MORE—CONNECT

*MORE-CONNECT PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S H2020 FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION UNDER GRANT AGREEMENT NO 633477. THE INFORMATION IN THIS PUBLICATION DOES NOT NECESSARILY REPRESENT THE VIEW OF THE EUROPEAN COMMISSION.*

*© MORE-CONNECT*

# D5.3 Prototypes of prefabricated modular renovation elements

## for markets in The Netherlands, Latvia, Estonia, Denmark, Czech Republic, Portugal

MORE—CONNECT

# Production of the prototypes of the prefabricated elements

This deliverable documents the work of task 5.3, which concerns the actual manufacturing of the prototypes of the prefab renovation elements by the participating MORE-CONNECT producers: BJW, WEBO, Matek, ZTC, Invela, Innogie & Darkglobe.

This includes prefab renovation modules for markets in:
The Netherlands,  Latvia, Estonia, Czech Republic, Denmark & Portugal

# Content of deliverable

For each of the producers in the member countries this presentation documents the actual manufactoring of the prototypes of the prefab renovation elements. For each manufactorer this documentation covers:

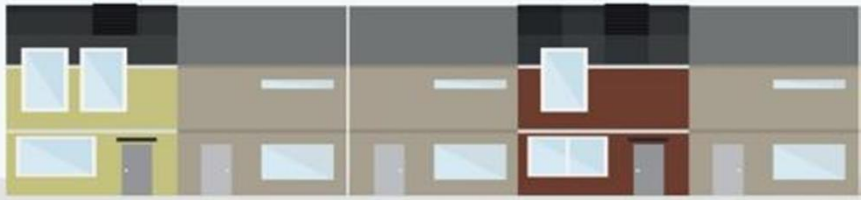
- Photos of the elements with comments about the details/components and production process
- Details about the production, e.g. amount, production time, etc.
- Results of quality control checks

MORE — CONNECT

# Czech Republic - prototypes of prefabricated modular renovation elements for the Czech market


- Antonín Lupíšek, Martin Volf, Petr Hejtmánek, Radek Brandejs, Kateřina Sojková, Jakub Spurný
- Czech Technical University in Prague, University Centre for Eenrgy efficient Buildings

# CZECH company – RD RýMAŘOV



MORE — CONNECT

- RD Rýmařov s. r. o. is the biggest producer of constructions based on light prefabrication of wood in the Czech Republic and one of the leading manufacturers of prefabricated family houses in the European Union.
- Actual production:
  - Completed family houses made of timber-based prefabricated elements (600 units per year)
  - Timber-based prefabricated panels for third parties (300 family house sets for per year)
- Through a number of activities, it strives to promote wood-based family and apartment houses and support their construction.
- The company is an active member of the Association of Building Entrepreneurs of the Czech Republic and a member of the Moravian-Silesian Wood Cluster.

RD RÝMAŘOV

# Prototyping within MORE-CONNECT in CZECHIA

MORE — CONNECT

- 1. Full scale testing of prototypes of façade elements
  - Test of layers and composition of the elements
  - Test of technology of connections of two façade elements
  - Test smart connectors and air inlets
  - Full-scale mock-up of connection of a façade element to an existing window
  - Also produced several prototypes of HVAC inlets, junction boxes for the control system and housing of sensors
- 2. Fire test of an inner corner made from prototypes of two façade elements with integrated air ducts
  - Test of internal temperatures rise under fire conditions

# FULL-SCALE testing of façade elements

MORE — CONNECT

- The testing consisted of two samples – one full scale prototype and (left) one full-scale mock-up of the upper part of a façade element (right).

# FULL-SCALE testing of façade elements

MORE — CONNECT

- Preparation for the assembly test – fixing the connection elements for air ducts

# FULL-SCALE testing of façade elements

MORE — CONNECT

- Preparation for the assembly test – fixing the connection elements for piping

# FULL-SCALE testing of façade elements

MORE — CONNECT

- Assembly test – lifting the the full façade element by crane and its shift to the mounting position above the bottom element.

# FULL-SCALE testing of façade elements

MORE — CONNECT

- Interconnection of wiring between panels

# FULL-SCALE testing of façade elements

MORE — CONNECT

- Navigation of the hanging element to its position

# FULL-SCALE testing of façade elements

MORE — CONNECT

- Interconnection of air ducts

# FULL-SCALE testing of façade elements

MORE — CONNECT

- Letting the wall element down to its position on the anchors

# FULL-SCALE testing of façade elements

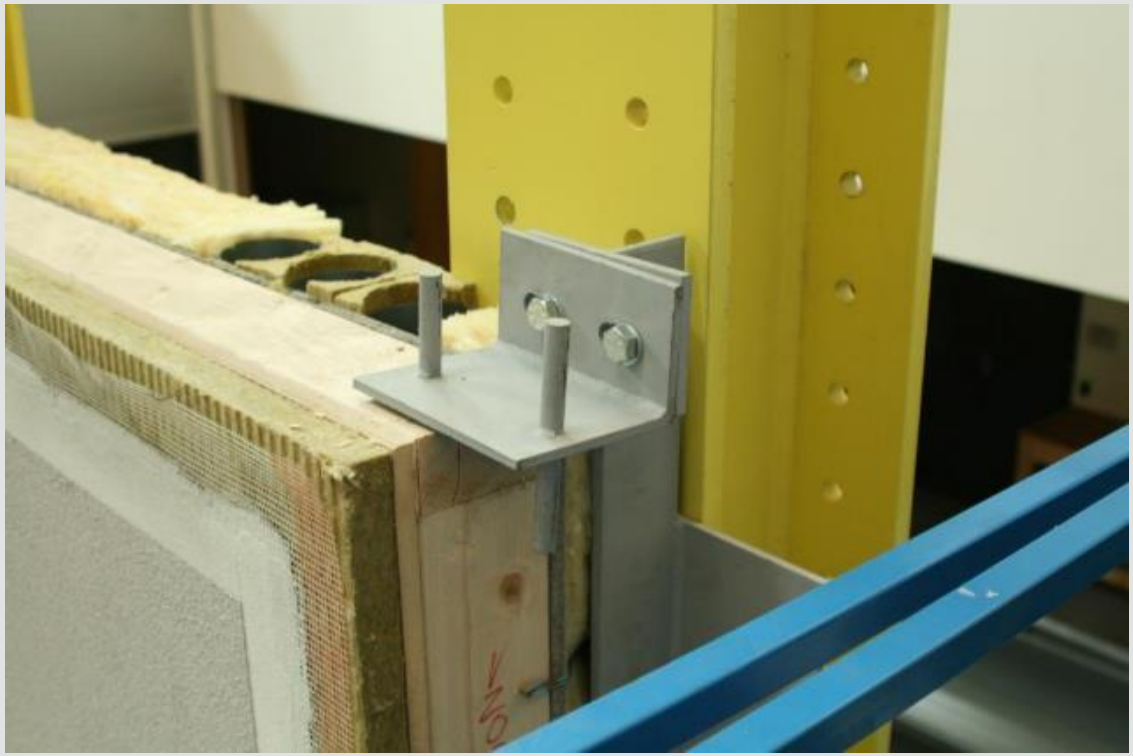
MORE — CONNECT

- Final position

# FULL-SCALE testing of façade elements

MORE — CONNECT

- Fixing the top anchor



# FULL-SCALE testing of façade elements

MORE — CONNECT

- Testing of prototypes of air inlets, custom made boxes for control systems and mock-up of an existing window opening (testing of airtight connection).

# PROTOTYPES FOR TESTED UNDER FIRE CONDITIONS

MORE — CONNECT

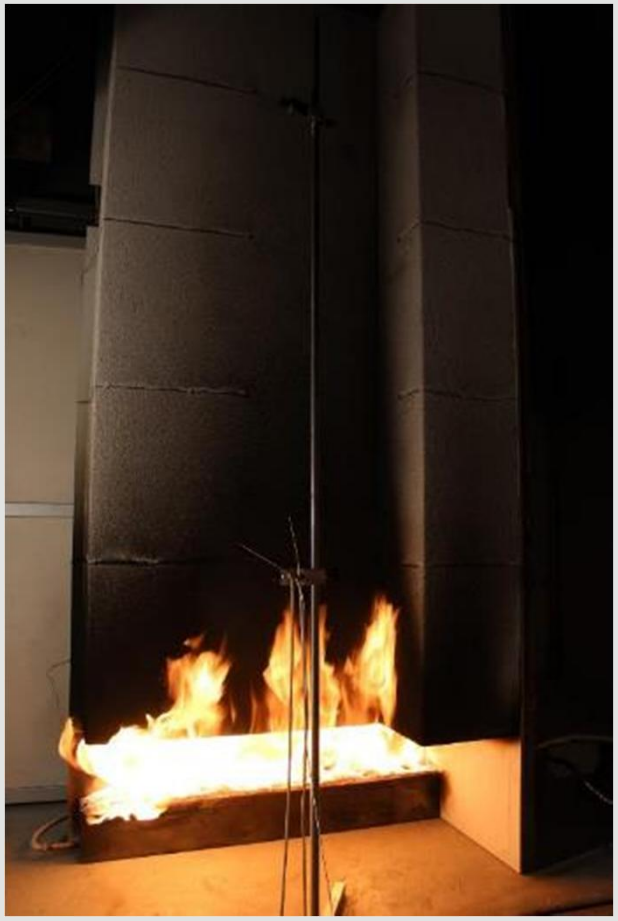
- **Fire risks of MC panel**
  - fire spread on the facade
  - fire spread through piping
  - use of combustible materials

- **MC panel can be assumed as ETICS**
  - fire test according to ČSN ISO 13785-1
  - intermediate reaction to fire facade test
  - requirements:
    - no fire spread above 0,5 m
    - temperature at 0,5 m below 350 °C

# PROTOTYPES FOR TESTED UNDER FIRE CONDITIONS

MORE — CONNECT

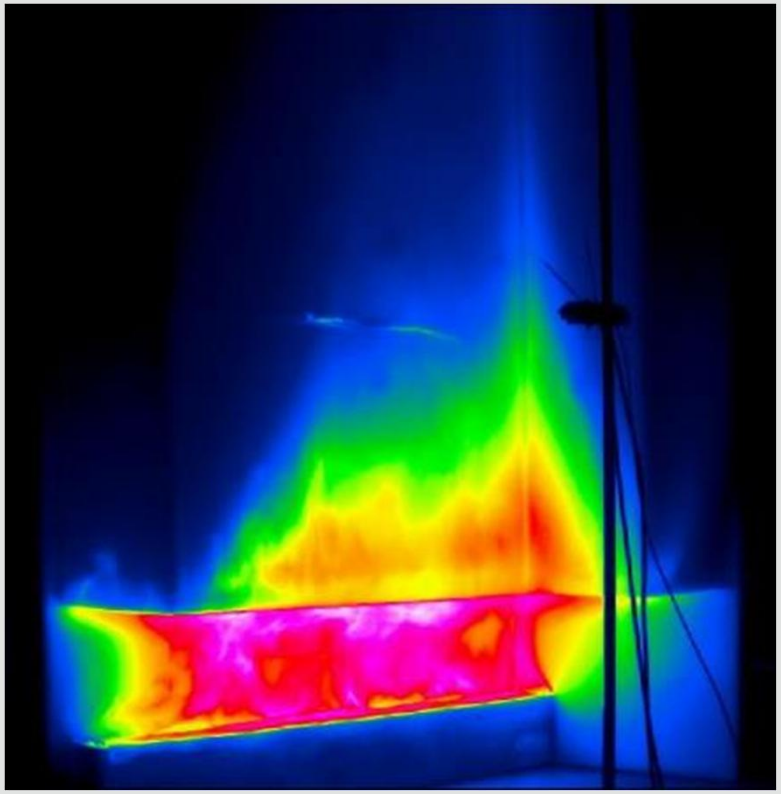
- Test in FireLAB



# PROTOTYPES FOR TESTED UNDER FIRE CONDITIONS

MORE — CONNECT

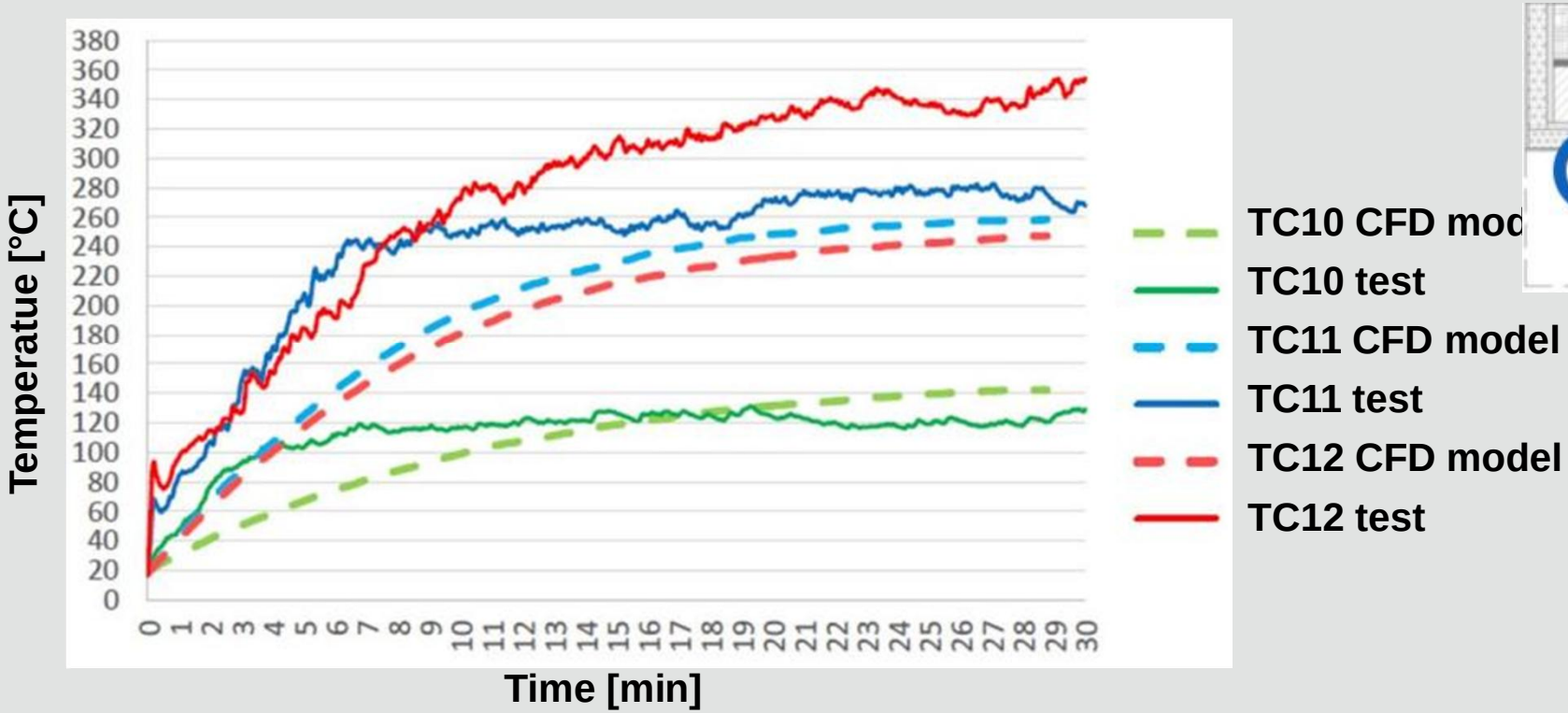
- Test in FireLAB

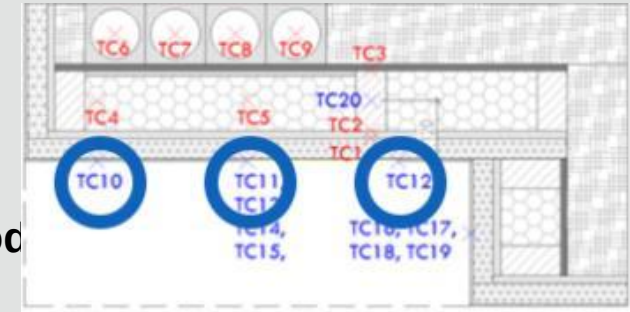


# PROTOTYPES FOR TESTED UNDER FIRE CONDITIONS

MORE — CONNECT

- Surface temperatures at 0,5 m

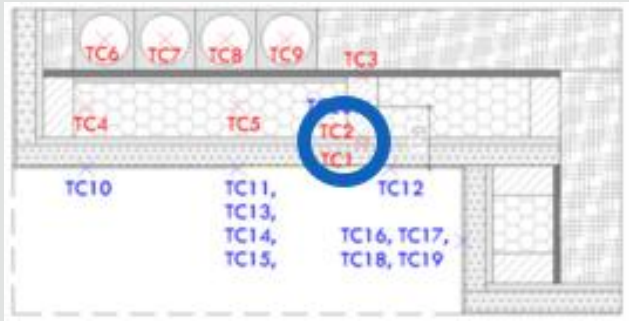


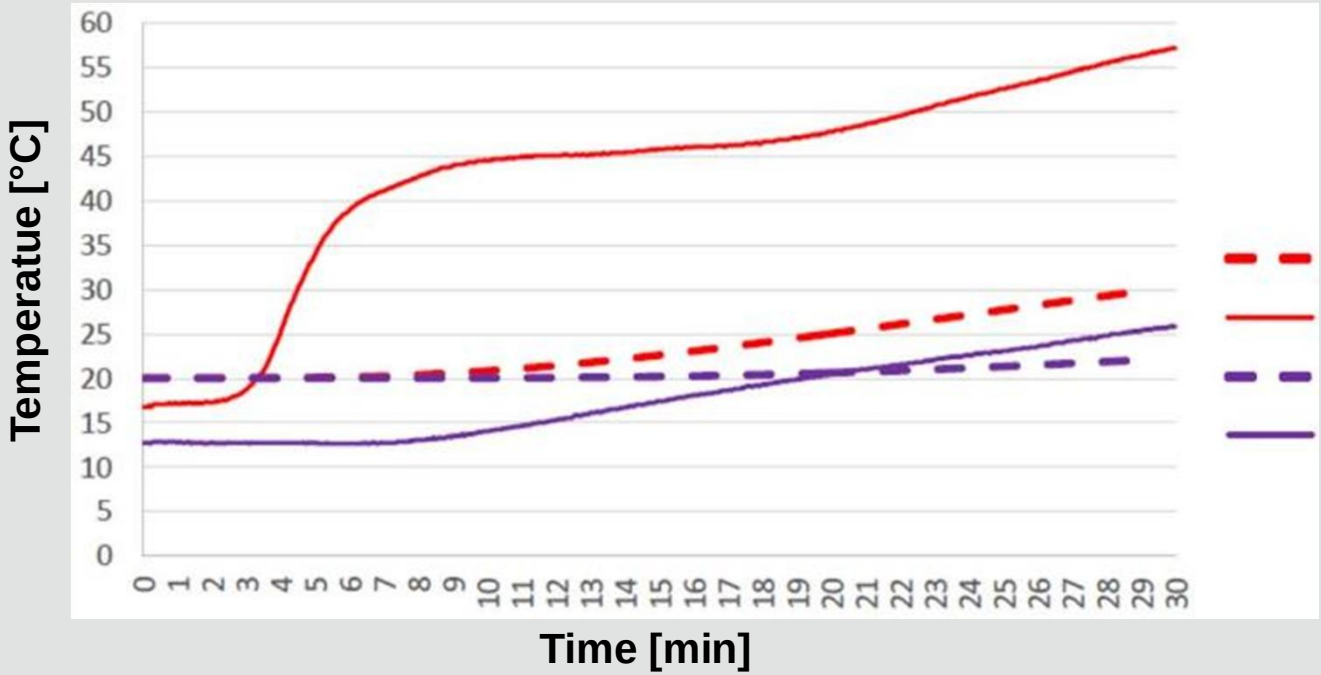



# PROTOTYPES FOR TESTED UNDER FIRE CONDITIONS

MORE — CONNECT

- Inside temperatures at 0,5 m



# PROTOTYPES FOR TESTED UNDER FIRE CONDITIONS

MORE — CONNECT

- Conclusions:
  - temperature at 0,5 m below 300 °C
  - temperature in pipes around 20 °C
  - no damage of the timber frame
  - --> no fire risk in Czech buildings up to 5 storeys

MORE—CONNECT

# Denmark - prototypes the MORE-CONNECT renovation elements in Denmark

- Ove Mørck, CENERGIA at Kuben Management, Stephan Olesen, Innogie and Finn Christensen, Invela.

In Denmark two products have been further developed in the MORE-CONNECT project:

1. The company Innogie has developed a roof consisting of solar cell panels

2. The company Invela has developed a system for finishing and decoration of externally insultated external walls carried out by a robot.

# Innogie - Denmark

Innogie is a company specializing in innovative use of solar energy with special attention to power adequacy, design and profitability for the consumer. Innogie is a R&D company in the use of different technologies and since establishment in 2010 have been working with the use and implementation of solar power to eliminate the use of fossil fuels for the heating, cooling and power generation of a household.

Within the More-Connect project Innogie has developed several prototypes of its Solar Energy Roof - in particular concerning methods of mounting and flashing details to create a customer and installer driven plug-and-play solution.

# The Innogie solar cell roof

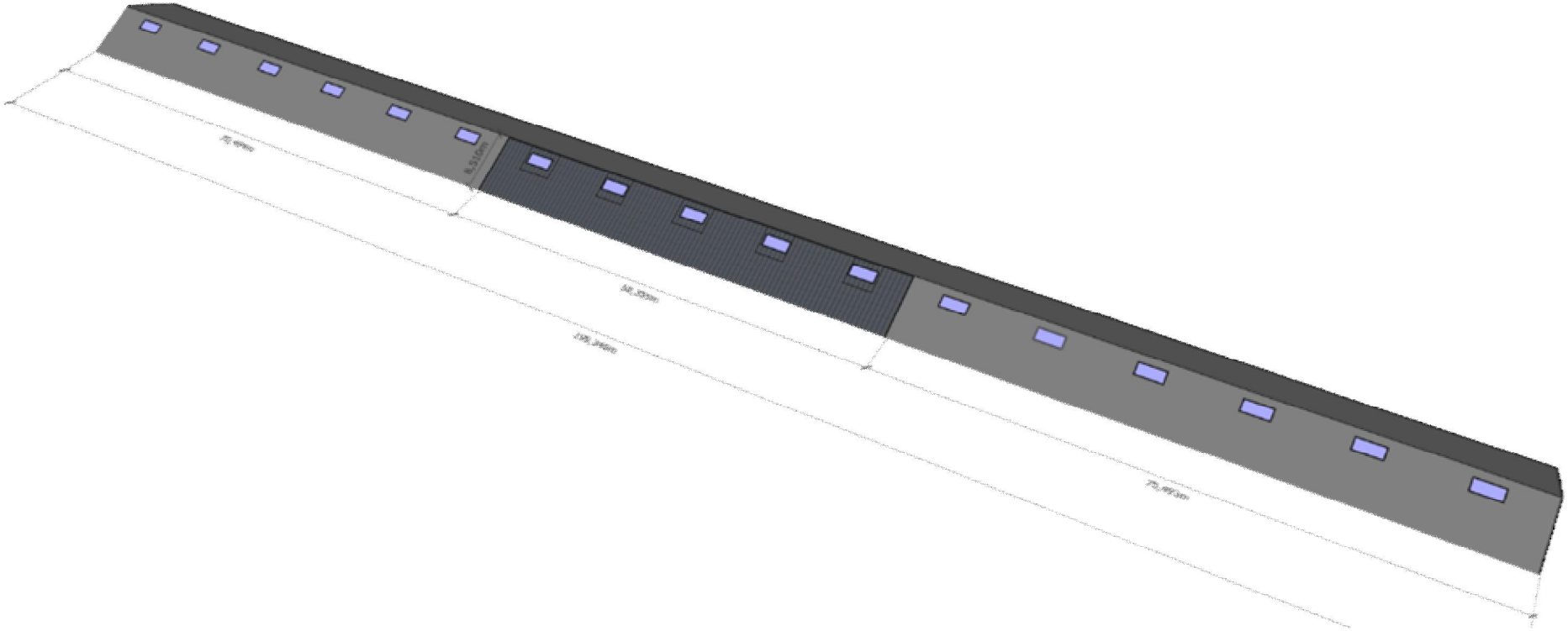
MORE — CONNECT

# Innogie PV-prototype installation in Haderslev, DK

MORE — CONNECT

# Korsløkkeparken, Odense

- Active area covers approx. 450 m2 (installed together with new fiber cement sheets)



# Invela - Denmark

Invela is a small company (SME), which mainly works in new innovation development projects within the building sector. With a large network of global companies and partners we create the right possibilities for new building materials or new building projects in total.

Invela has through its work with developing a new solution for prefab manufacturing of façade elements gone from thoughts around the traditional factory prefab solutions using different types of materials herein to the generating of a new company called Robot At Work. Robot At Work aims at getting small intelligent robot solutions on the building site and collaborating with the craftsmen doing the actual work precise and with less hazards involved.

# The Invela robot development work

The new building solutions are being produced with our Robot At Work solutions and most importantly by using a tablet graphic user interface (GUI) for working onsite with small robots.

When developing the robot solution for onsite work, we found it very important for the craftsmen onsite to be able to control the solution with great ease and without the need of much training. Therefor a tablet control interface was essential and was developed alongside the whole development of the actual 3D façade solution to be tested in More-Connect.

This GUI is now the key product of Robot At Work and can control and be used in more and more applications for robotics. Described in short it allows the building constructors to generate small working packages from the drawings of the building and to postprocess them through the “black box” in Robot At Work, and then deliver these packages for onsite work and application with the robot solution at hand. This is very unique and one of a kind software for construction work.

Below some photos of the work that has been performed in the developing process and tested onsite in some cases is shown.

# Milling with high precision (1 of 3):

# Milling with high precision (2 of 3):

# Milling with high precision (3 of 3):

# Rendering with spraygun and pump and 3D printing on a wall (1 of 2):

# Rendering with spraygun and pump and 3D printing on a wall (1 of 2):

# Test of robot applied glass fiber reinforced mortar

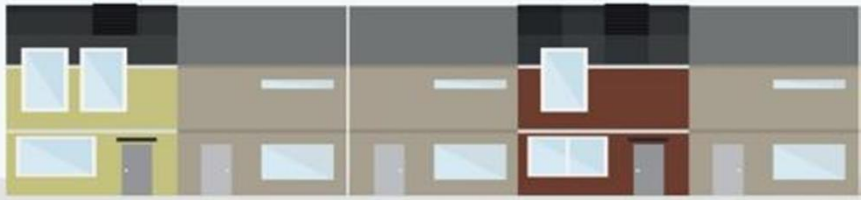
Re-inforcing the first layer af mortar with glass fiber

Top mortar as a finish layer

# Glass fiber reinforcement of an 8 meter facade

# Complete prototype of insulated wall with robot made decoration and robot applied finishing.

MORE — CONNECT

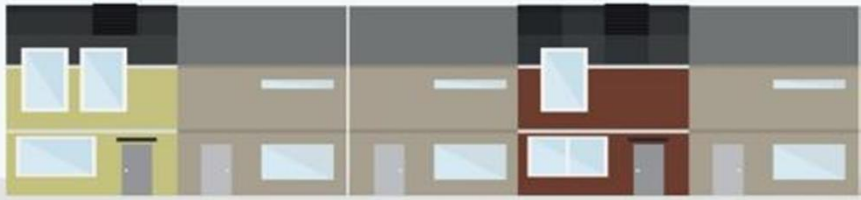


# Estonia - prototypes the MORE-CONNECT renovation elements in Estonia


- Targo Kalamees, Peep Pihelo, Kalle Kuusk: Tallinn University of Technology
- Raivo Külaots, Sven Mats, Leho Varik: AS Matek


Pilot object: TUT dormitory

# Estonian company - AS MATEK



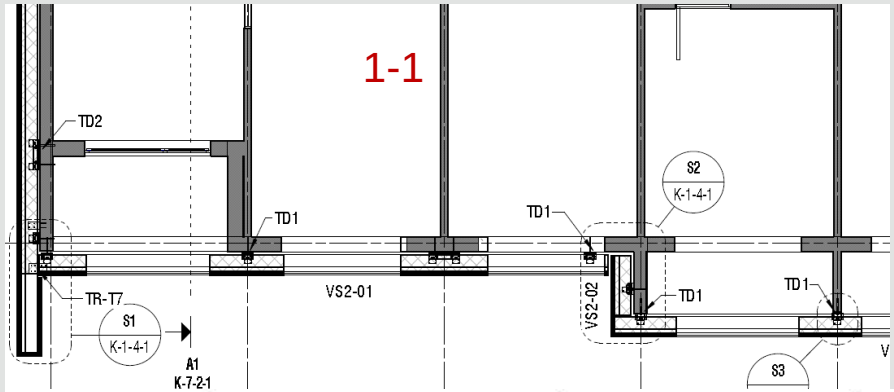
MORE — CONNECT

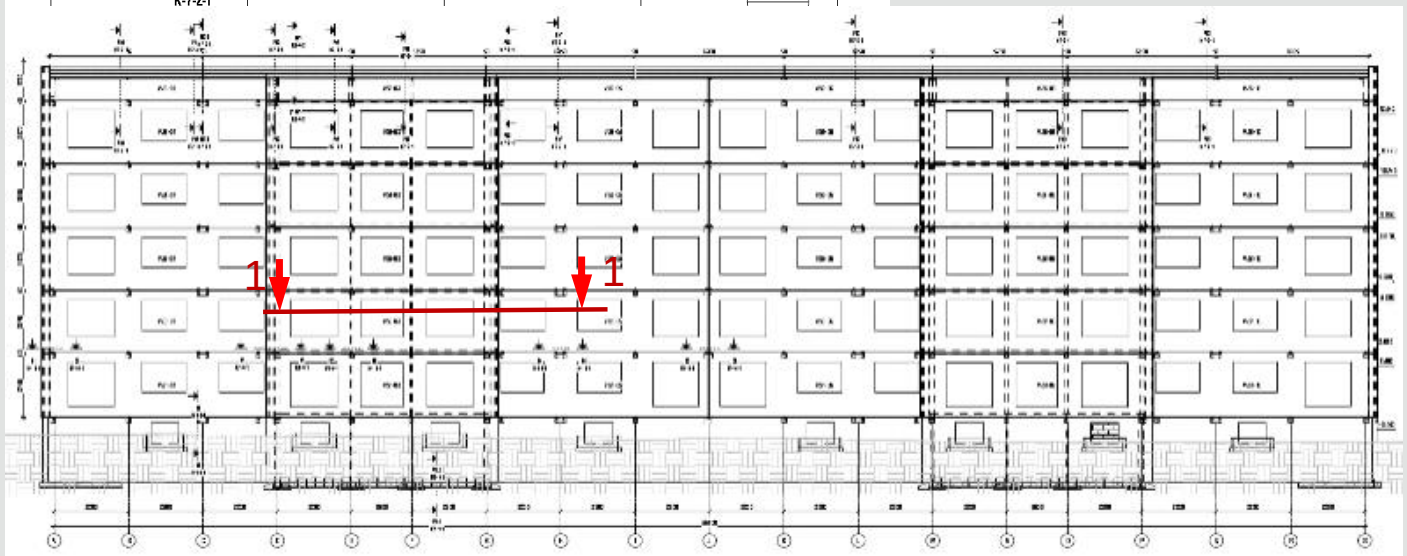
- AS Matek is the oldest and most experienced off-site built timber frame  element house and modular producer in Estonia. Matek´s main business focus is on multi-storey houses, kindergartens, schools and integrated living environments of elements and modules with low energy consumption.
- To achieve the best result, we have organised our work on the principle that rules out errors and deviations -every employee has the responsibility to double-check the previous and just performed operation
- Each house is carefully designed, taking into consideration site - specific natural conditions

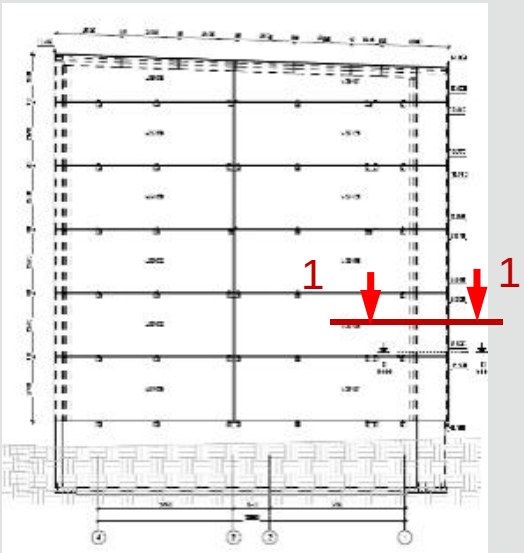
# Modules in Estonian Pilot

MORE — CONNECT

- Dimensions ~9.3 x 2.7m (3 windows)



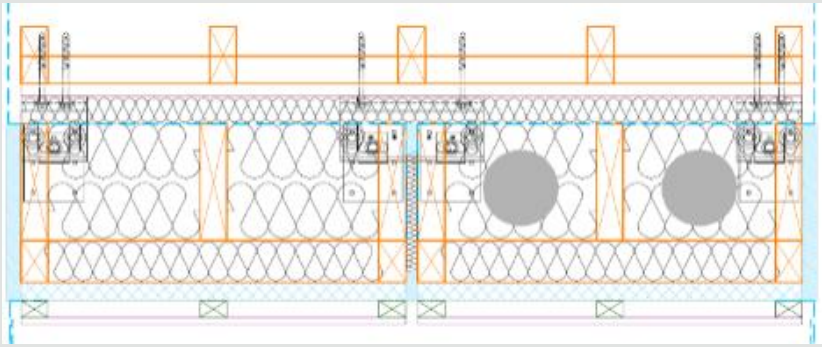



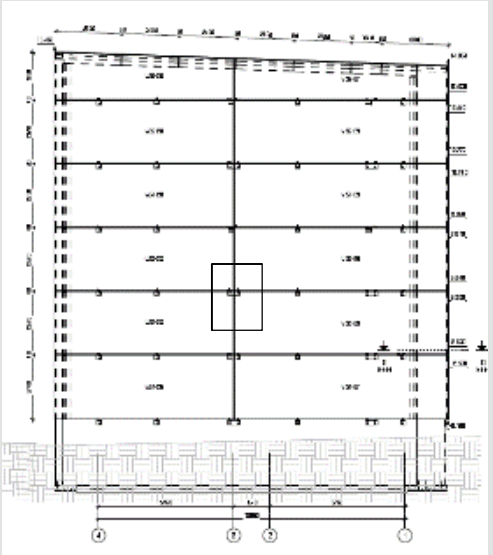



# Development basic modular elements for facades

MORE — CONNECT

- Objectives to test:
  - design and construction of panels
  - installation of vent. duct into panel
  - connections of panels (hor., vert)
  - fixing of panels to wall
  - mounting of panels (incl. vent. modules)
  - airtightness of panel and connections
- Realization in factory (Matek)
  - dimensions ~0.6 x 1.1m (w, w.o vent)
  - $U$ = 0.10 W/(m$^2$K)

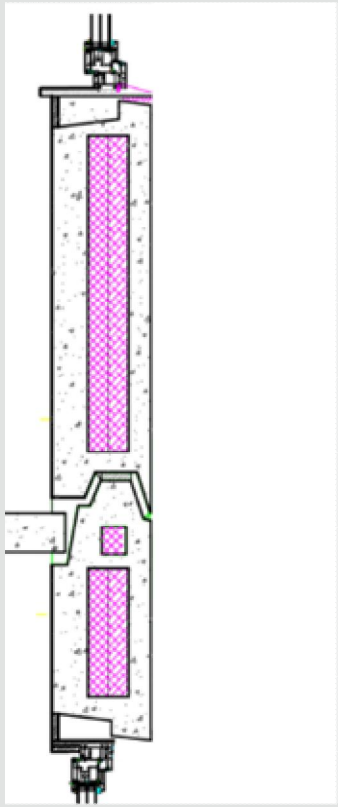


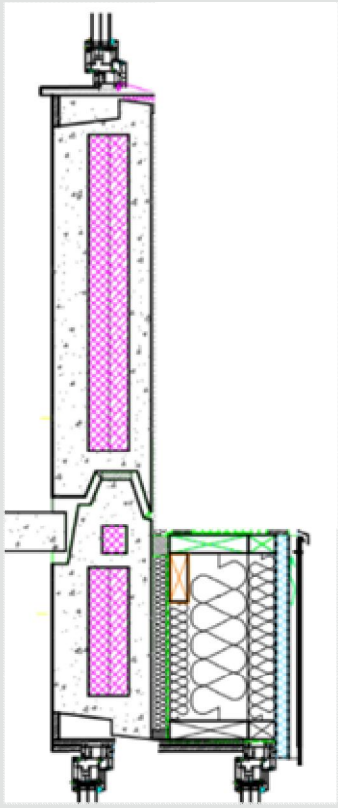


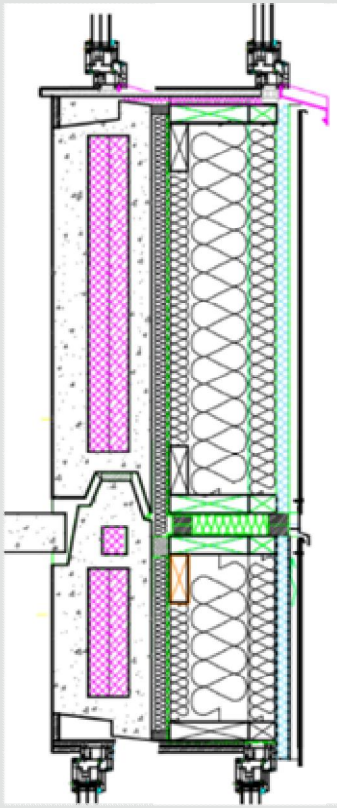
# Development basic modular elements for facades

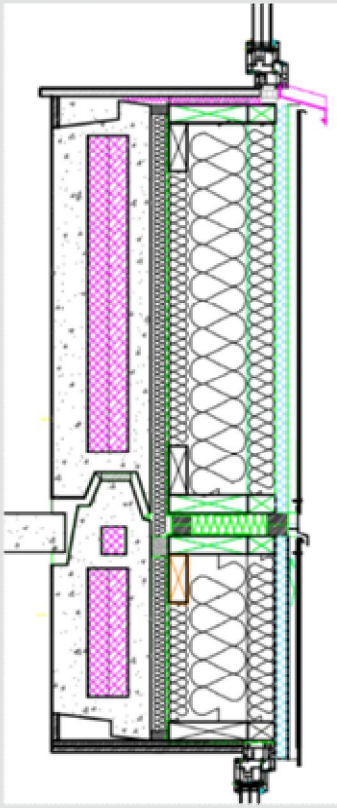
MORE — CONNECT

- **Design** and construction of panels



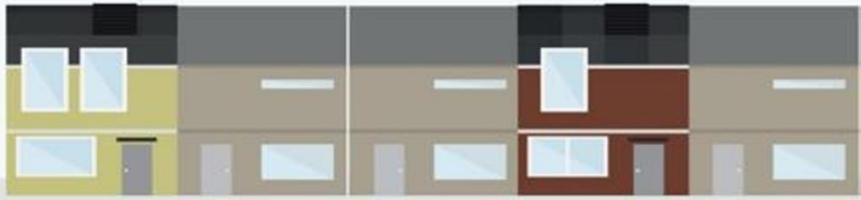




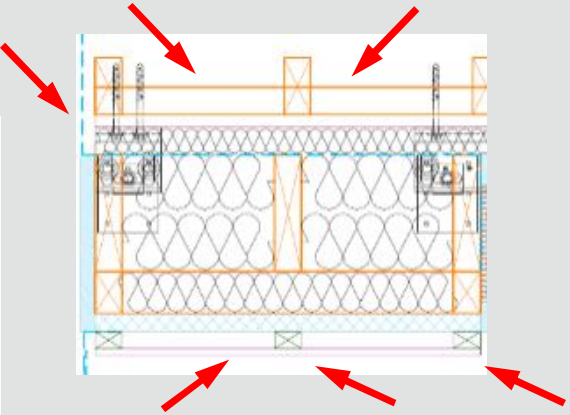


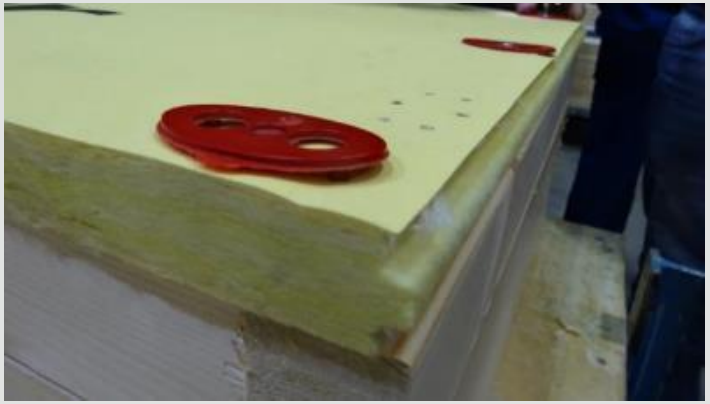
# Development basic modular elements for facades

MORE — CONNECT



- Design and **construction** of panels

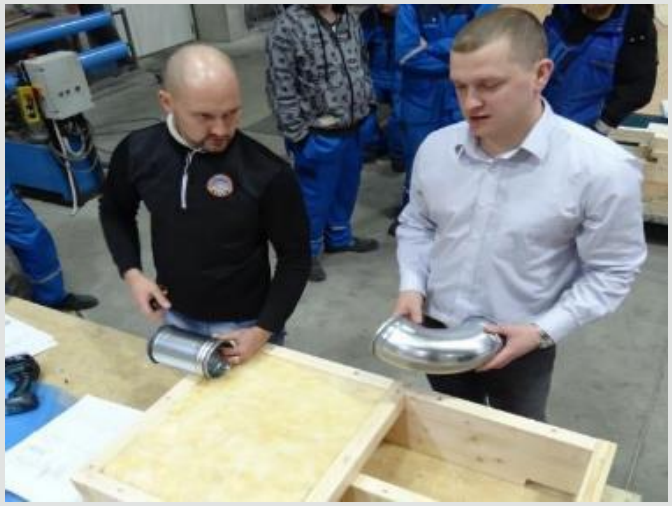


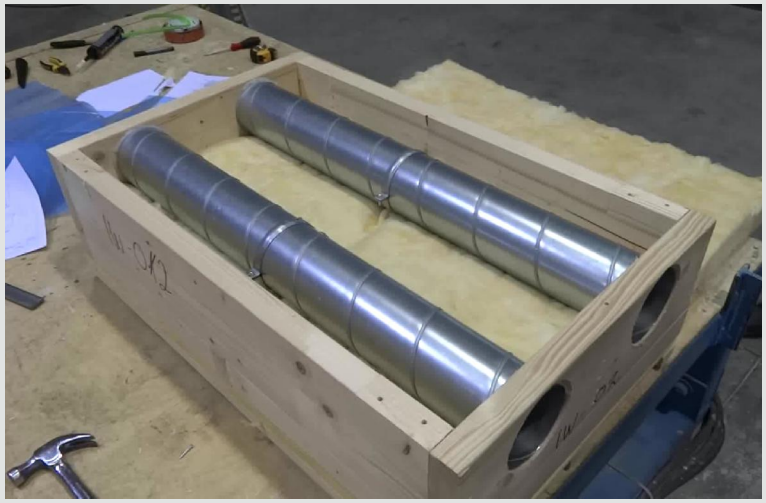


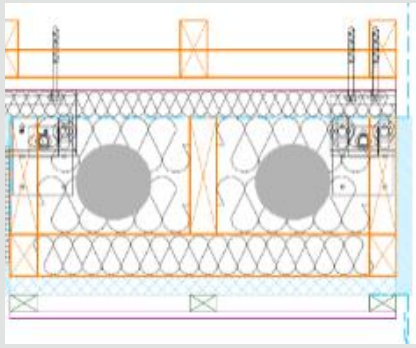
# Development basic modular elements for facades

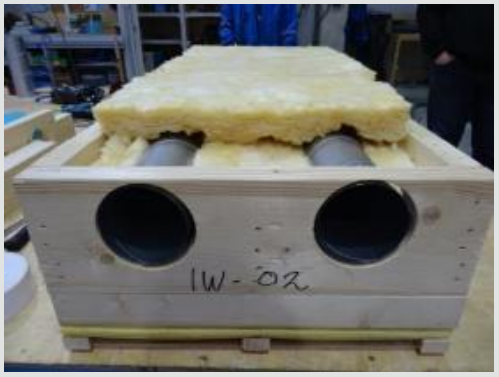
MORE — CONNECT

- Installation of **ventilation duct into panel**





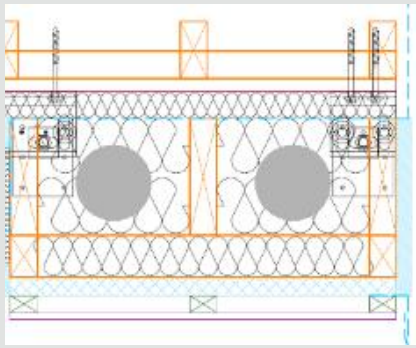




# Development basic modular elements for facades

MORE — CONNECT

- Connectors of **ventilation ducts**



# Development basic modular elements for facades

MORE — CONNECT

- Connections of panels (hor., vert): **raintightness**
- We affray:
  - Rendered, undrained, unventilated facade

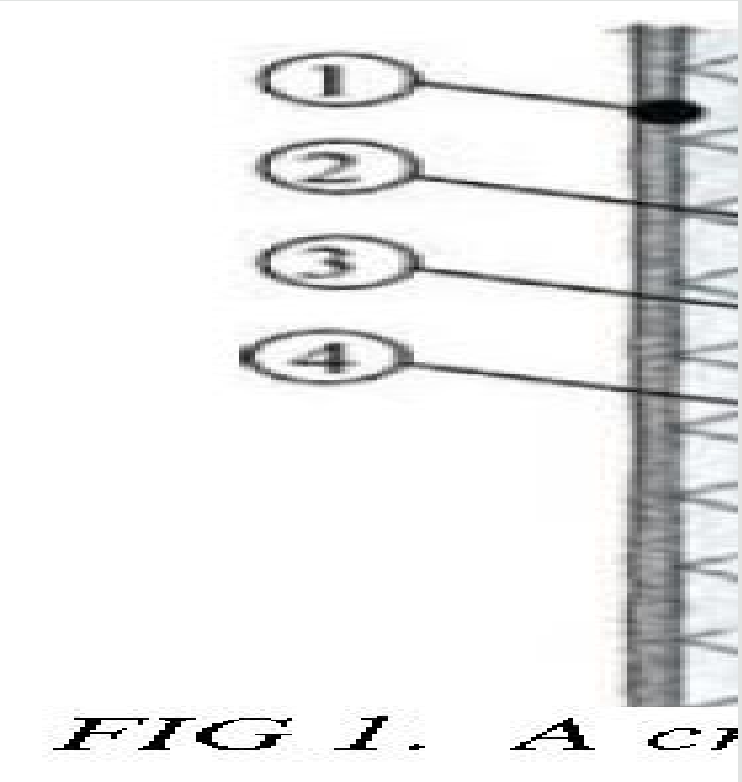
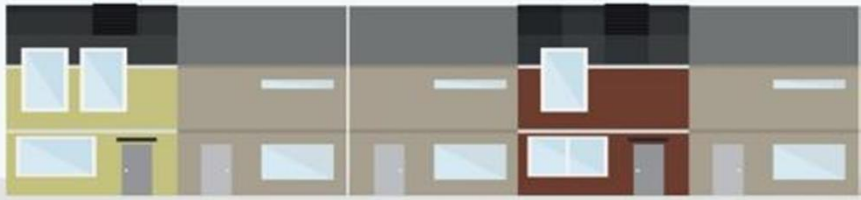


*FIG 3. Microbial growth on the outer gypsum board, caused by water leaking in through a defective connection. Picture from the inside.*

# Development basic modular elements for facades

MORE — CONNECT

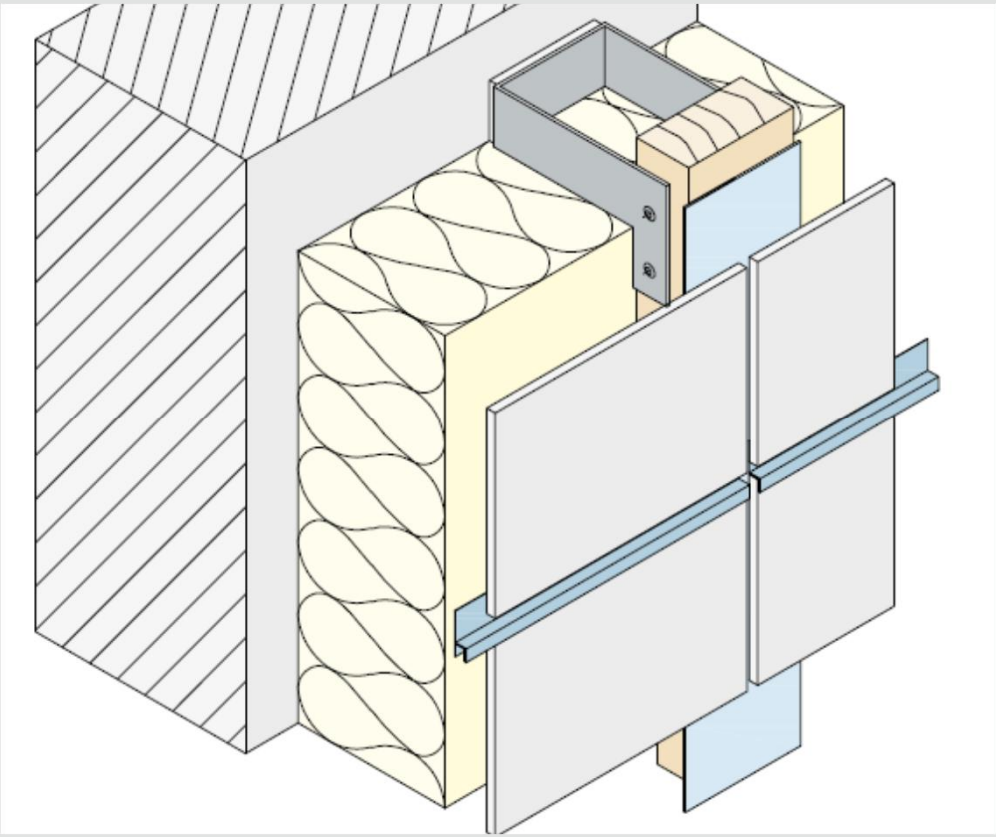


- Connections of panels (hor., vert): **raintightness**
- We affray:
  - Rendered, undrained, unventilated fa
  - Open joints in ventilated facade

# Development basic modular elements for facades

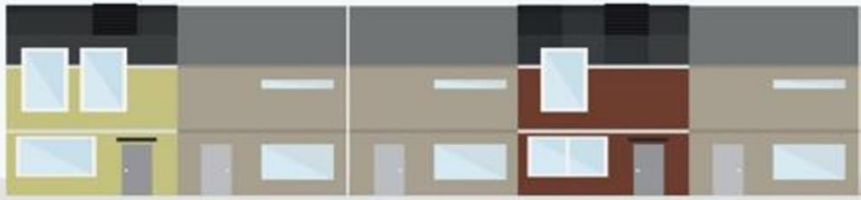
MORE — CONNECT

- Connections of panels (hor., vert): **raintightness**
- **Our design solution**

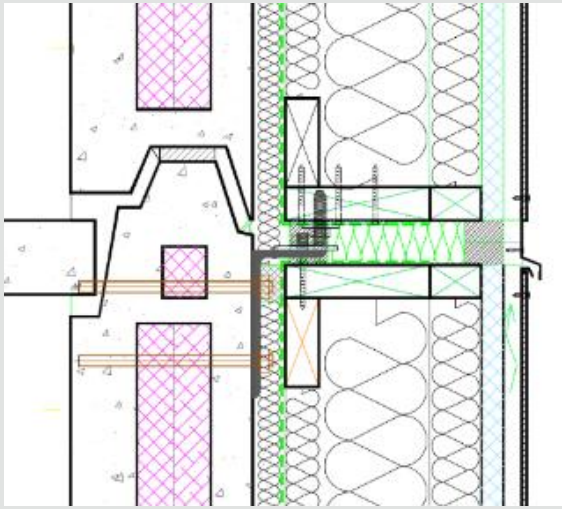


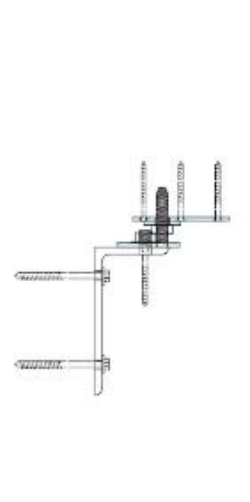
# Development basic modular elements for facades

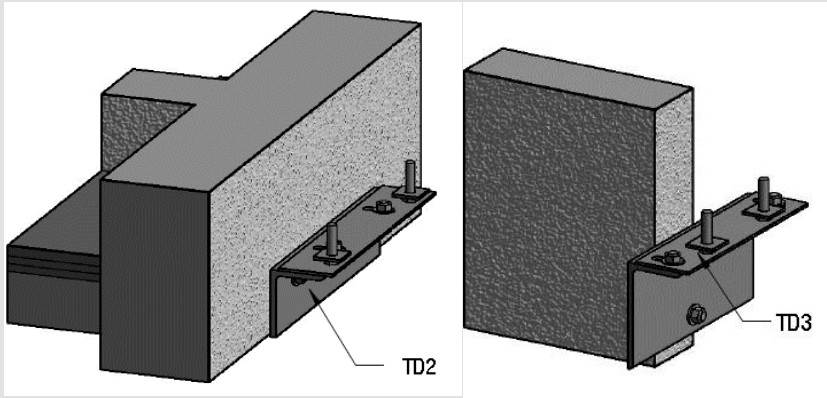
MORE — CONNECT



- **3D** movable connectors for panels







# Development basic modular elements for facades

MORE — CONNECT

- Installation of panels to wall

MORE — CONNECT

# LATVIA - prototypes of prefabricated modular renovation elements for the LATVIAN DEMO BUILDING


- Anatolijs Borodinecs, Riga, Technical University, Latvia
- Martins Klauzs, ZTC , Latvia

# LATVIAN company
# Zemgales tehnoloģiskais centrs Ltd.

MORE — CONNECT

- Zemgales tehnoloģiskais centrs (ZTC), founded in 1991, is the most experienced prefabricated wood house company in Latvia
- Mission of ZTC is to provide effective and sustainable building solutions
- Active member of Latvian Wood Construction Cluster

# LATVIAN company
# Zemgales tehnoloģiskais centrs Ltd.

MORE — CONNECT

- Design, prrefabrication and construction of:
  - Single family houses
  - Apartment houses
  - Public buildings

- Main markets: Sweden, Norway, Denmark, The Netherlands, France, Latvia

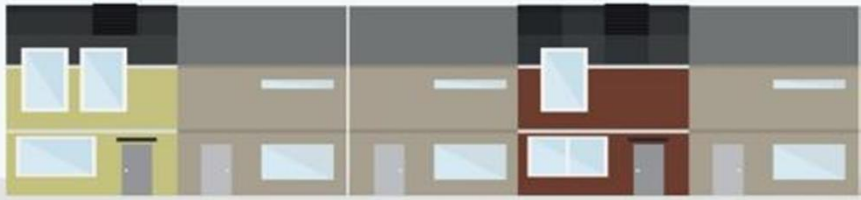
# Prototyping in Latvia

MORE — CONNECT

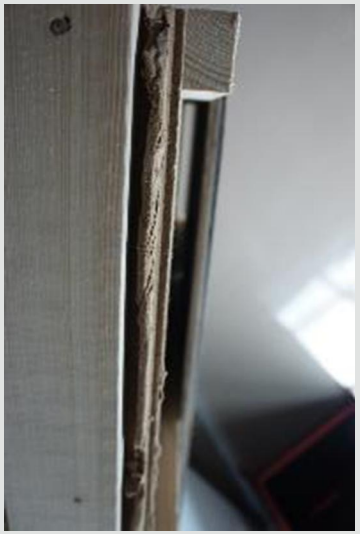
- Test of layers and composition of the elements;
- Test of technology of connections of two façade elements;
- Selection of materials;
- Development and demonstration of facades demonstration panels.

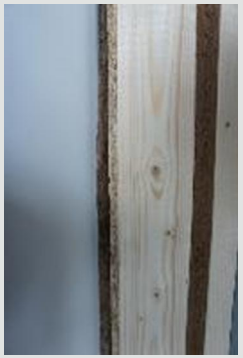
# Demo samples of façade elements

MORE — CONNECT



Demo samples were produced to test their durability and to evaluate possible installation solutions;





# Testing of façade elements

MORE — CONNECT

Evaluation of joints sealing options and test of panel connections

MORE — CONNECT

# Netherlands - prototypes and real life realization of prefabricated modular renovation elements for the Netherlands buildings Zoetermeer Graaf Jan Straat (row house, one piece) and Arnhem Presikhaaf (appartment building, 32 appartments)


- Ronald Roovers, John van Oorschot, Hogeschool Zuid
- Jan Kamphuis, BJW b.v.
- Bart Voortman, Jan Nijmeier, Willem Haase, Webo b.v.

# Netherlands company BJW Wonen b.v.

MORE — CONNECT

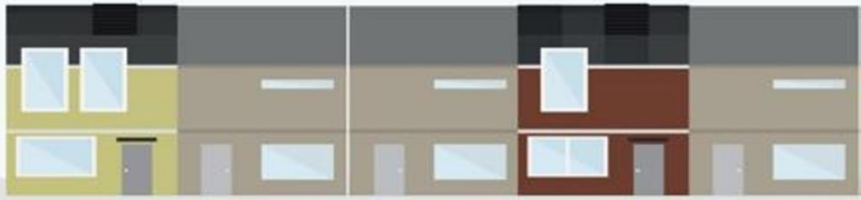
- BJW Wonen b.v is founded in 2014 with the aim of developing solutions for deep retrofit renovation that exceed the level of NZEB. BJW develops integral solutions including roof, wall and full electric solution for heating, hot water, ventilation including monitoring and generating electricity
- BJW develops integral solutions including roof, wall and full electric solution for heating, hot water, ventilation including monitoring and generating electricity. Mission of BJW is to make deep retrofit renovations affordable for social housing companies.
- Active member of Stroomversnelling. Which focus is on developing deep retrofit solution for the Dutch market

# Prototyping in Netherlands

MORE — CONNECT

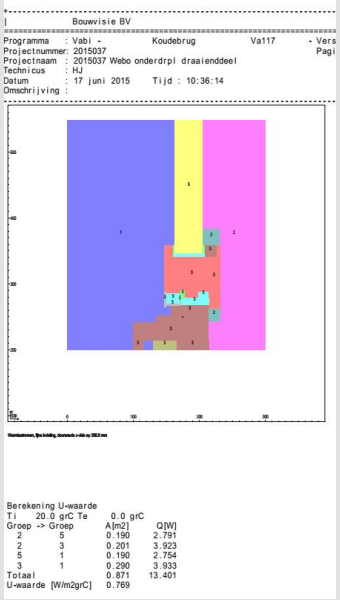
- Test and composition of windows and doors
- Test of layers and composition of the elements;
- Test of technology of connections of two façade elements;
- Selection of materials;
- Development and demonstration of facades demonstration panels.
  - Zoetermeer Graaf Jan straat
  - Arnhem Presikhaaf

# Demo and test of windows



MORE — CONNECT

Demo samples were produced to test their durability and performance and to evaluate possible installation solutions, real life production and realization Presikhaaf;



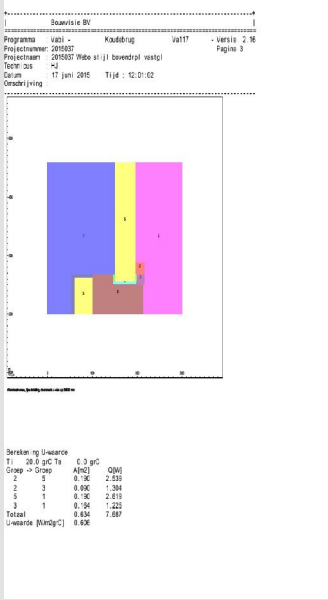
Bouwvisie BV

Programma : Vabi - Koudebrug Va117 - Vers
Projectnummer: 2015037 Pagi
Projectnaam : 2015037 Webo onderdrpl draaienddeel
Technicus : HJ
Datum : 17 juni 2015 Tijd : 10:36:14
Omschrijving :

Berekening U-waarde
Ti 20.0 grC Te 0.0 grC

| Groep -> | Groep | A[m2] | Q[W] |
|---|---|---|---|
| 2 | 5 | 0.190 | 2.791 |
| 2 | 3 | 0.201 | 3.923 |
| 5 | 1 | 0.190 | 2.754 |
| 3 | 1 | 0.290 | 3.933 |
| Totaal | | 0.871 | 13.401 |

U-waarde [W/m2grC] 0.769



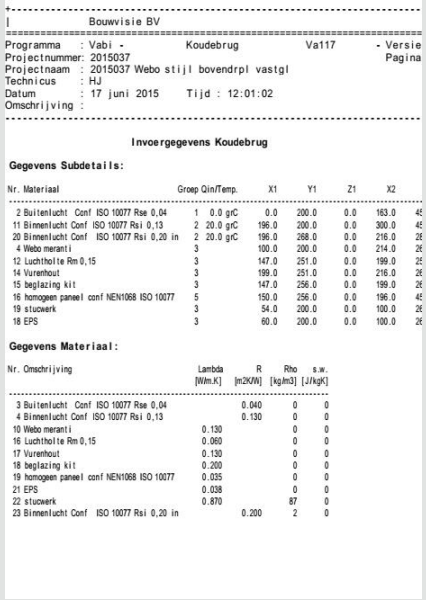
Bouwvisie BV

Programma Vabi - Koudebrug Va117 - Versie 2.16
Projectnummer: 2015037 Pagina 3
Projectnaam 2015037 Webo stijl bovendrpl vastgl
Technicus HJ
Datum 17 juni 2015 Tijd : 12:01:02
Omschrijving

Berekening U-waarde
Ti 20.0 grC Te 0.0 grC

| Groep -> | Groep | A[m2] | Q[W] |
|---|---|---|---|
| 2 | 5 | 0.190 | 2.839 |
| 2 | 3 | 0.890 | 1.384 |
| 5 | 1 | 0.190 | 2.619 |
| 3 | 1 | 0.194 | 1.225 |
| Totaal | | 0.634 | 7.887 |

U-waarde [W/m2grC] 0.636



Bouwvisie BV

Programma : Vabi - Koudebrug Va117 - Versie
Projectnummer: 2015037 Pagina
Projectnaam : 2015037 Webo stijl bovendrpl vastgl
Technicus : HJ
Datum : 17 juni 2015 Tijd : 12:01:02
Omschrijving :

**Invoergegevens Koudebrug**

**Gegevens Subdetails:**

| Nr. | Materiaal | Groep | Qin/Temp. | X1 | Y1 | Z1 | X2 |
|---|---|---|---|---|---|---|---|
| 2 | Buitenlucht Conf ISO 10077 Rse 0,04 | 1 | 0.0 grC | 0.0 | 200.0 | 0.0 | 163.0 |
| 11 | Binnenlucht Conf ISO 10077 Rsi 0,13 | 2 | 20.0 grC | 196.0 | 200.0 | 0.0 | 300.0 |
| 20 | Binnenlucht Conf ISO 10077 Rsi 0,20 in | 2 | 20.0 grC | 196.0 | 268.0 | 0.0 | 216.0 |
| 4 | Webo meranti | 3 | | 100.0 | 200.0 | 0.0 | 214.0 |
| 12 | Luchtholte Rm 0,15 | 3 | | 147.0 | 251.0 | 0.0 | 199.0 |
| 14 | Vurenhout | 3 | | 199.0 | 251.0 | 0.0 | 216.0 |
| 15 | beglazing kit | 3 | | 147.0 | 256.0 | 0.0 | 199.0 |
| 16 | homogeen paneel conf NEN1068 ISO 10077 | 5 | | 150.0 | 256.0 | 0.0 | 196.0 |
| 19 | stucwerk | 3 | | 54.0 | 200.0 | 0.0 | 100.0 |
| 18 | EPS | 3 | | 60.0 | 200.0 | 0.0 | 100.0 |

**Gegevens Materiaal:**

| Nr. | Omschrijving | Lambda [W/m.K] | R [m2K/W] | Rho [kg/m3] | s.w. [J/kgK] |
|---|---|---|---|---|---|
| 3 | Buitenlucht Conf ISO 10077 Rse 0,04 | | 0.040 | 0 | 0 |
| 4 | Binnenlucht Conf ISO 10077 Rsi 0,13 | | 0.130 | 0 | 0 |
| 10 | Webo meranti | 0.130 | | 0 | 0 |
| 16 | Luchtholte Rm 0,15 | 0.060 | | 0 | 0 |
| 17 | Vurenhout | 0.130 | | 0 | 0 |
| 18 | beglazing kit | 0.200 | | 0 | 0 |
| 19 | homogeen paneel conf NEN1068 ISO 10077 | 0.035 | | 0 | 0 |
| 21 | EPS | 0.038 | | 0 | 0 |
| 22 | stucwerk | 0.870 | | 87 | 0 |
| 23 | Binnenlucht Conf ISO 10077 Rsi 0,20 in | | 0.200 | 2 | 0 |

Windows are designed, tested and realized for Passive House Level performance.

# Demo and test of elements

MORE — CONNECT

Demo samples were produced to test their durability and performance and to evaluate possible installation solutions, real life production and realization Presikhaaf and Zoetermeer;

Arnhem Presikhaaf

testing of connection new wall elements on to existing construction

Afbeelding 5.3.5:
proefkast vullen met artificiële rook bij overdruk 50 Pa

Afbeelding 5.3.6:
artificiële rook verlaat proefkast

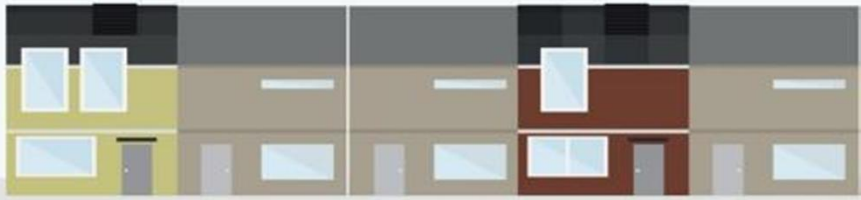
testing of airtightness of ducts through wall elements

Zoetermeer Graaf Janstraat

Elements are designed, tested and realized for Passive House Level performance.

# Demo and test of elements

MORE — CONNECT

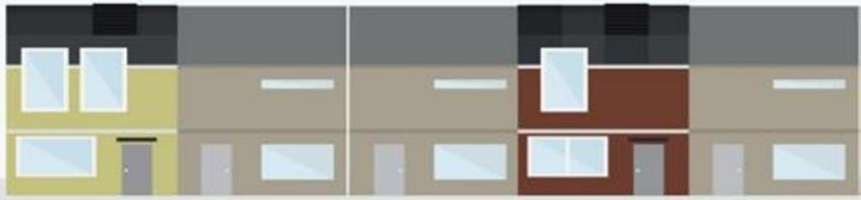


Demo samples were produced to test their durability and performance and to evaluate possible installation solutions;

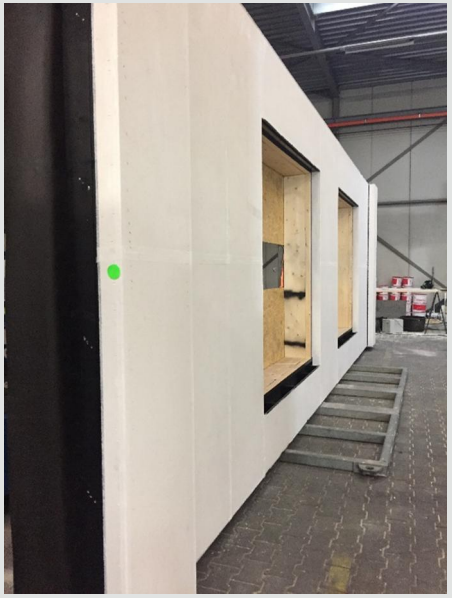
We bought 4 tunnel elements to represent the renovation excisting walls which will have the new elements attached.

# Demo and test of elements

MORE — CONNECT



Demo samples were produced to test their durability and performance.



Different element compositions are tested on fire resistance, air and water tightness including connections between elements.

The latest development is timberframe elements without EPS reaching Passive House Level of insulation and airtightness .

# Demo and test of blowerdoor quality control

MORE — CONNECT

The internal quality control is tested as well

Elements are designed, tested and realized for Passive House Level performance therefore the test set up must be better then Passive House Level.

The first test runs the leakage of the test set up was more then then the elements and windows to be tested

**Afbeelding 5.1.1:**
verbinding proefkast

**Afbeelding 5.1.2:**
afronding regelwerk gevelelement

**Afbeelding 5.2.1:**
afgeplakte verbinding proefkast

**Afbeelding 5.2.2:**
afgeplakte verbinding proefkast

# Testing of crane support

MORE — CONNECT

Wall elements are heavy, craning the elements could bring damage and therefore this needed testing

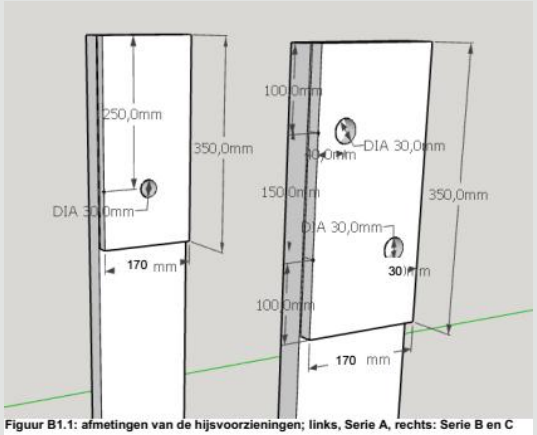
**Bijlage 2: Individuele resultaten testen**

**Tabel B2.1** Testresultaten hijsvoorziening, Serie A: 1 gat, gelijmd

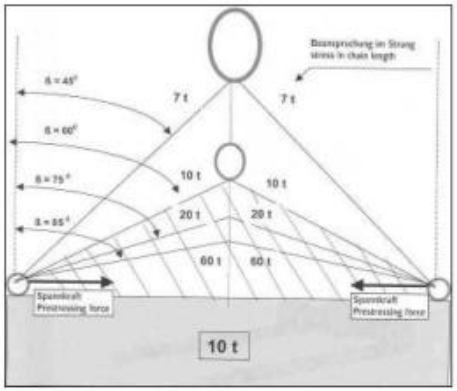
| | $F_{max,opsluitbank}$ [N] | $F_{max,\ trekbank}$ [N] | $F_{max,\ totaal}$ [N] | $F_{max}$ [kg] |
|---|---|---|---|---|
| A1 | 34.900 | 33.660 | 34.900 | 3.558 |
| A2 | 34.300 | 29.330 | 34.300 | 3.496 |
| A3 | 33.620 | 40.100 | 40.100 | 4.088 |
| A4 | 33.380 | 40.000 | 40.000 | 4.077 |
| A5 | 32.880 | 38.790 | 38.790 | 3.954 |
| A6 | 33.140 | 38.030 | 38.030 | 3.877 |
| A7 | 33.260 | 37.180 | 37.180 | 3.790 |
| A8 | 33.340 | 36.160 | 36.160 | 3.686 |
| | | | gemiddeld | 3.816 kg |
| | | | standdev. | 224 kg |
| | | | fractielfactor k, volgens NEN-EN 1990, tabel D1 | 2,00 |
| | | | 5% onderschrijdingskans | 3.368 kg |
| WLL | | | x/5 | **673,5** kg |

Example of testresults.

3 different approaches where tested




Figuur B1.1: afmetingen van de hijsvoorzieningen; links, Serie A, rechts: Serie B en C




Figuur 1. Verhoging van de belasting op de hijsvoorziening door hijsen onder een hoek

assembly equipment

Opstelling universele testbank

MORE — CONNECT

# Portugal- prototypes of prefabricated modular renovation elements for the Portuguese market


- Manuela Almeida, Ricardo Barbosa - University of Minho, Department of Civil Engineering, CTAC (Centre for Territory, Environment and Construction)
- Dário Santiago, João Faria - DarkGlobe

# Dark Globe - Portugal

Dark Globe is a construction company with special attention to prefabricated structures, insulation procedures and exterior claddings.

The company operates internationally,  with a work portfolio including not only Portugal and European Union but also Morocco and Middle East countries.

Within the More-Connect project, Dark Globe has been responsible for prototype development, in particular concerning material assembly, structural tests and implementation planning.

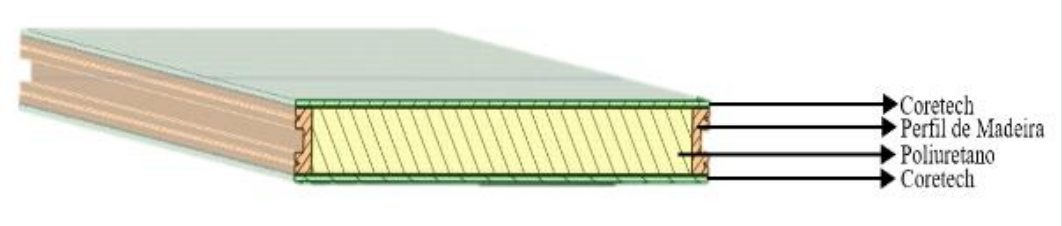
DARK GLOBE
CONSTRUÇÃO E ELECTRICIDADE

# Development of the prefabricated modular panel.

**PINEWOOD FRAME**
- Good thermal performance
- Innovative in the construction sector, which is used to work with aluminium

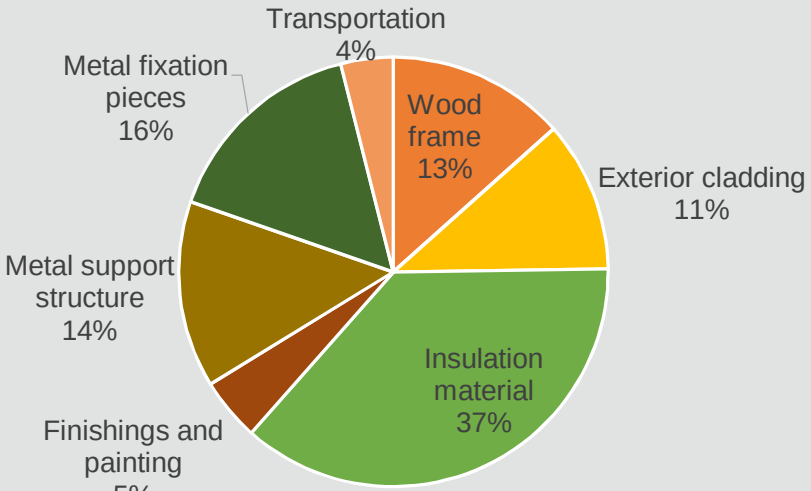
**CORETECH PANELS**
- Recycled material from automotive industry (kraft and cellulosic paper, polyurethane foam, fabrics and fiberglass)
- High durability, water and fire resistant, very good thermal performance
- Supports any type of coating (paint, ceramic, plaster, etc)

**POLYURETHANE FOAM**
- Injected into the panel
- High thermal performance and durability



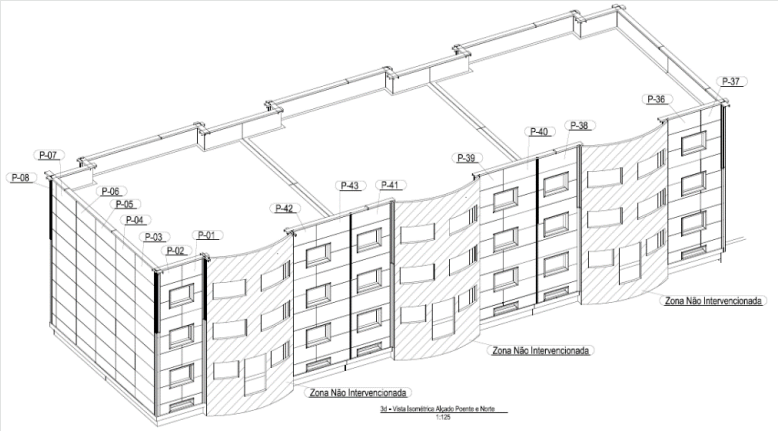

**Module composition illustration**

THICKNESS: 12 CM
DENSITY: 19.7 KG/M$^3$

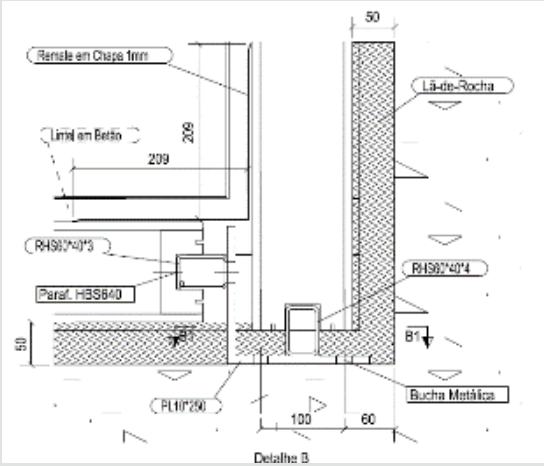



**Panel cost structure**

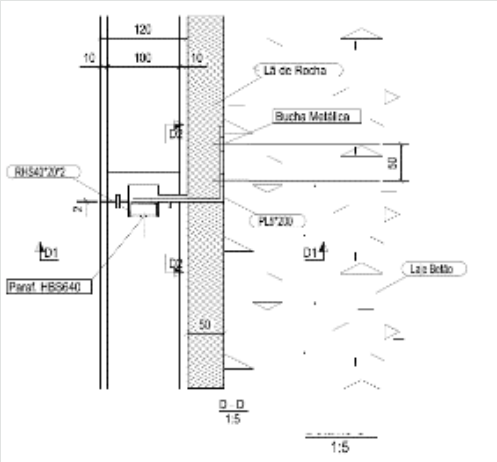
# Development of the prefabricated modular panel.



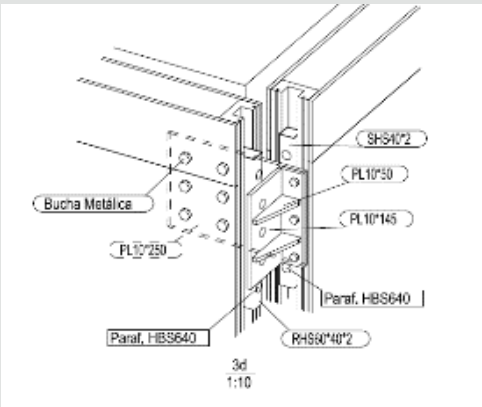

**Planning of module fixation in the West façade**




**Example of designed connection between modules in interior wall corners**

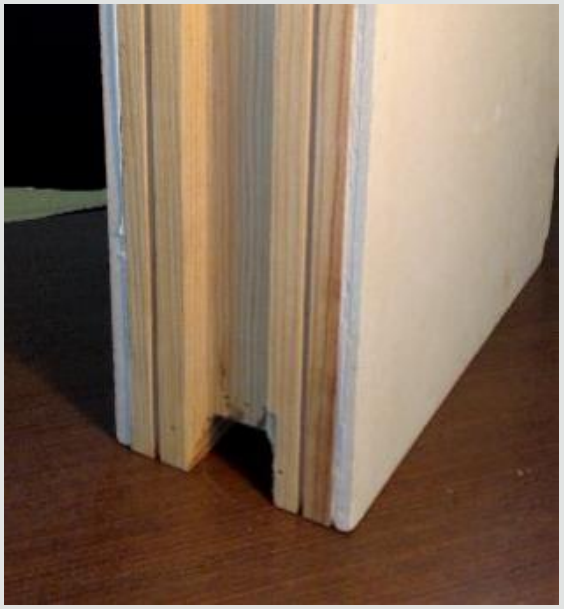



**Example of designed connection between modules and concrete slabs (top view)**




**Example of designed connection between modules in exterior wall corners**

# Prototype assembly of prefabricated modular panel.

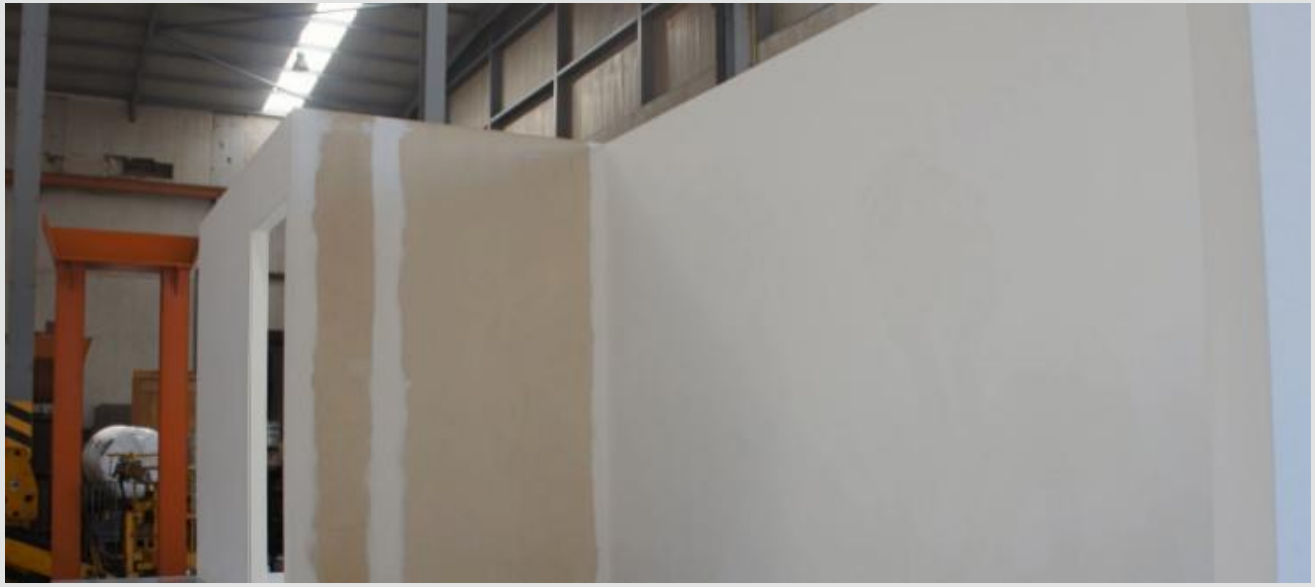


**Frame detail**

**Prototype assembly**

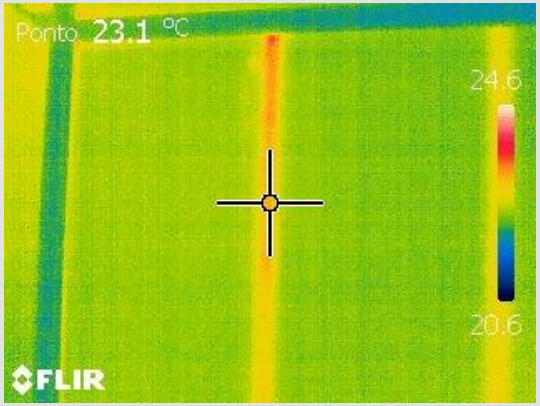
# Prototype assembly of prefabricated modular panel.

**Frame detail (demo wall)**

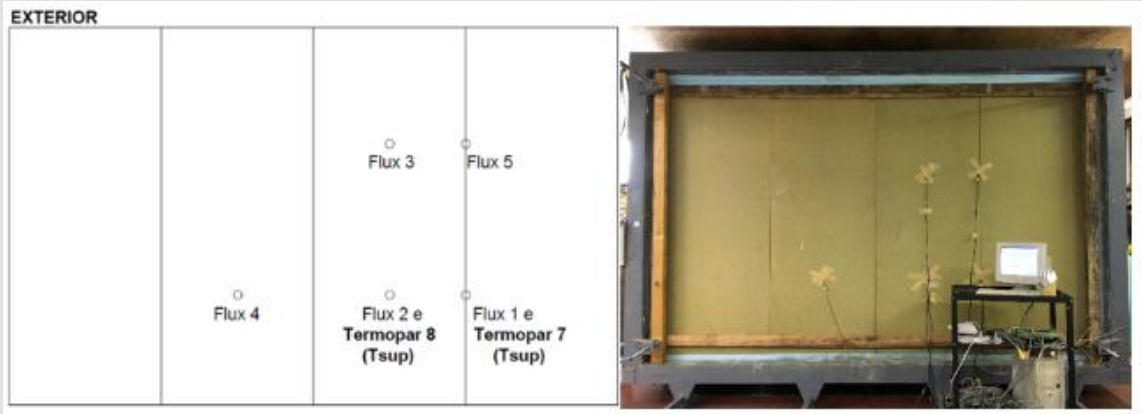


**Demo wall for panel connection test**

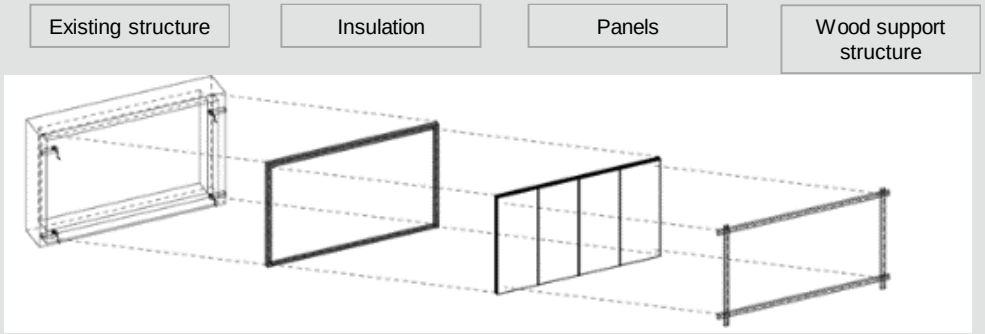
# Testing of prototype in thermal chamber




**Thermal imaging of the panel in the thermal chamber**



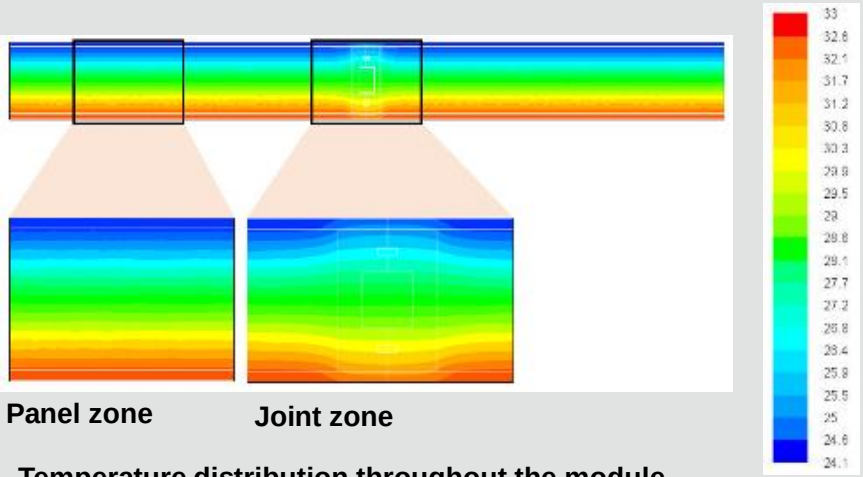

**Prototype experimental layout and thermal chamber implementation**




**Module assembly scheme (for thermal chamber)**

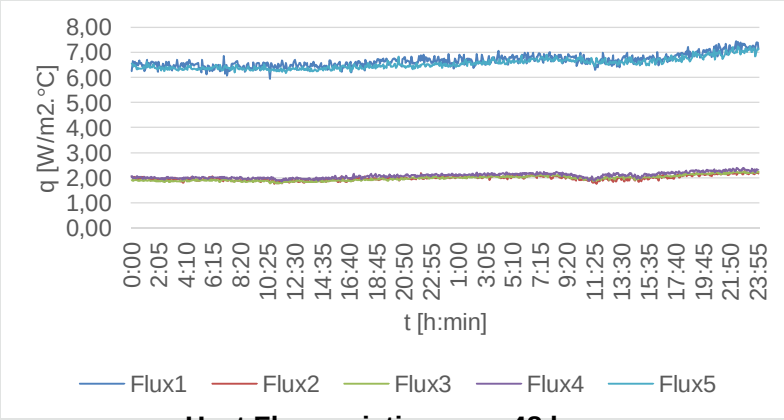
MORE — CONNECT

# Testing of prototype in thermal chamber




**Panel zone** **Joint zone**

**Temperature distribution throughout the module**

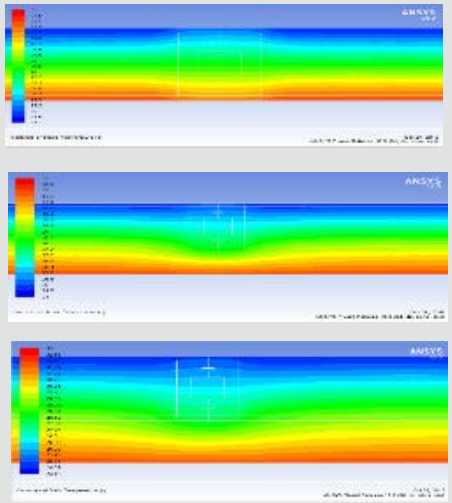



**Joint zone**

**Panel zone**

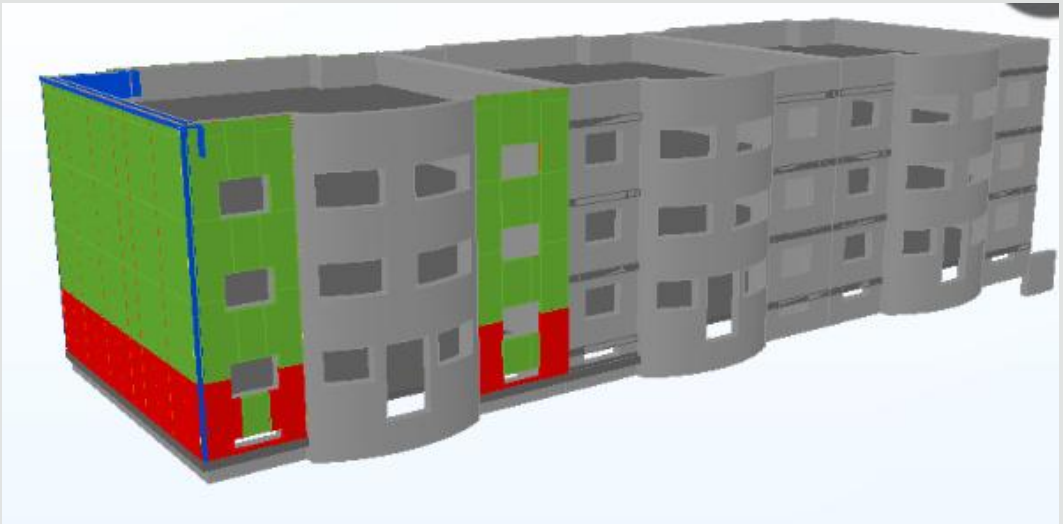
**Heat Flux variation over 48 hours**

| Zone of the prototype | U W/m².K |
|---|---|
| Flow | 0.26 |
| Joints | 0.96 |
| Total (weighted value) | 0.31 |

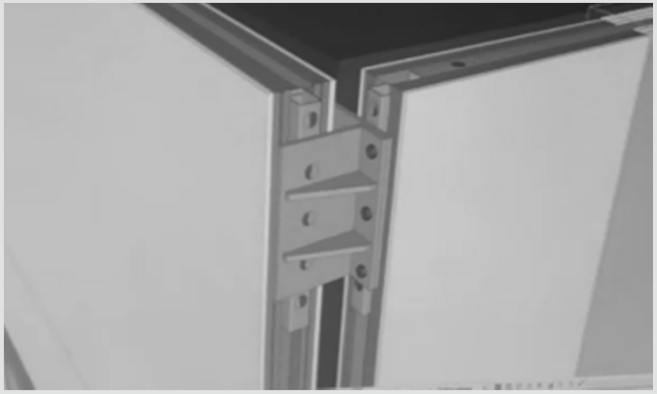


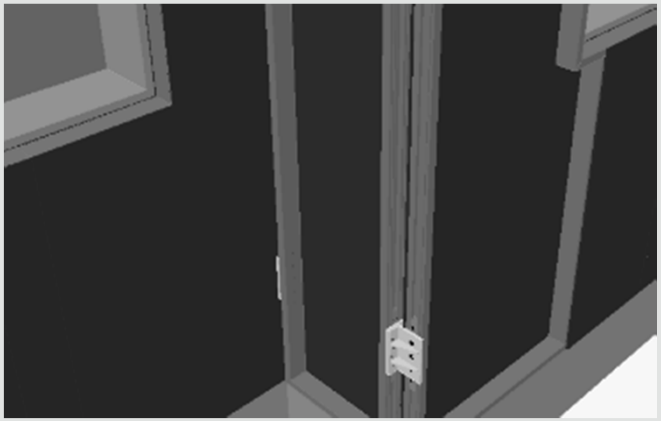
**Insulation optimization through numerical simulation (ANSYS)**

# Planning panel implementation using BIM software



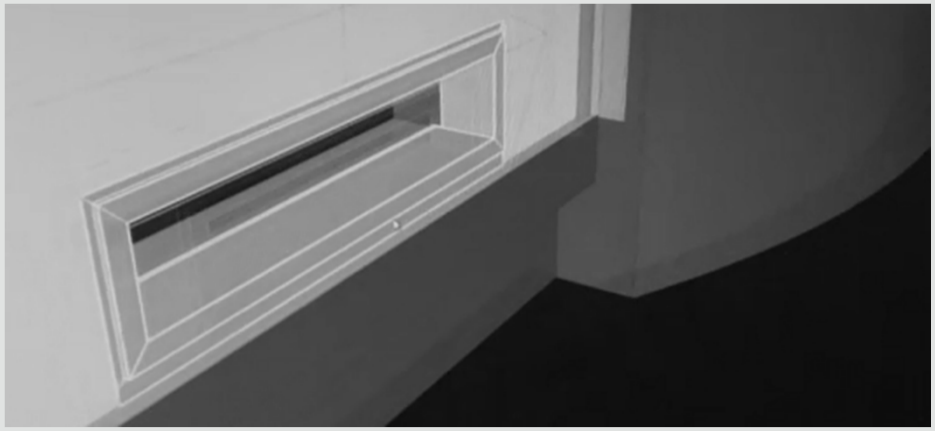
**General view of panel mounting in West façade**



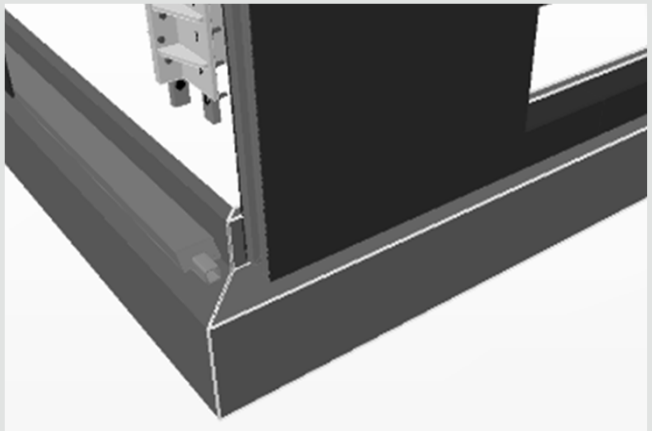


**Corner detail**

# Planning panel implementation using BIM software



**Window sealing box**



**Lintel detail**