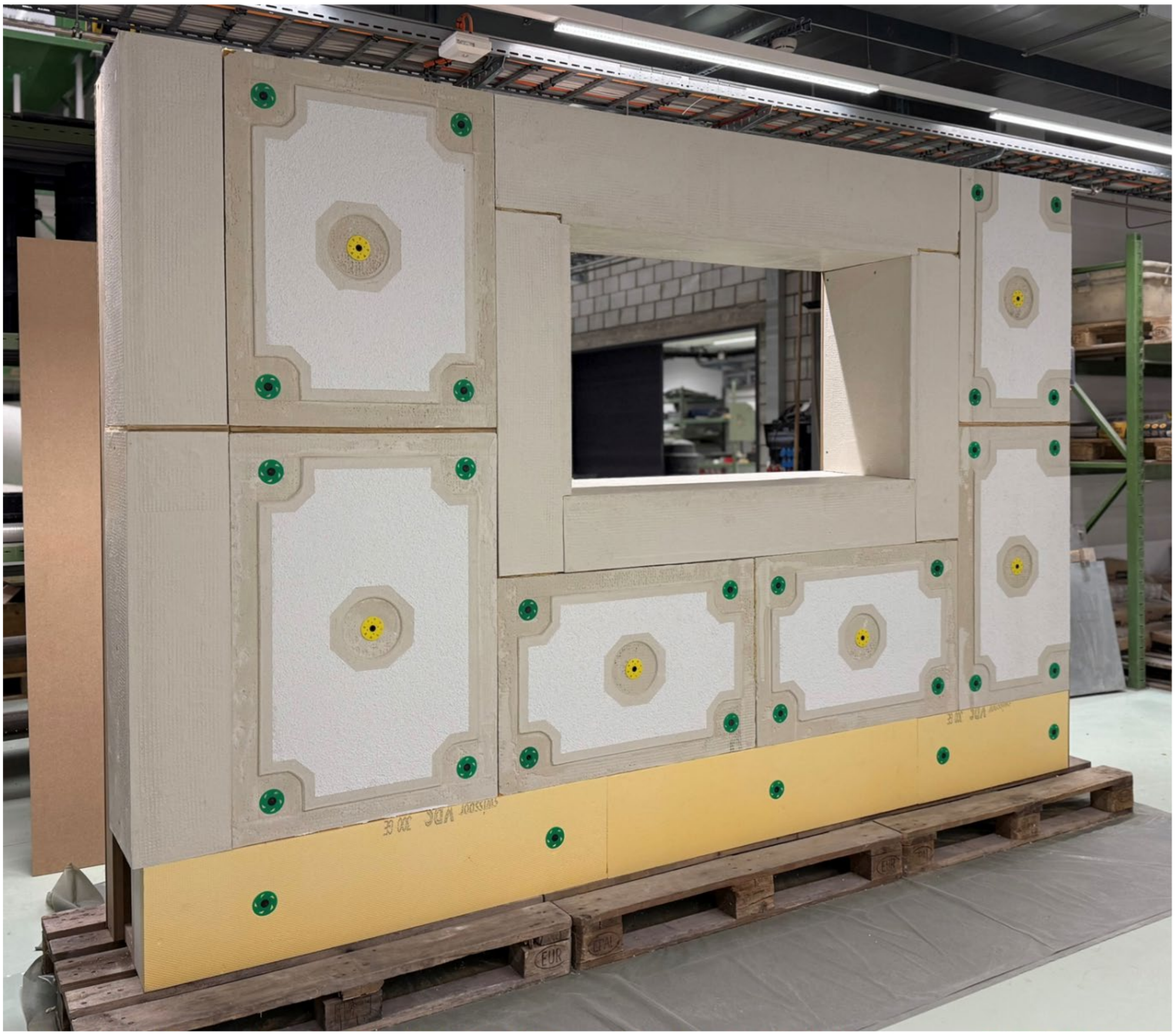
On-site workflow testing: Building structure and Panels installation

To complement the second iteration, we integrated a new testing setup. It consisted in building a wooden structure and test the on-site workflow. To make the test comparative, we mirrored the façade on the back side of the wooden structure, setting the back side as a reference. The purpose was to compare the time that takes for the installation of the KK71 + mesh, as well as the rough cast on both sides. The reference side surface had to be applied in full, whereas the front side, only the overlapping panel areas. In this sense, it was assumed that the internal side of the prefabricated corner panels for the windows were ready for the rough cast, therefore, the application of the window corner protection profiles from the back side and KK71 + mesh on the reveals was accounted only as required in the reference. Front (left image below) and back side (right image below) of the wooden structure as follows.



Once the wooden structure was built, the next step was to install and fix the prefabricated panels, starting from the window elements:

Next step was to install all the remaining panels, applying the 10 mm glass wool roll at all transitions for fitting.

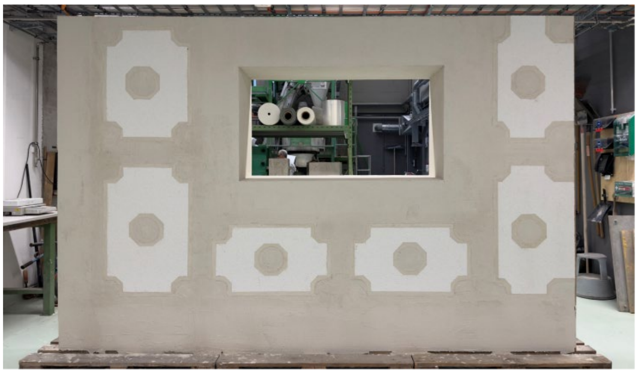


As can be observed in the images, the panels already included the rough cast (applied once they were back from the building). This allows to test if partial rough surface can be included in the prefab (initially planned).

Before continuing with the front side, the KK71 + mesh was applied on the back side first.

The work started by measuring and cutting the corner protection profiles for the window, as well as the meshes to be installed within the KK71 mortar.

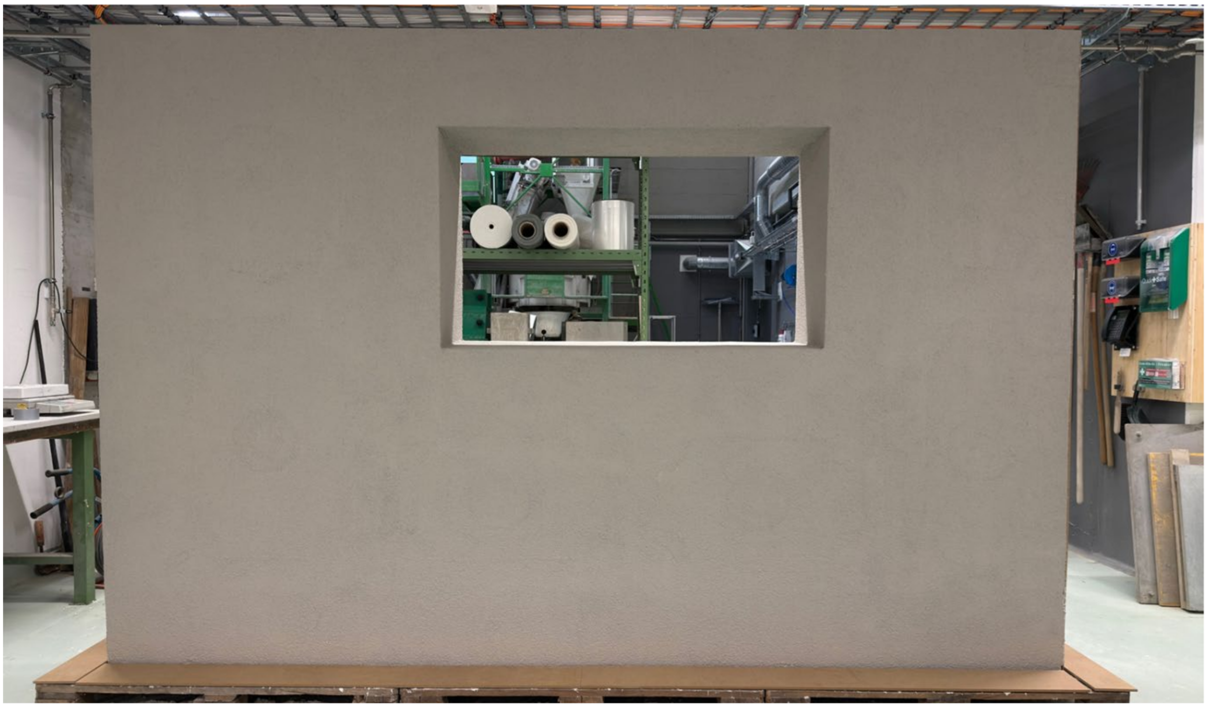

Once the application of the KK71 + mesh was finished on the back side, the work continued on the front side, applying the KK71 mortar + mesh on the transition zones.

The next layer to apply was the rough cast, first on the back side.

After the back side was finished, the rough cast was applied on the front side.

The surface quality of the front side was lower than the back side. The final step was to apply the paint to see if the quality improves.



Appearance: Even visual quality is decent, highest standard was not fully achieved due to the pre spraying. Overlapping zones are very difficult to dissimulate.

Timing: Overall timing of the KK71 application was highly reduced, due to the pre-finishing of the window reveal (time savings of 70 minutes), however, working around the fixations and the existing rough cast areas, made the overall process tedious and not efficient.

The following table shows the difference in timing for both sides.

Back side: KK71 + mesh	
Cutting and preparing the corner protection profiles	20 min
Cutting of meshes for the entire surface + window reveals	40 min
Application of the KK71 + mesh on the window reveals	70 min
Application of the KK71 + mesh on the wall surface	80 min
Total application time:	**150 min**

Front side (Prefabricated panels): KK71 + mesh	
Cutting and preparing the corner protection profiles	0 min
On-site cutting of meshes for the overlapping zones (cut during prefabrication)	0 min
Application of the KK71 + mesh on the window reveals	0 min
Application of the KK71 + mesh on the wall surface (overlapping zones)	120 min
Total application time:	**120 min**

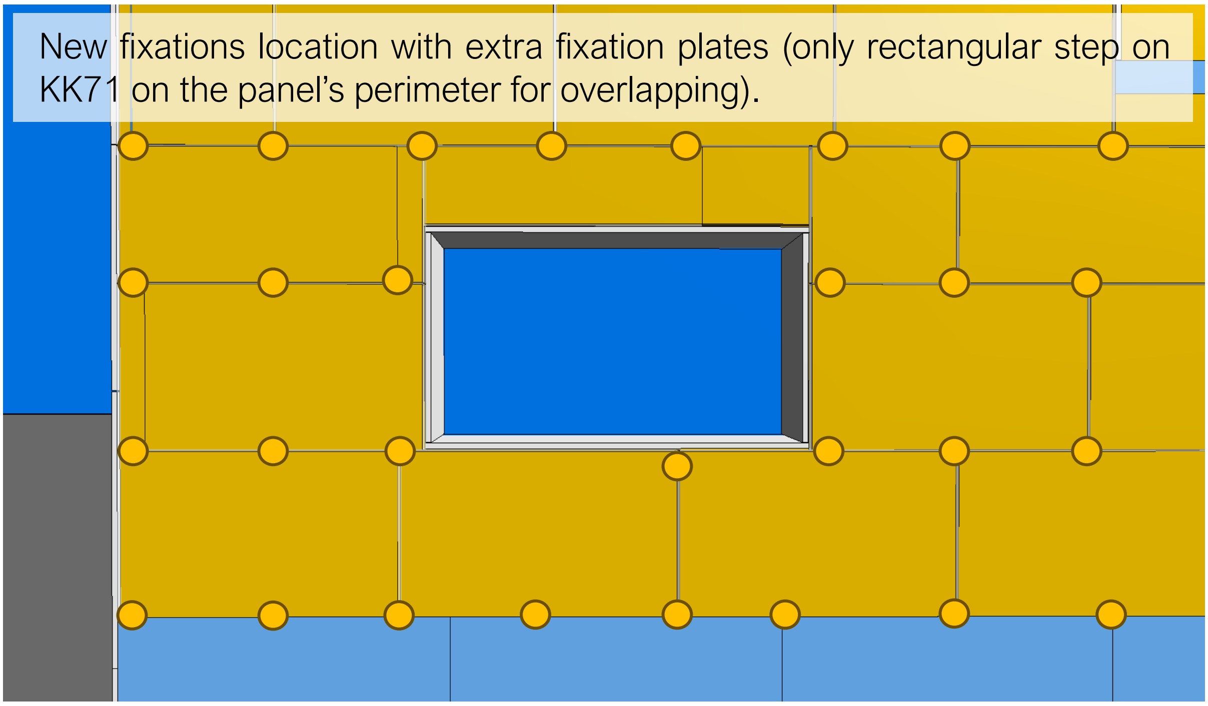
Overall, the prefabricated side was ***20% faster***, however, the complex shapes of the overlapping zones, particularly due to the fixations that made the application not efficient.

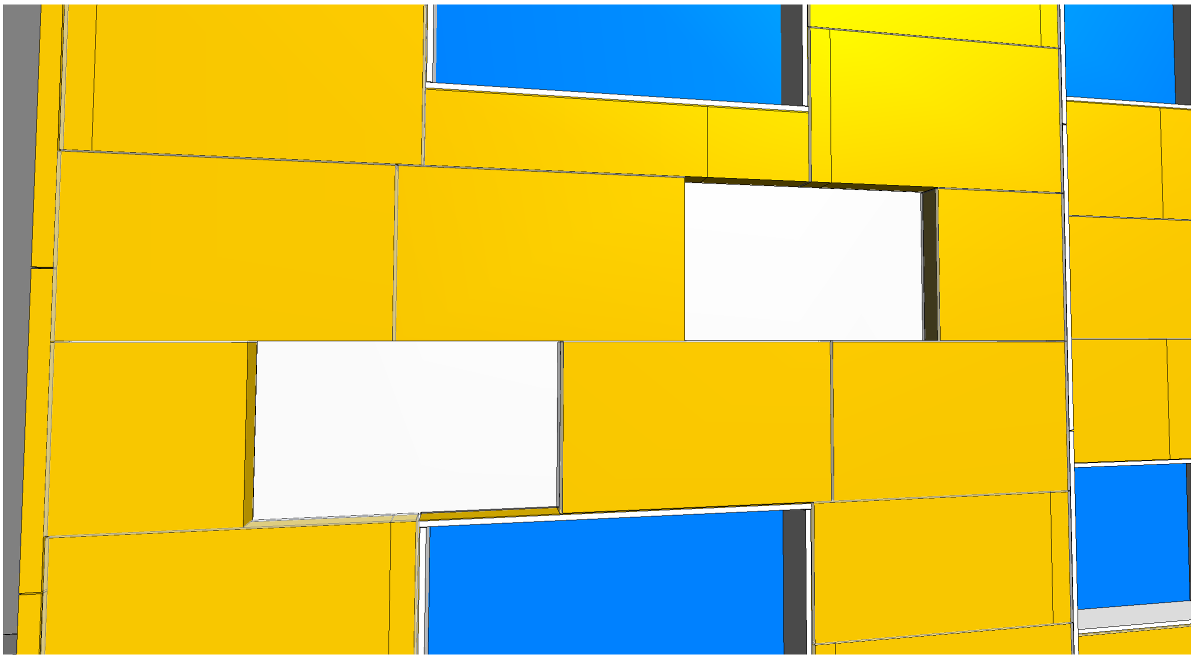
Back side: Rough Cast	
Application of the rough cast on the wall surface (without window reveals)	75 min
Total application time:	**75 min**

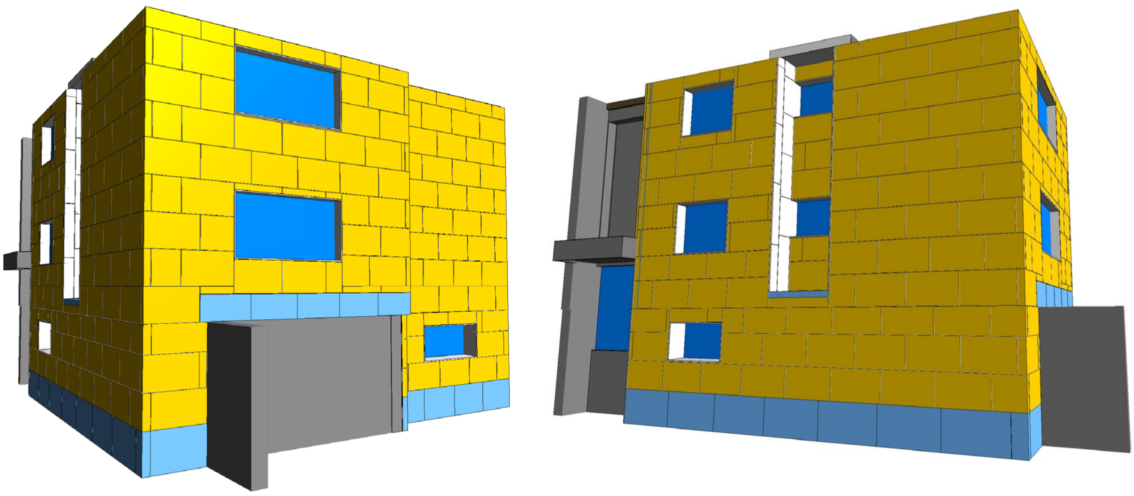
Front side (Prefabricated panels): Rough Cast	
Application of the rough cast on the overlapping zones	0 min
Total application time:	**115 min**

Overall, the application of the rough cast on the prefabricated side took ***53% more time***, particularly due to the fixations zones that made the application not efficient. The partial application of the rough cast to the prefabricated panels is not efficient and with lower quality, therefore discarded. A new iteration is proposed to make the entire process more efficient.

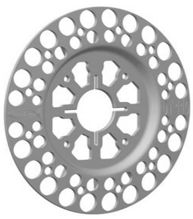
Final Version: Straight panel cut, independent window frames, standard panel size as possible







The final iteration changes the approach for optimal workflow, to reduce both prefabrication and on-site time and costs. Rough Cast is applied on-site. The building corners of glass wool to glass wool is solved by panel interlocking (typical practice in traditional applications).

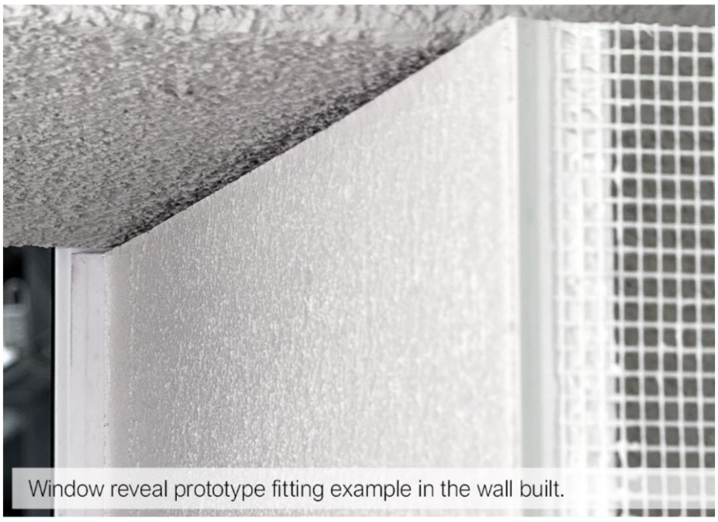


Panel sizes: Panels sizes on previous iteration were not big enough to cover much larger areas (larger not considered as they would need on-site cranes). A more traditional approach is now adopted: standard sizes and only glueing for façade fitting punctually. This keeps the initial philosophy of reducing the amount of different panels sizes, but without glueing on every panel to reach final dimension. Enlargement of fixation crown's diameter through Fischer 90745 product to ensure proper fixation area in now included.

Window reveals are changed: This element presents the biggest time-saving potential. Therefore, it will be exploded further, by the re-design of the element.

New window reveals element prototype

New approach: removing transition element (glass wool), but integrating a connexion and prefabrication. The prefabrication is now simpler, as there are no more corner elements, keeping the system efficiency.



Window reveal prototype fitting example in the wall built.

The proposed element contains the corner protection element integrated. The element has a nose that guides the application of the KK71 on the façade side, with the correct thickness, avoiding the use of any other tool. The back side contains another integrated element (available commercially), specifically designed for renovation of window reveals. The element contains a foam for sealing the back side at the window frame.

Moreover, this element can be sold standalone, as either standard or tailored sizes. The advantage is that it can be used in any building, even without 3D scanning or full prefabrication.

Next Steps

- **WP5 – Demonstrator Building:**

The final prefabricated system will be produced and installed at the renovation site in spring 2026. Full integration of all panel types, including window reveals, will be tested under real conditions.

- **WP6 – Cost calculation, energy consumption and LCA assessment:**

The time efficiency and cost-effectiveness of the prefabricated approach will be quantitatively assessed in comparison to conventional on-site ETICS application. Additionally, the production system will be assessed from the perspective of energy consumption, carbon footprint and production capacity (m^2/year).

Annex 1: Videos of Robotic Processes

Digital Casting:

https://drive.google.com/file/d/1vAob7ngaGxSmq5OGeO3YV6PfUOZup3X-/view?usp=sharing

Digital Cutting:

https://drive.google.com/file/d/1chXINxFRPoRCTfVMF5Gxg0My1wudObl2/view?usp=sharing

Digital Spraying:

https://drive.google.com/file/d/1GRvvq2-atwnw4V4zY57AbCr9a5tDBw-V/view?usp=sharing