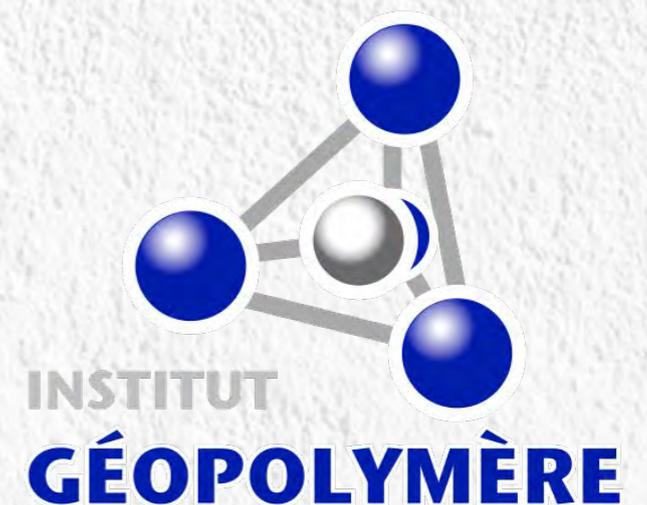


# **Renca 3D Printing Factory – The World's First Industrial 3D Printing With Geopolymer Concrete**

**Marina Dudnikova  
Andrey Dudnikov & Alex Reggiani  
RENCA Inc**



# The Idea of the House

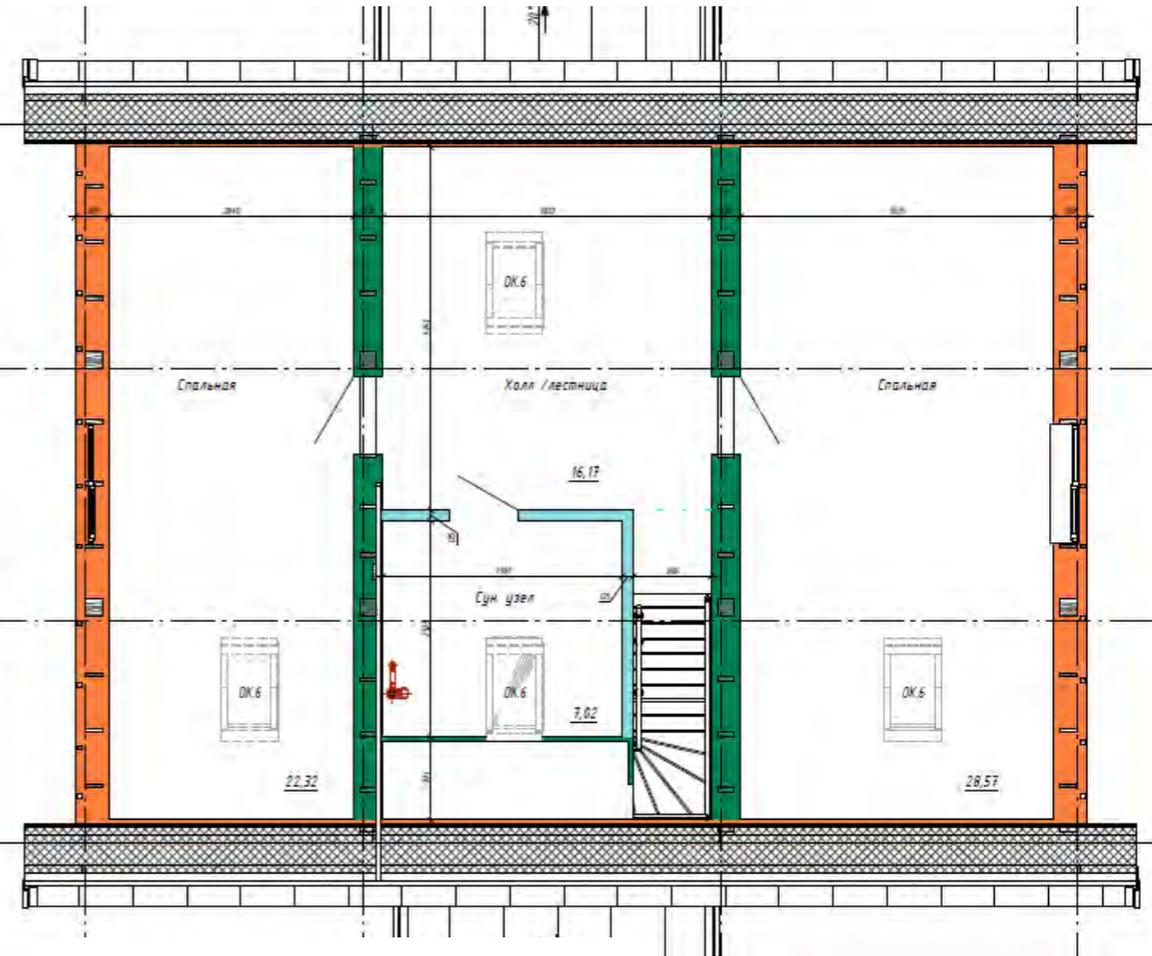
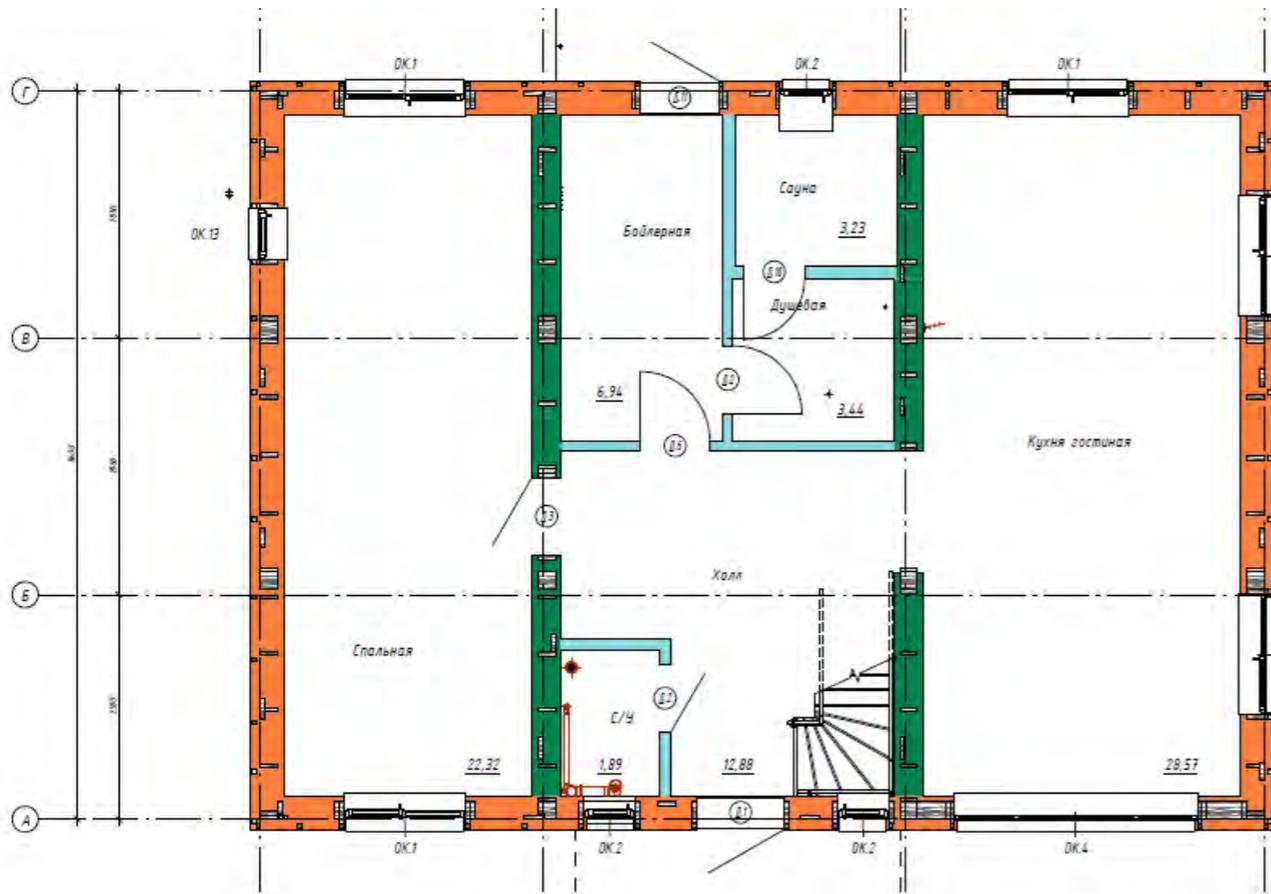




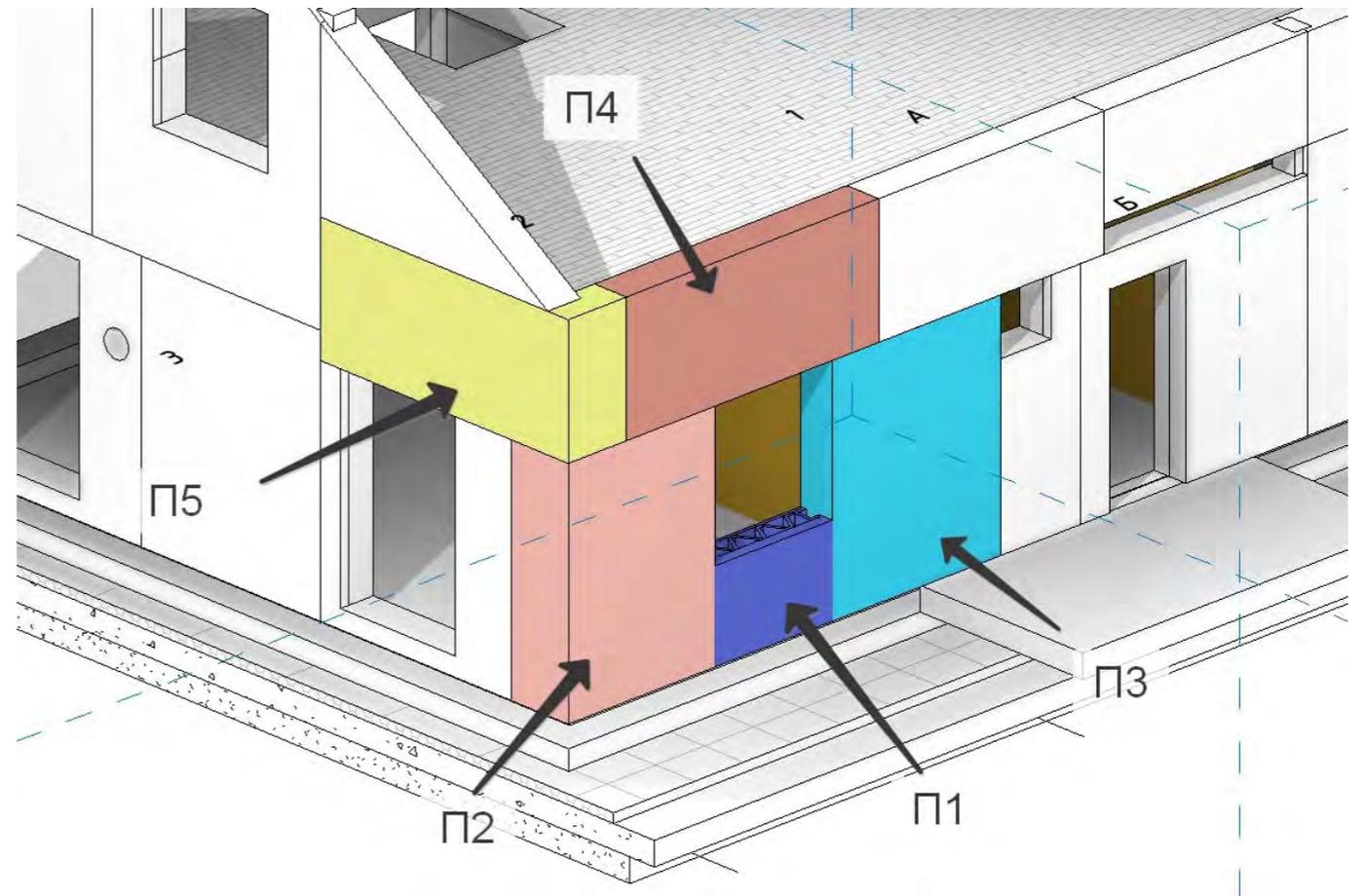
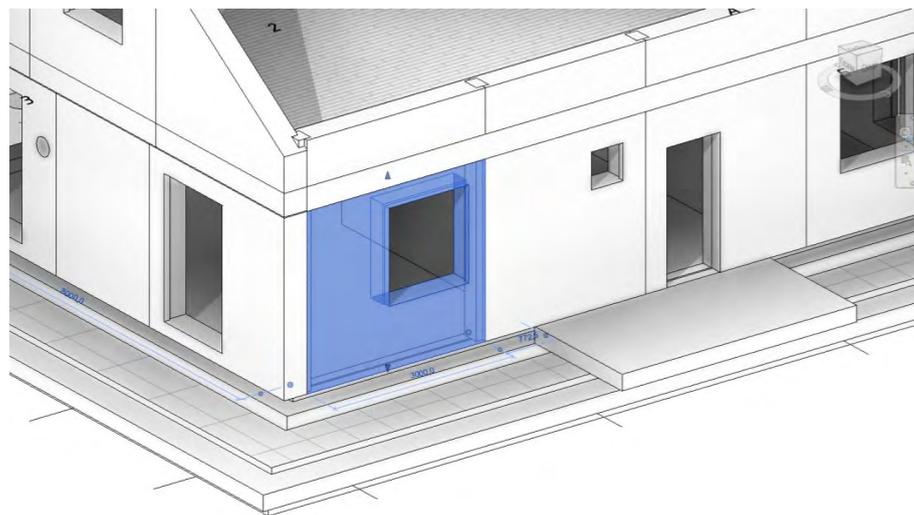
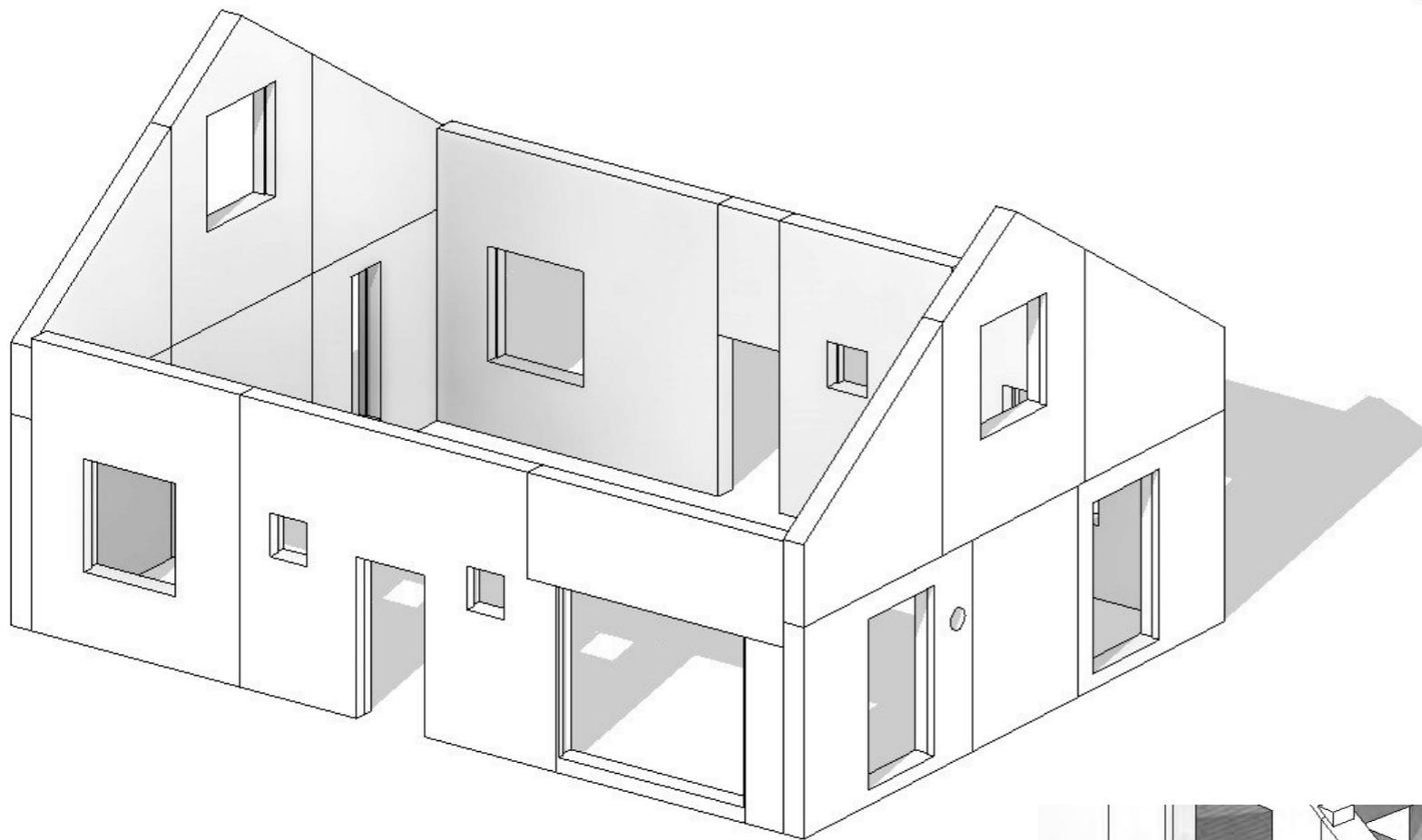
# Floor Plans of the House



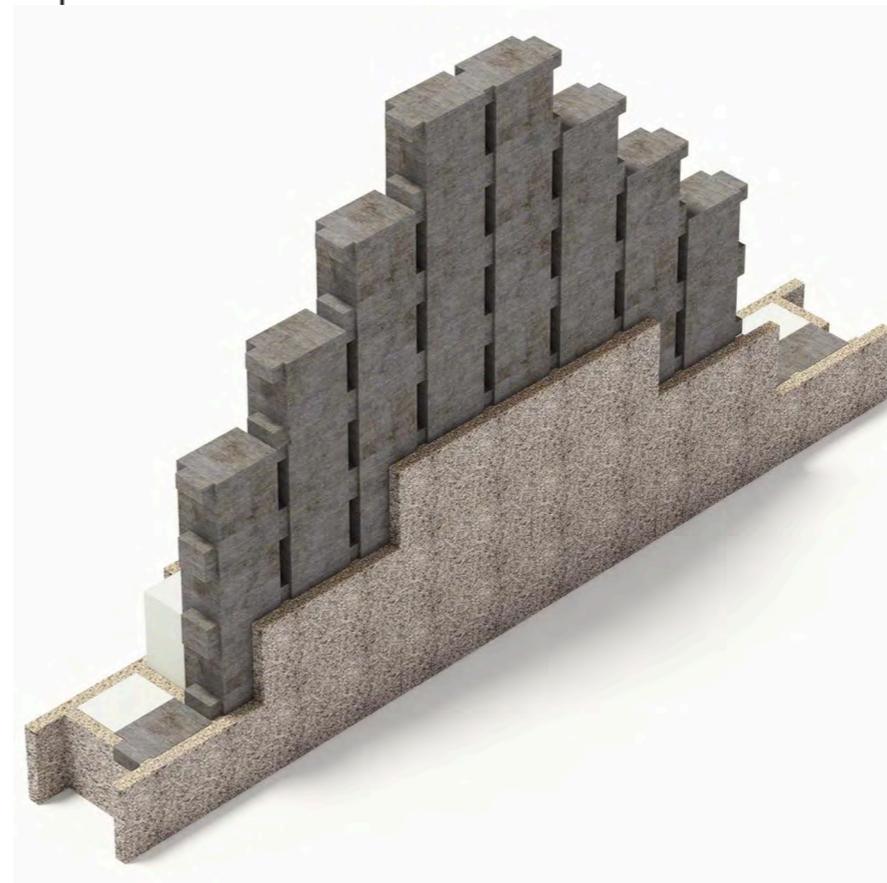
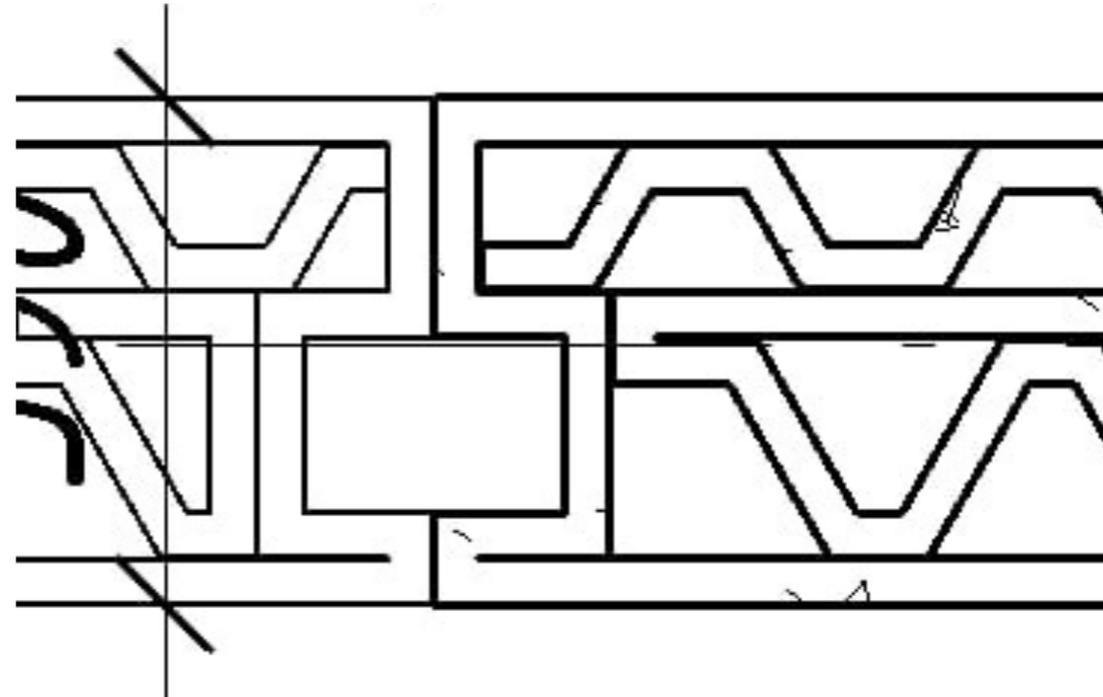
# Floor Plans of the House



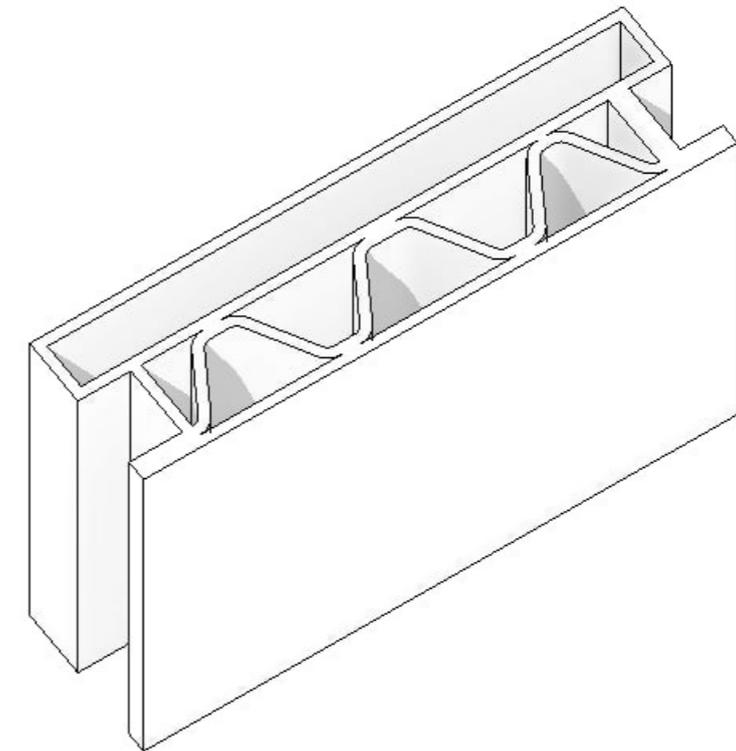
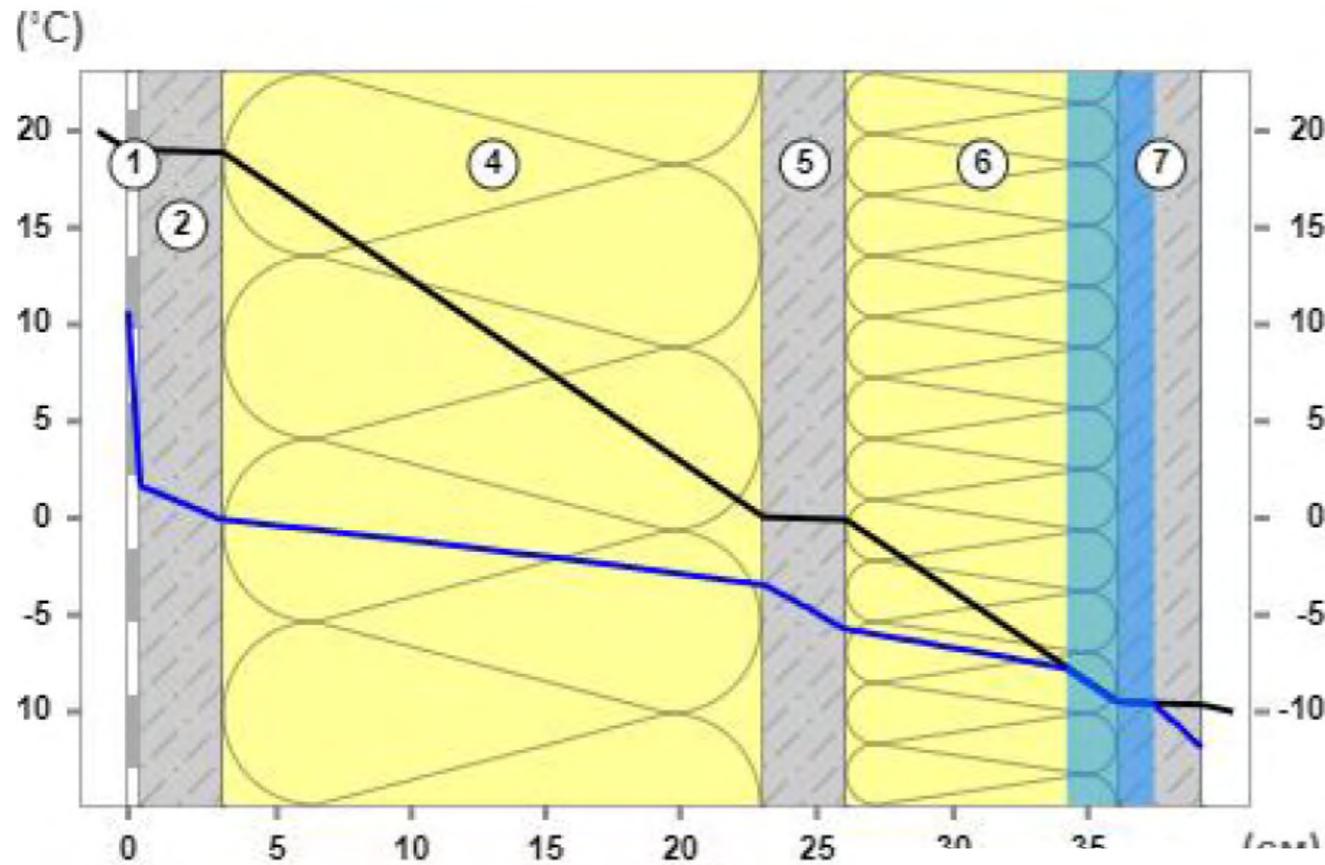




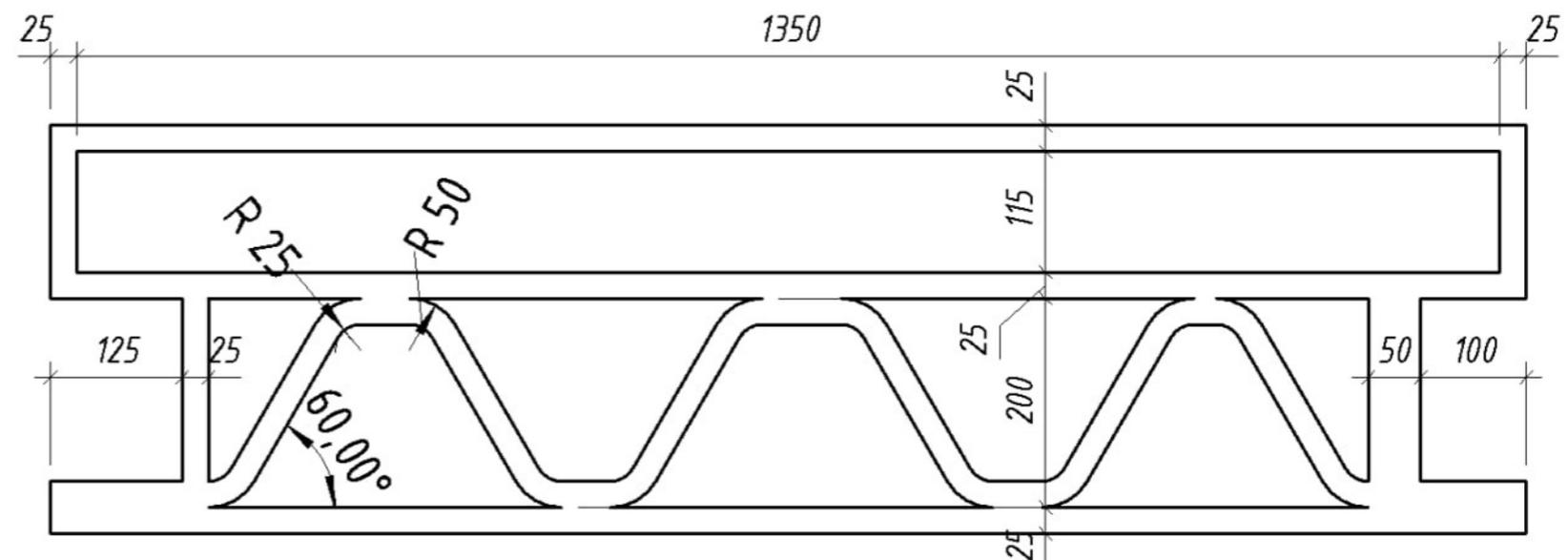
# Connecting the Wall Elements



# Thermal Properties of the Wall



R value – **3.08** m<sup>2</sup> x °C / W



# Thermal Properties of the Wall



Article

## Experimental Study on the Thermal Performance of 3D-Printed Enclosing Structures

Darya Nemova <sup>\*</sup>, Evgeny Kotov, Darya Andreeva, Svyatoslav Khorobrov, Vyacheslav Olshevskiy, Irina Vasileva, Daria Zaborova and Tatiana Musorina

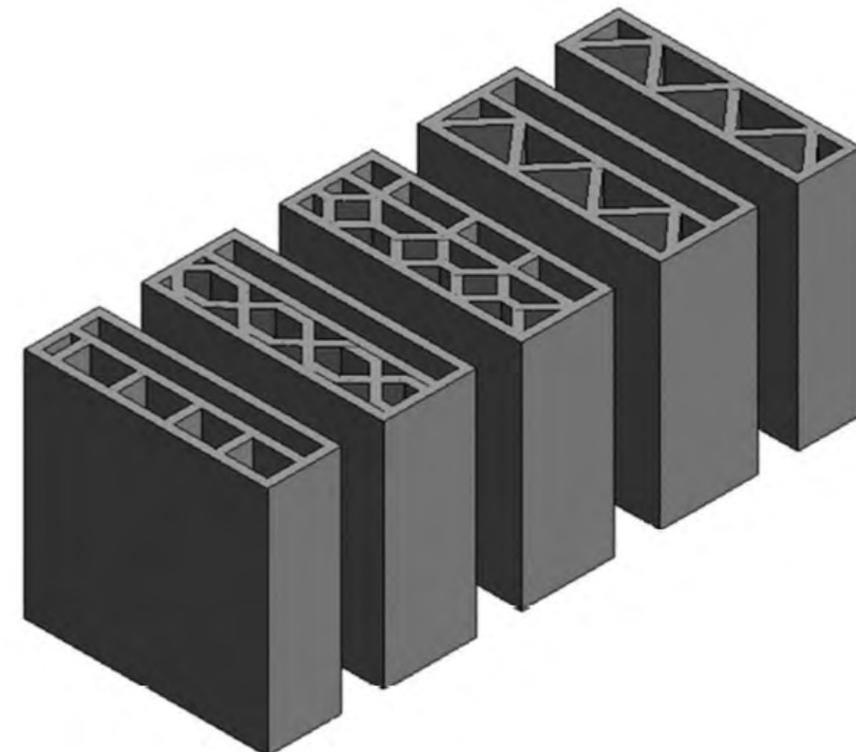
Received: 4 April 2022

Accepted: 6 June 2022

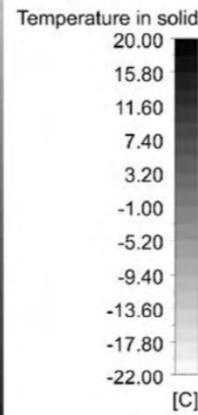
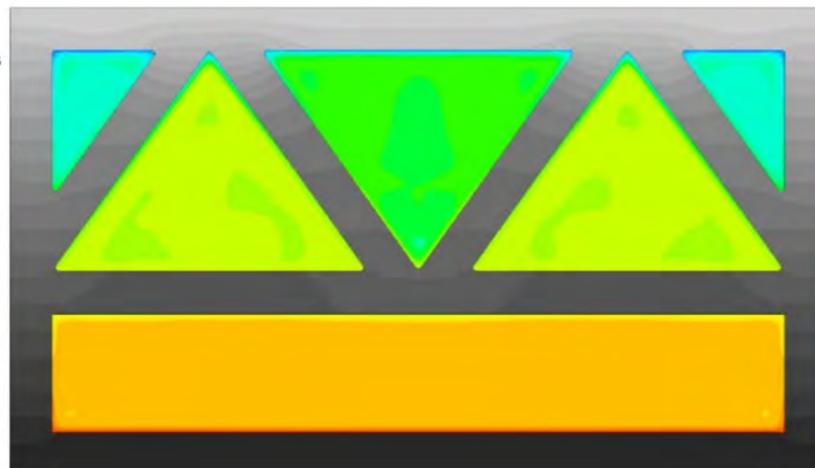
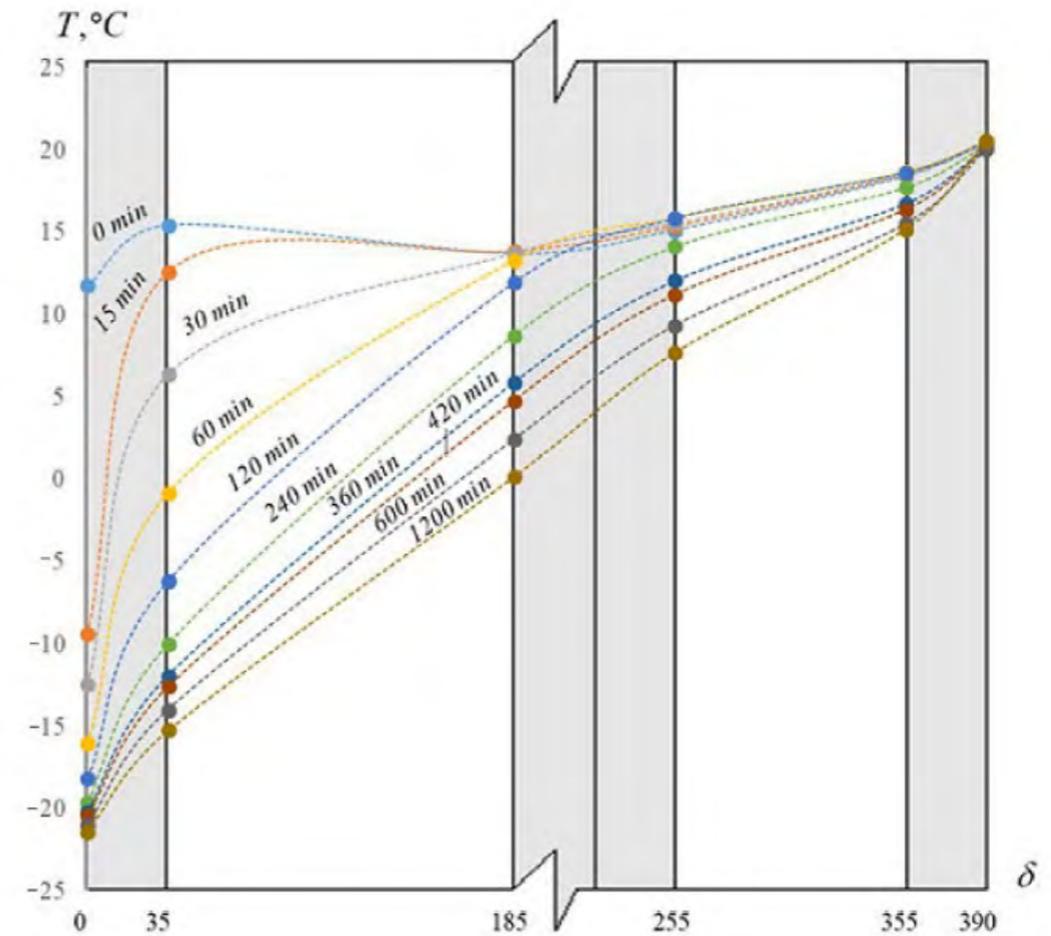
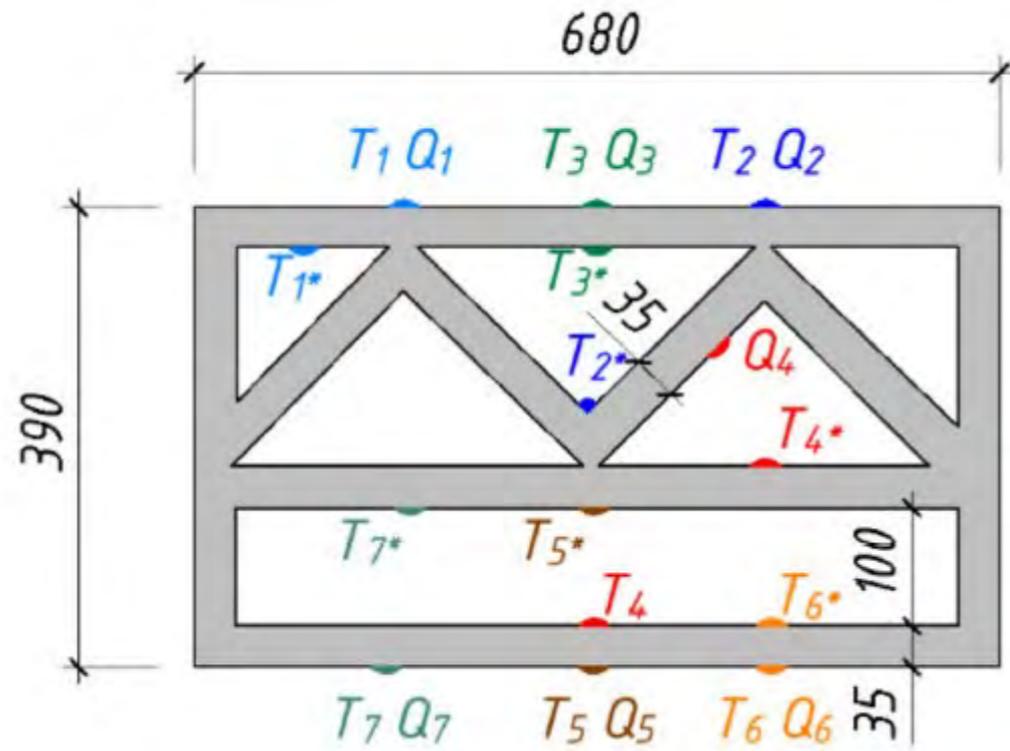
Published: 8 June 2022

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\* Correspondence: nemova\_dv@spbstu.ru



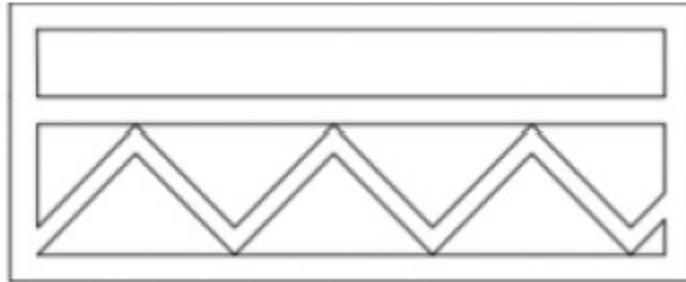
# Thermal Properties of the Wall



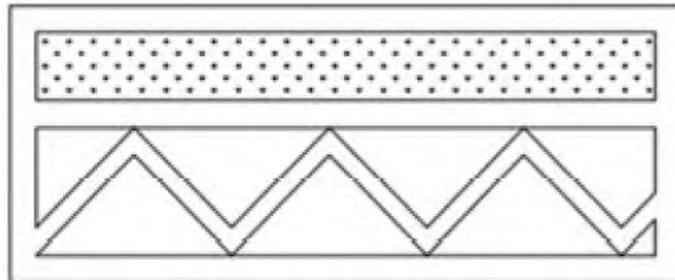
# U-values of 3D-printed Structures

$U$  is the coefficient of heat transmission,  $W/m^2 \cdot ^\circ C$ .

$U_c, W/m^2 \cdot ^\circ C$



1.15

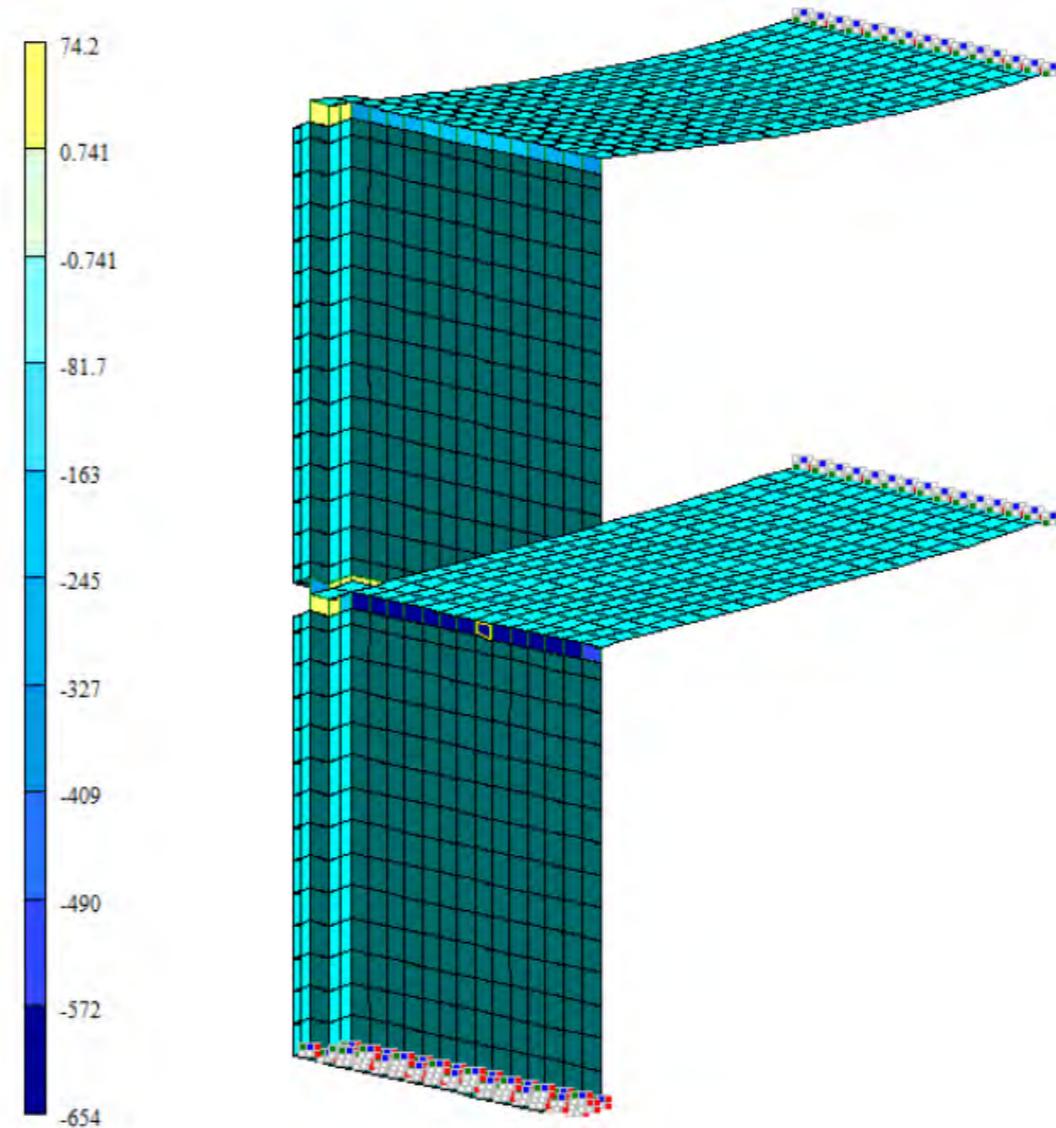
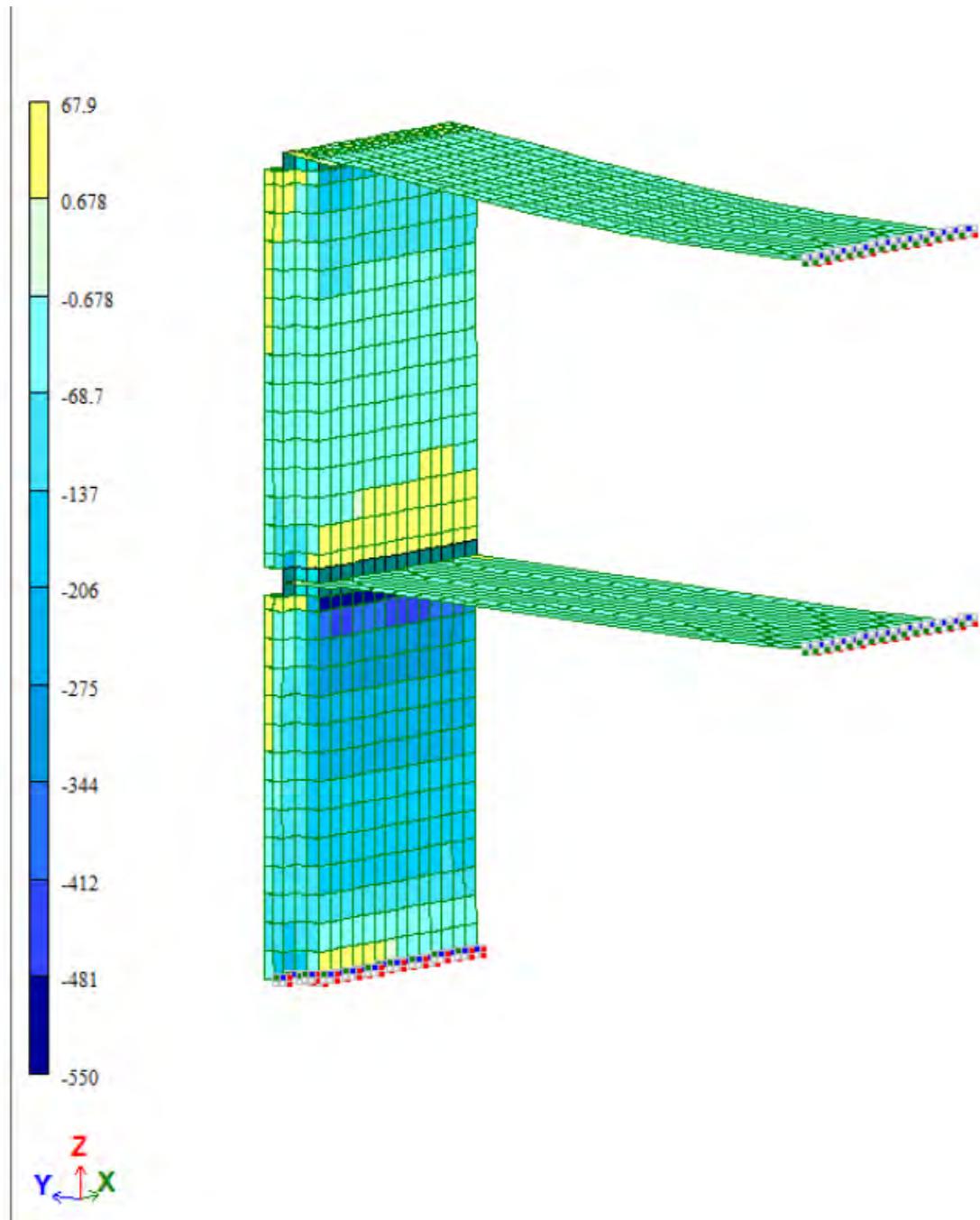


0.78

**RENCA engineered wall**

U value 0.32  $W / m^2 \times ^\circ C$

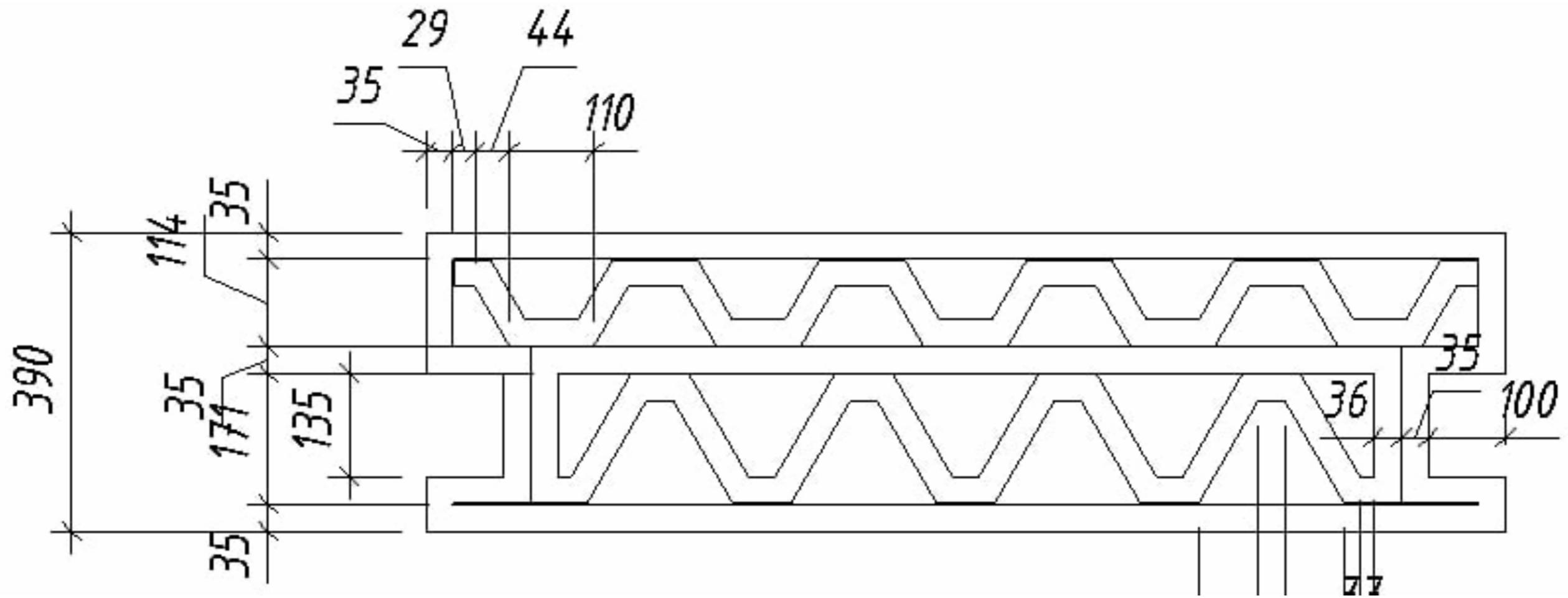
# Structural Stability Simulation



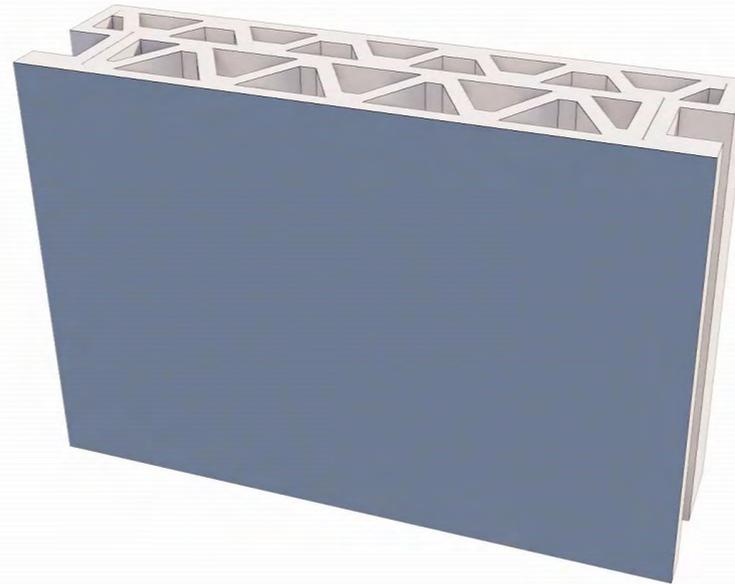
# Automated Infill Pattern Design



# The New Configuration of The Infill



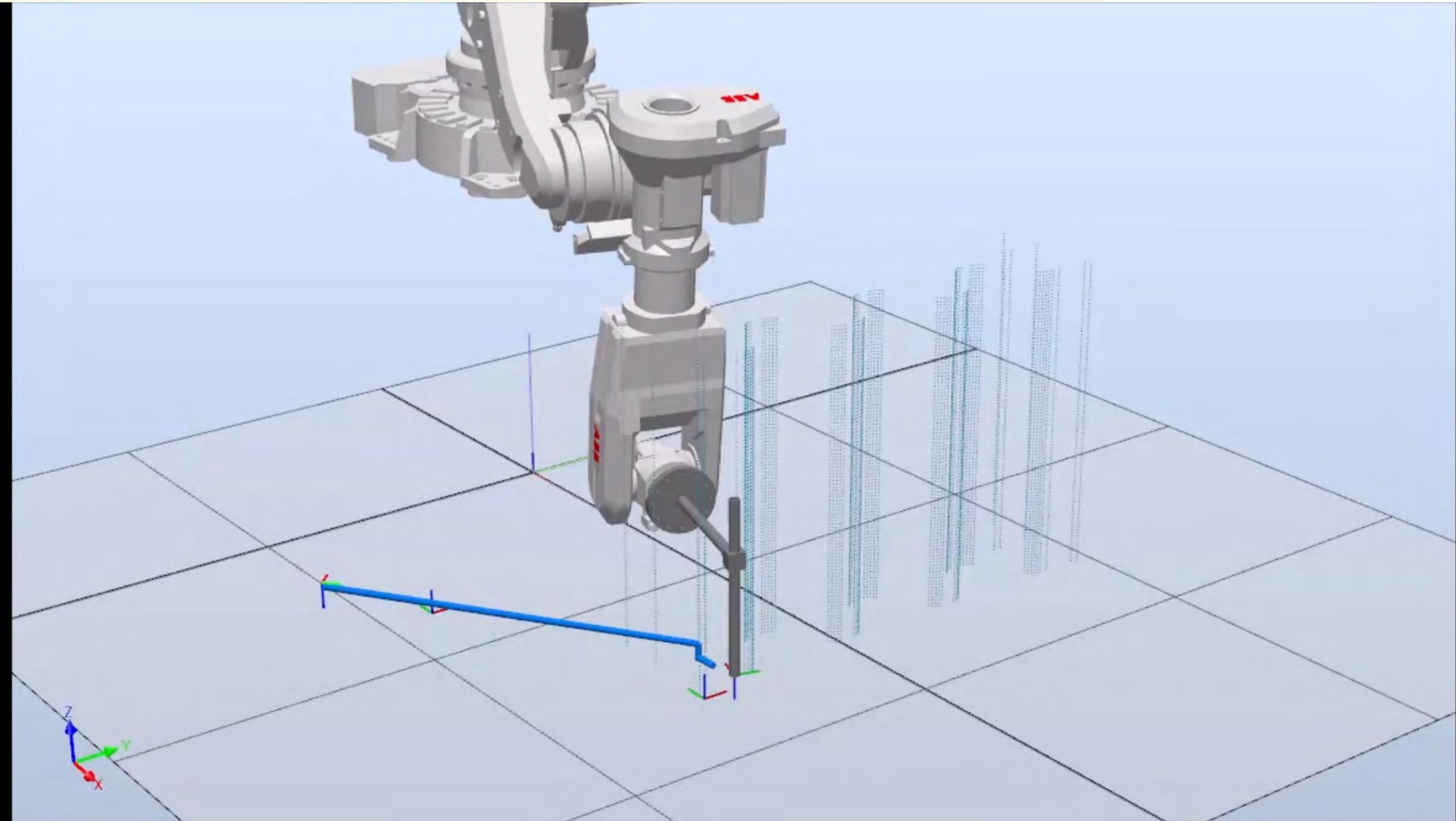
# Creation of 3D Model of the Panel



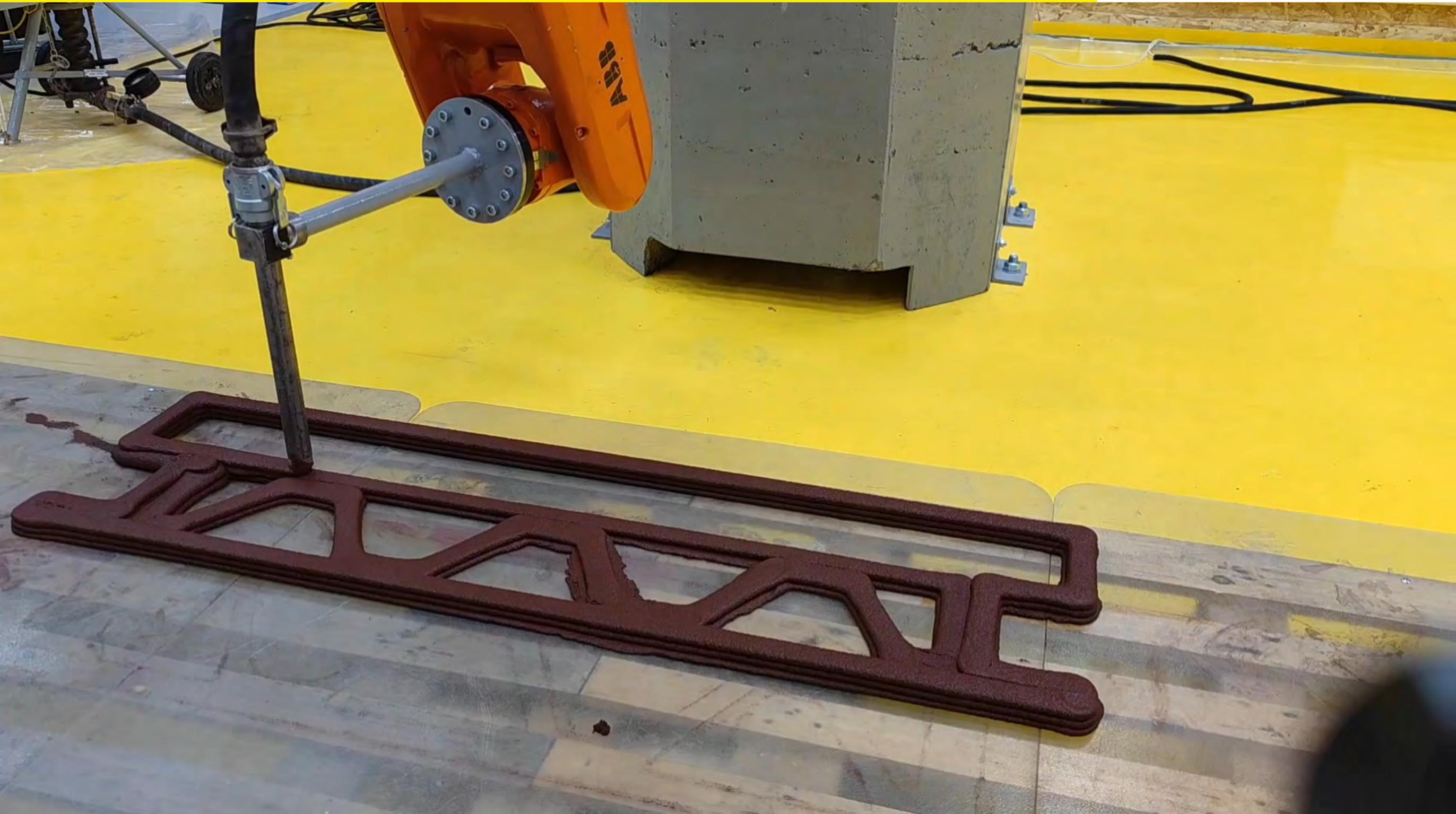
# Making Up the GCODE for Printing

The screenshot displays two overlapping windows. The background window is Autodesk Fusion 360, showing the 'MILLING' workspace. The 'BROWSER' panel on the left shows a tree structure with 'block parametric 2 v3' selected. The foreground window is OBS Studio 27.2.4, which is recording the Fusion 360 window. The OBS interface includes a 'Scenes' list, an 'Audio Mixer' with sliders for Desktop Audio, Mic/Aux, and Mic/Aux 2, and a 'Stats' panel showing CPU usage at 0.78% and FPS at 30.00. A settings panel is open on the right side of the OBS window, showing options like 'Show turning direction', 'Mode', 'Viewpoint', and 'Opacity'. At the bottom of the video frame, there is a playback control bar with standard media controls and a 'COMMENTS' section.

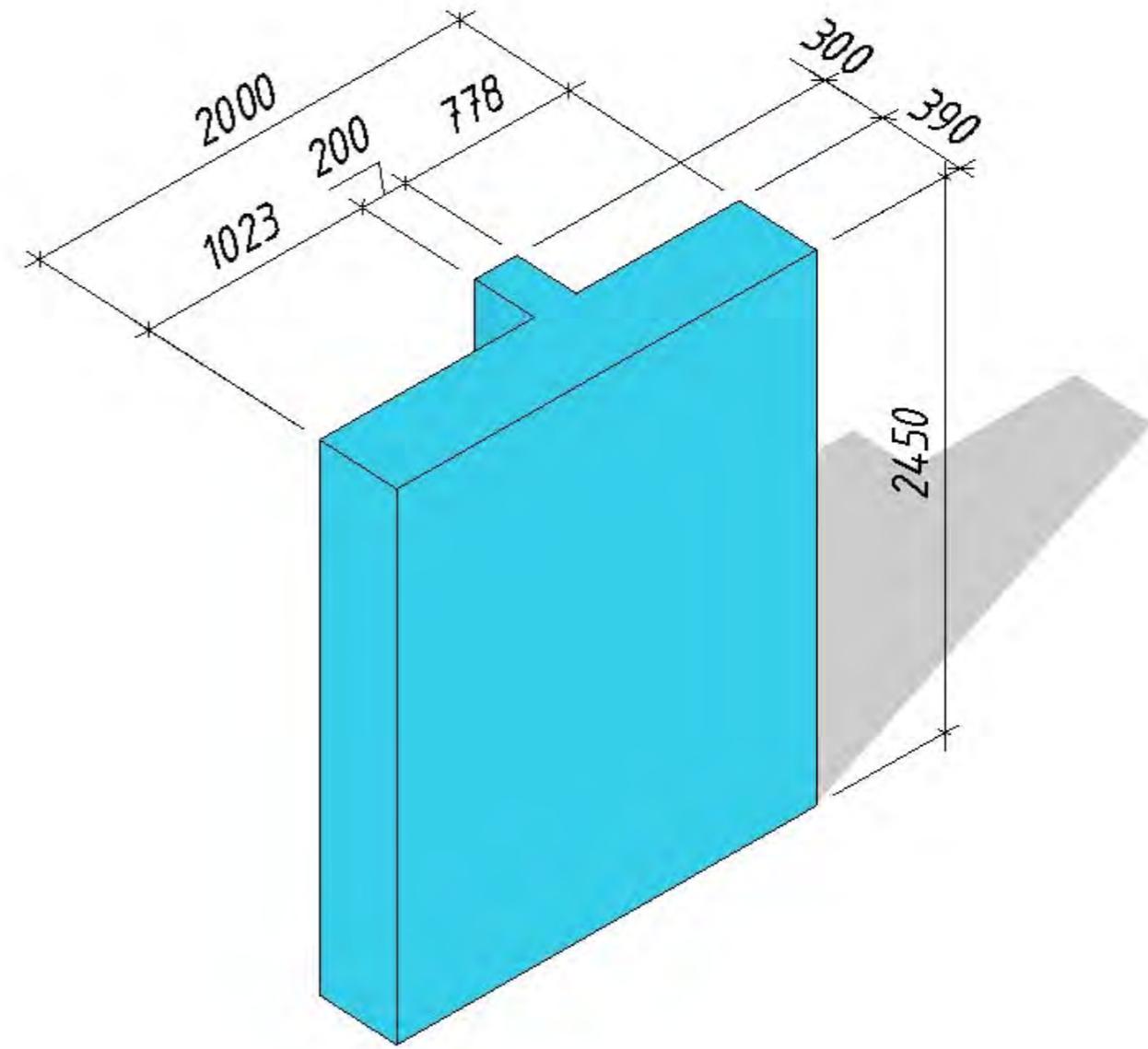
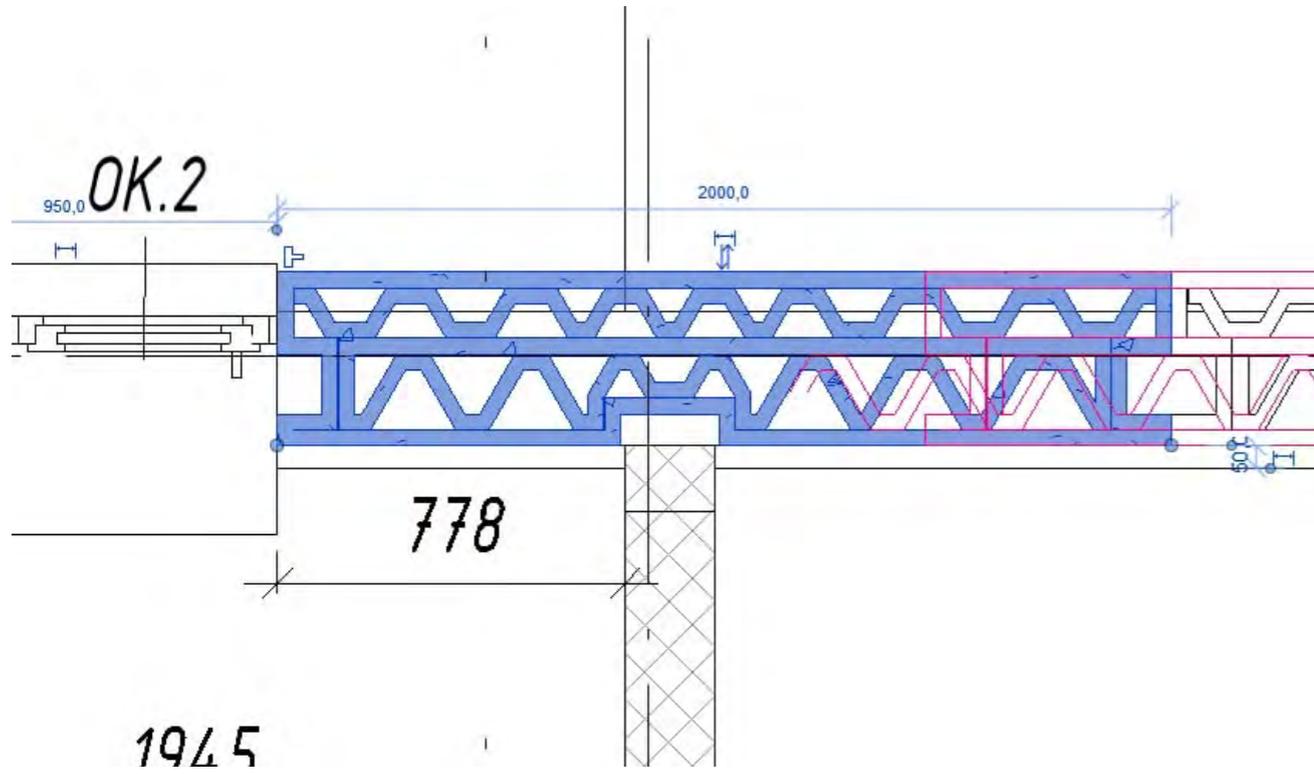
# Simulation of the Process in RobotStudio



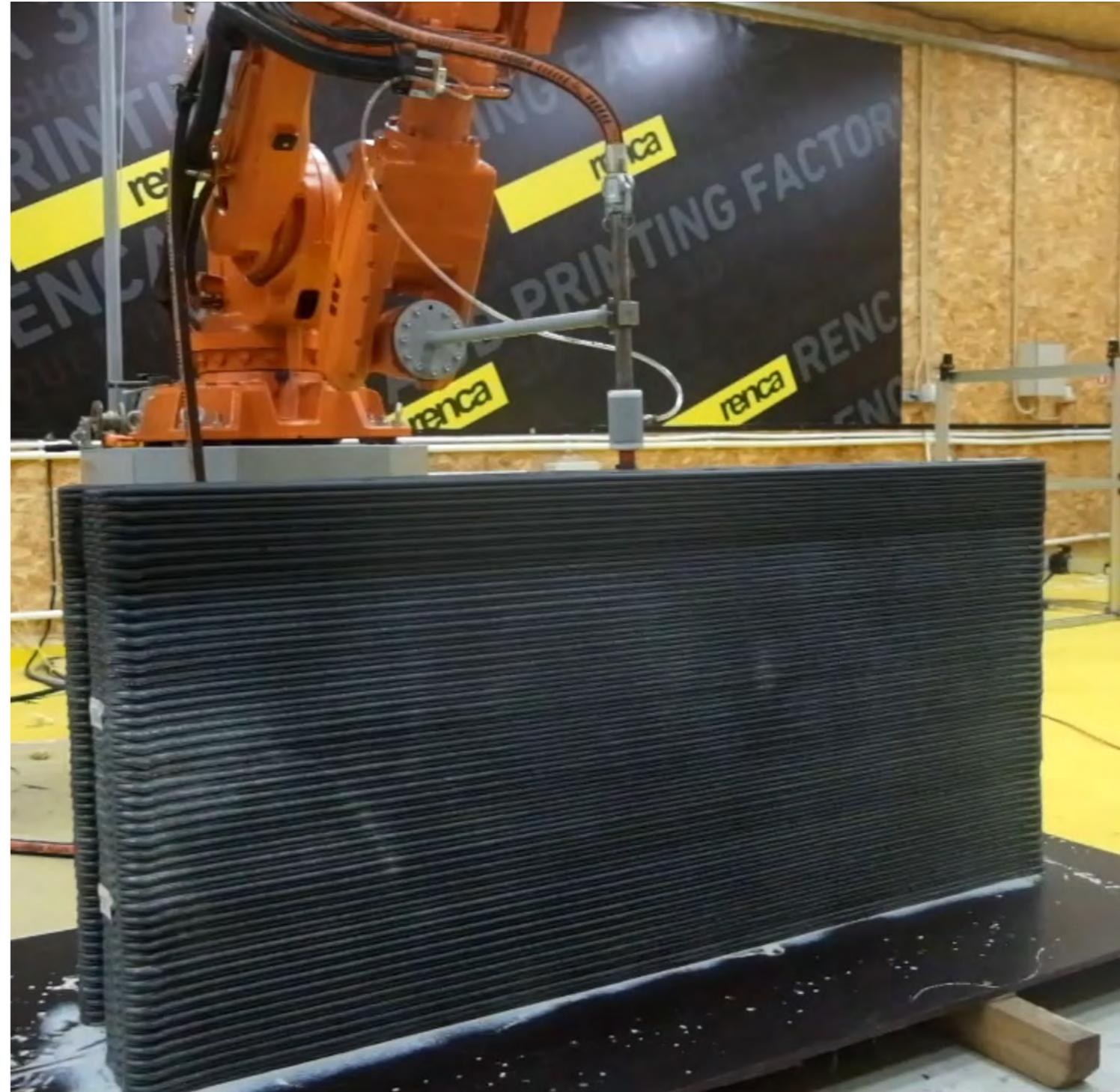
# 3D Printing Process



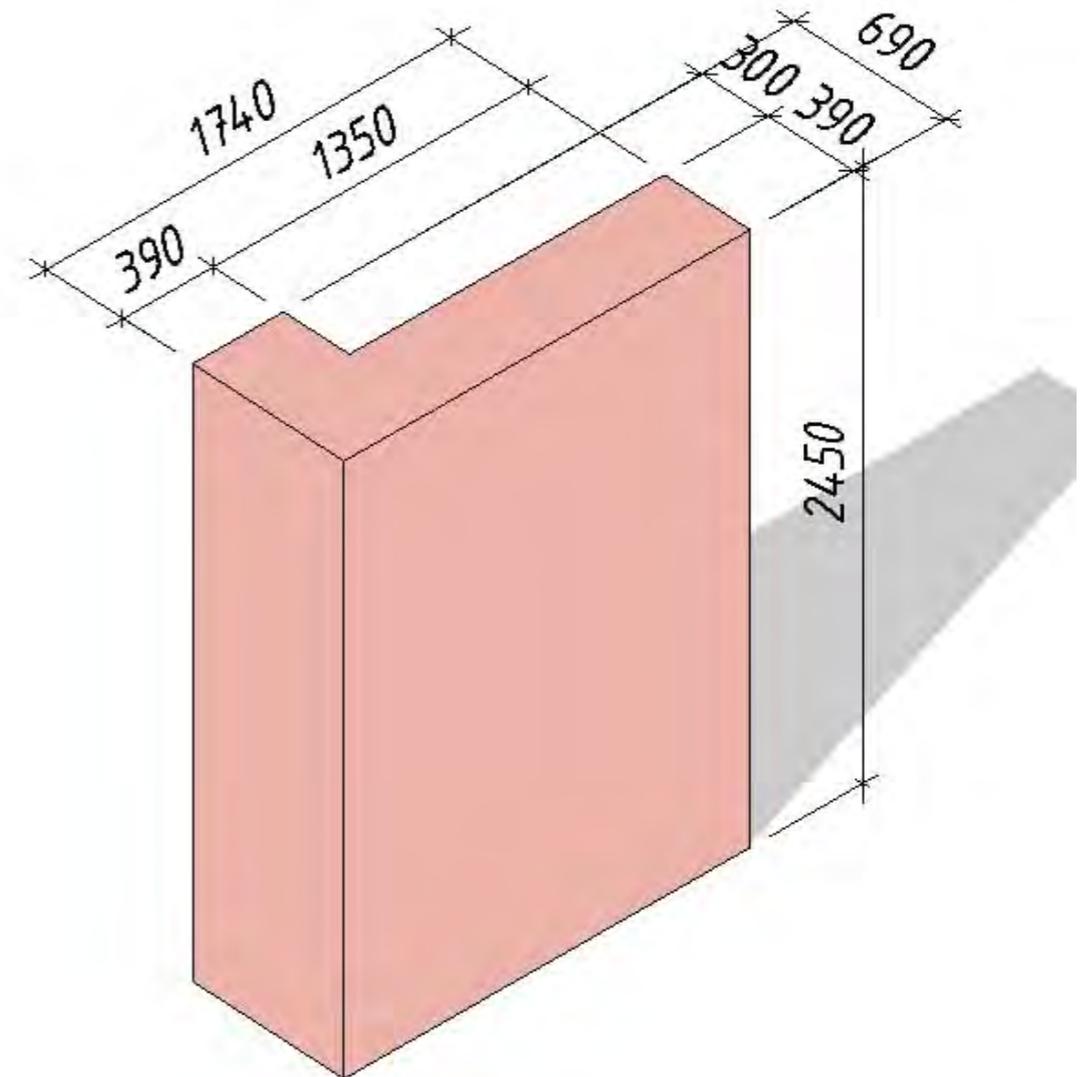
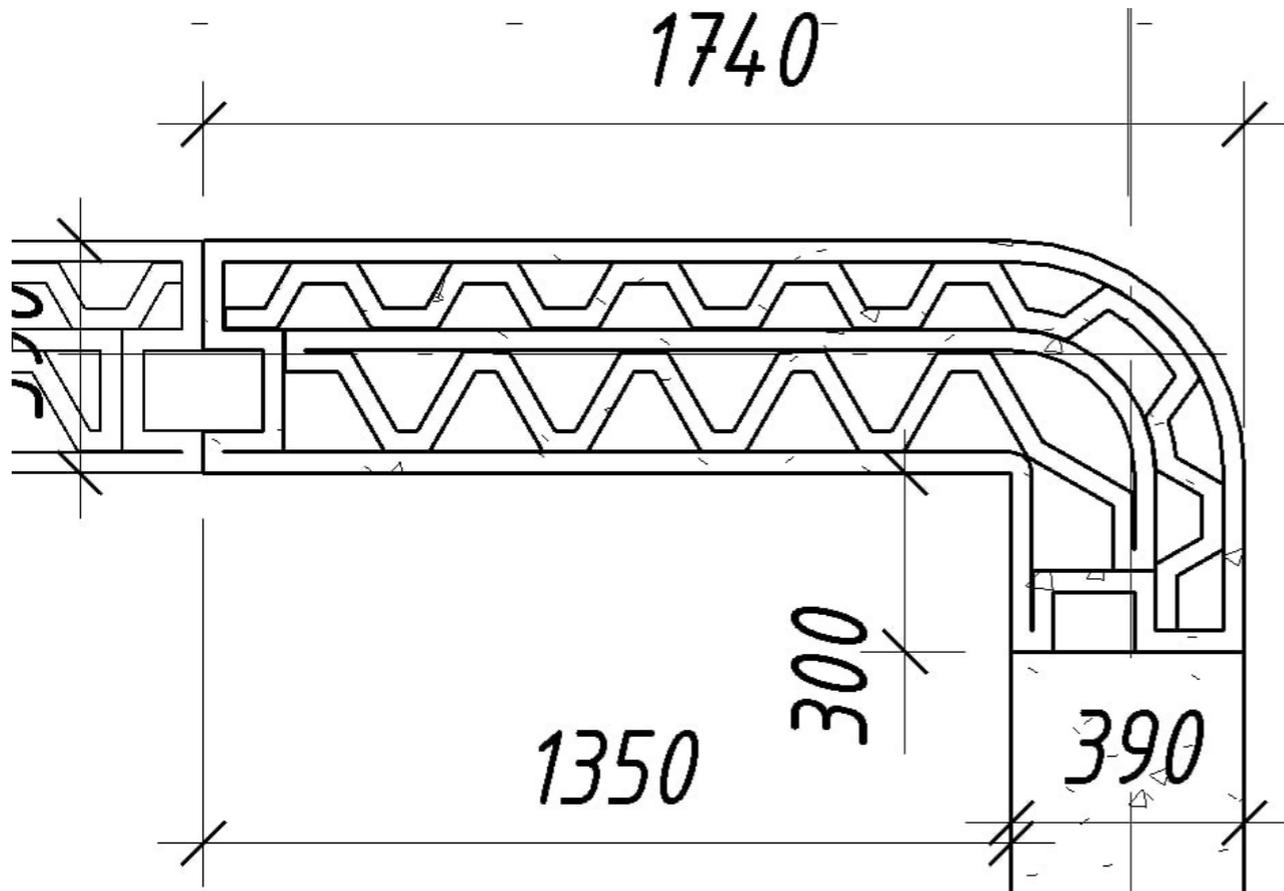
# Bigger Panels



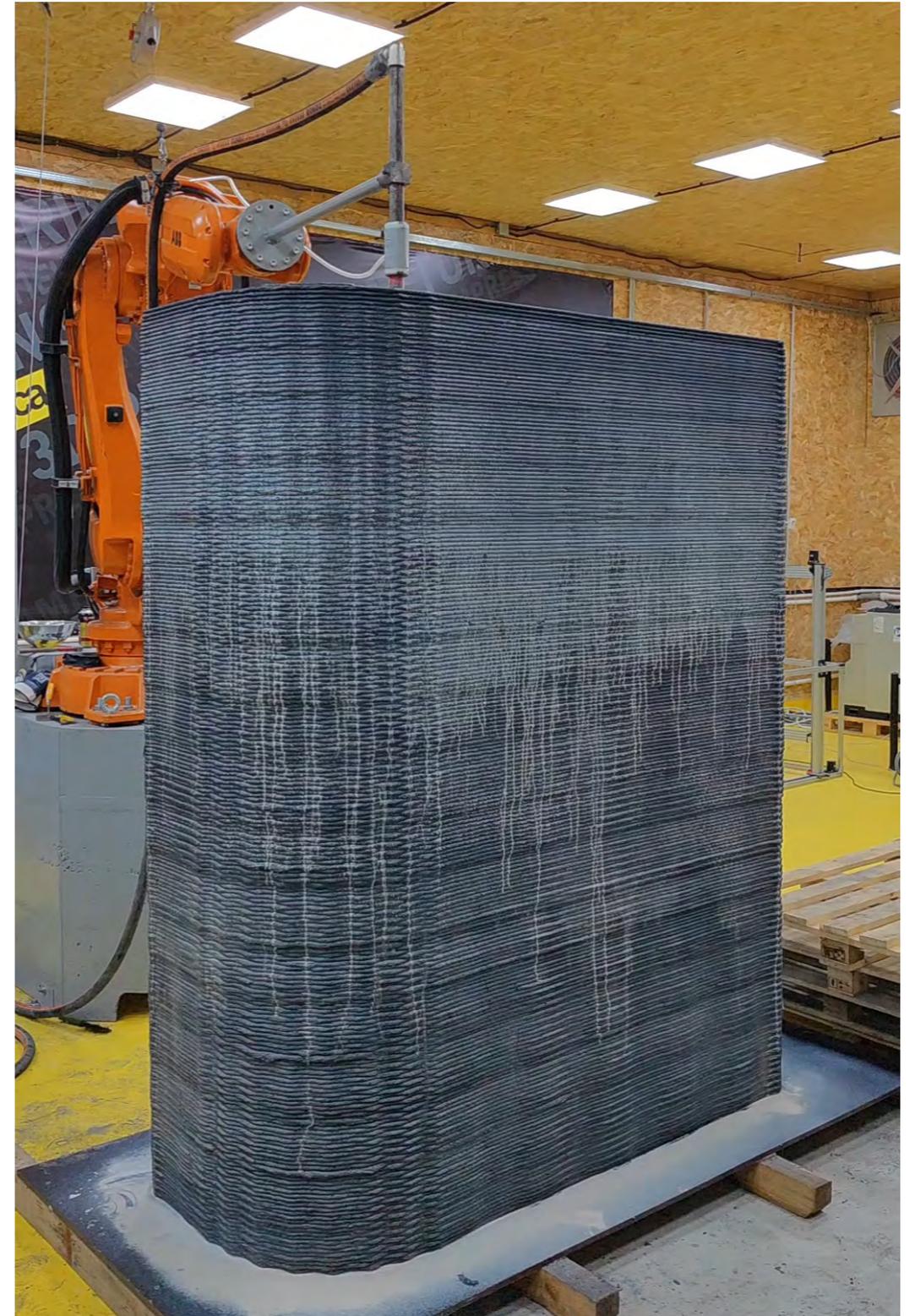
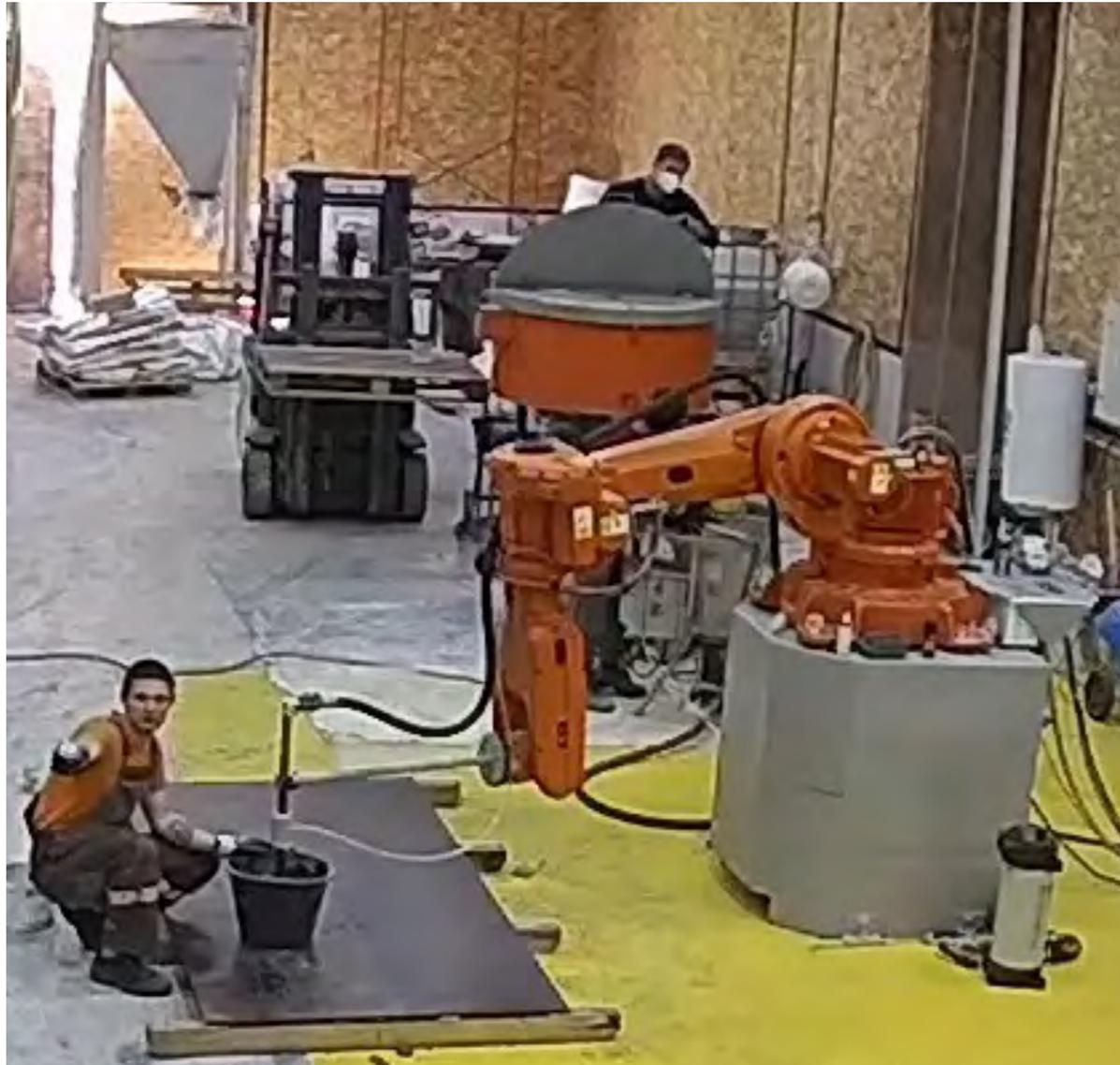
# 3D Printing Process



# Complex Elements – Rounded Corners

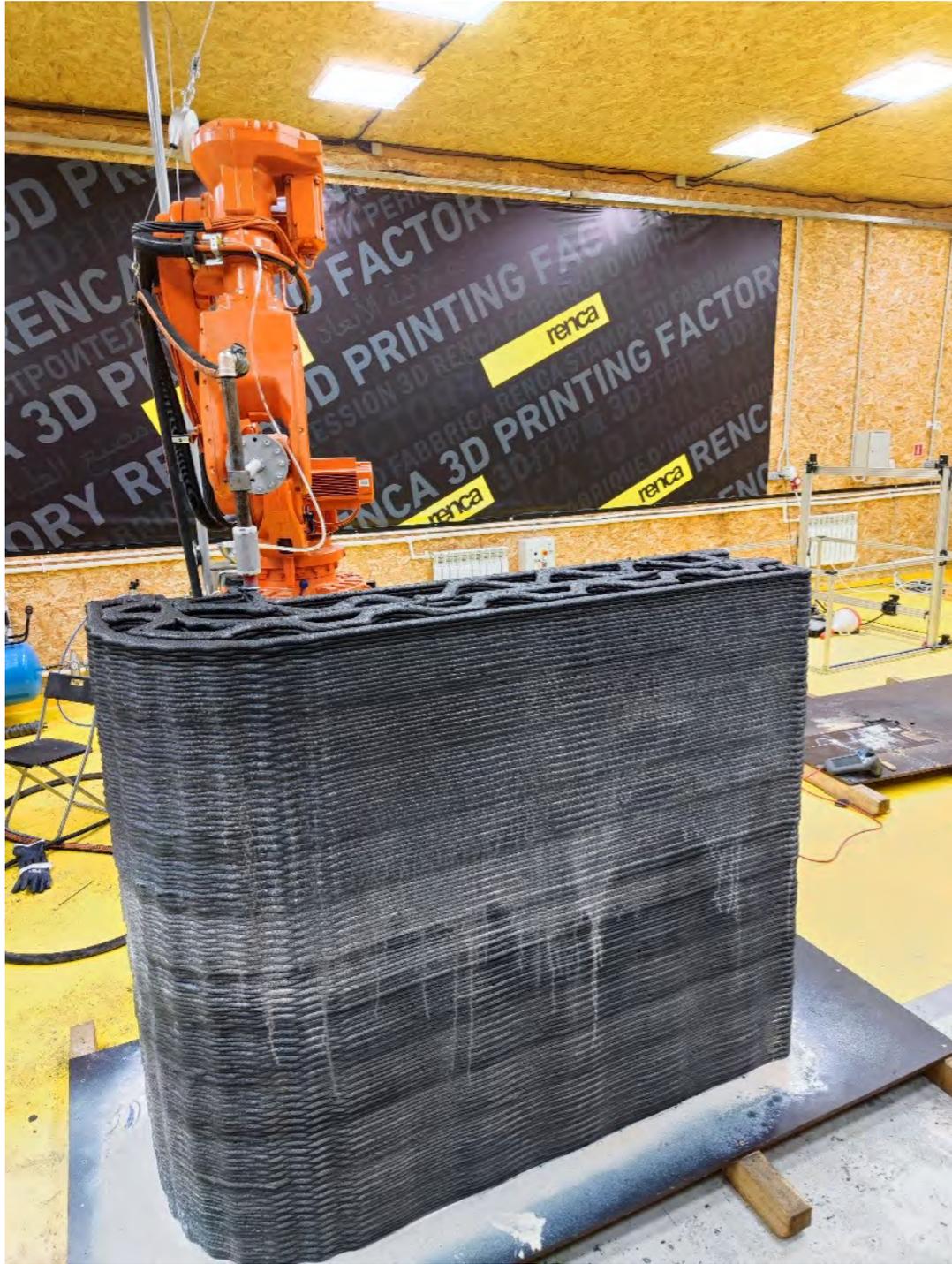


# 3D Printing Process



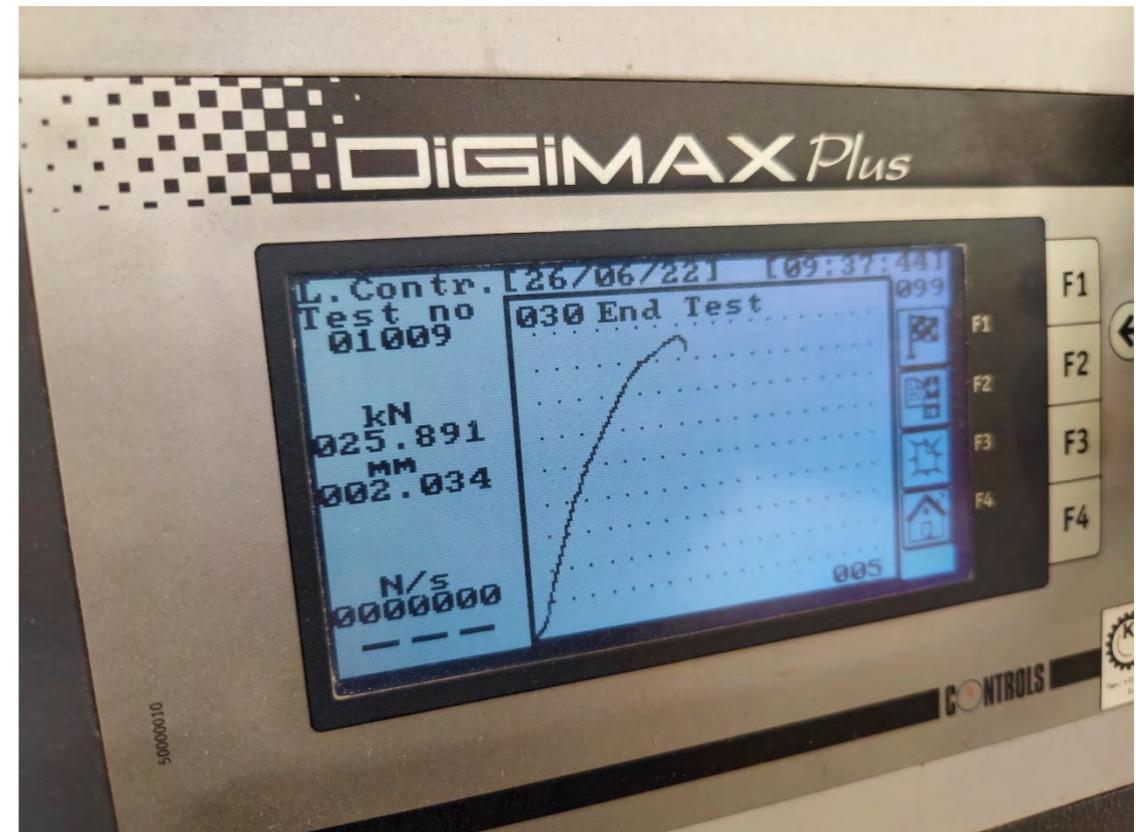
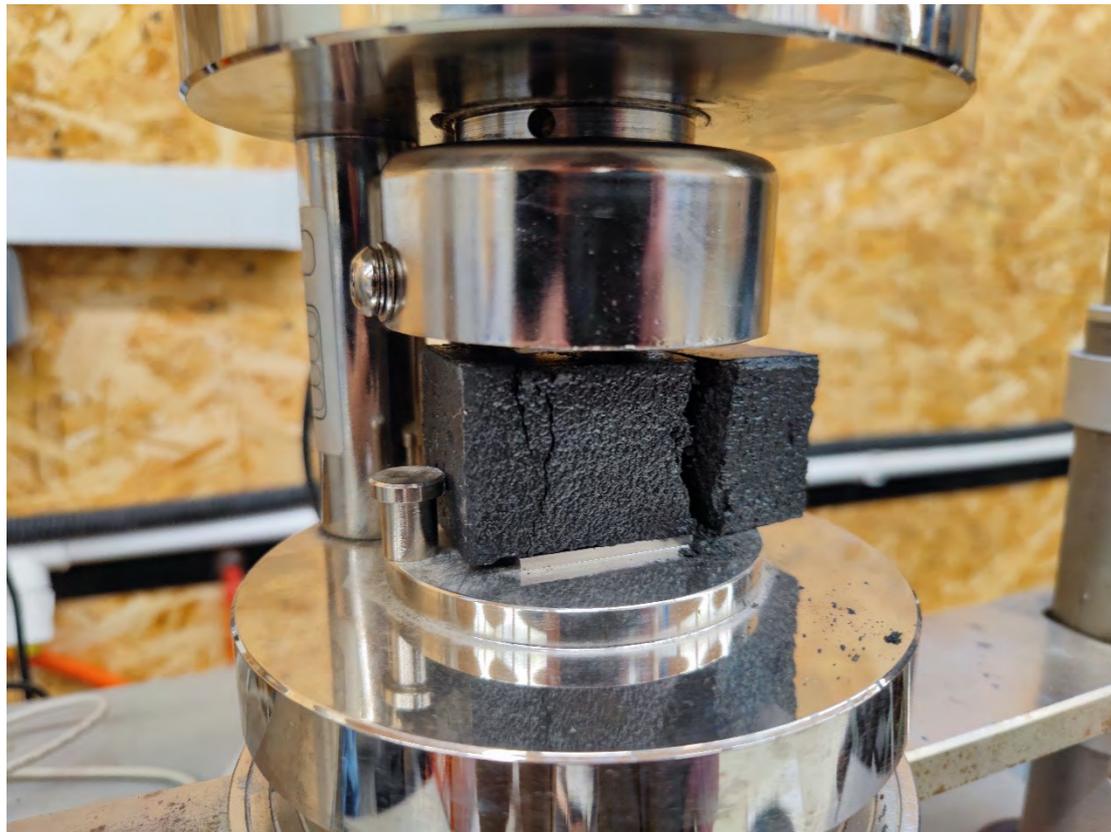
**4 hours 50 minutes  
non-stop 3D printing**

# 3D Printing Process



# Test Results

# Strength Test



## GP Lightweight material 1500 kg/m<sup>3</sup>

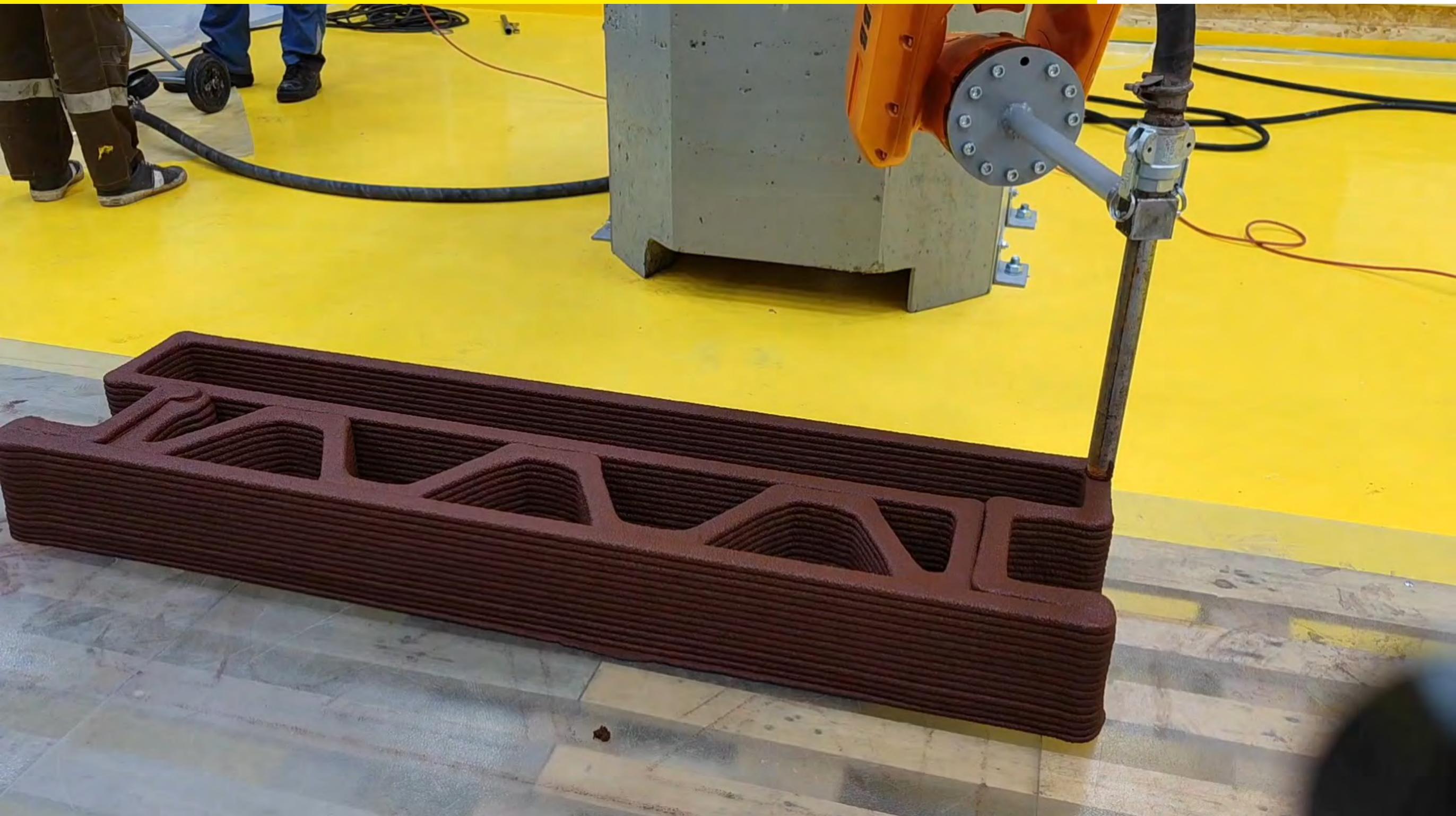
3 days:  $R_c = 4,9$  MPa;  $R_f = 1,0$  MPa;  
7 days:  $R_c = 16,0$  MPa;  $R_f = 3,3$  MPa;  
28 days:  $R_c = 25,4$  MPa;  $R_f = 4,5$  MPa;

## GP Mortar 2200 kg/m<sup>3</sup>

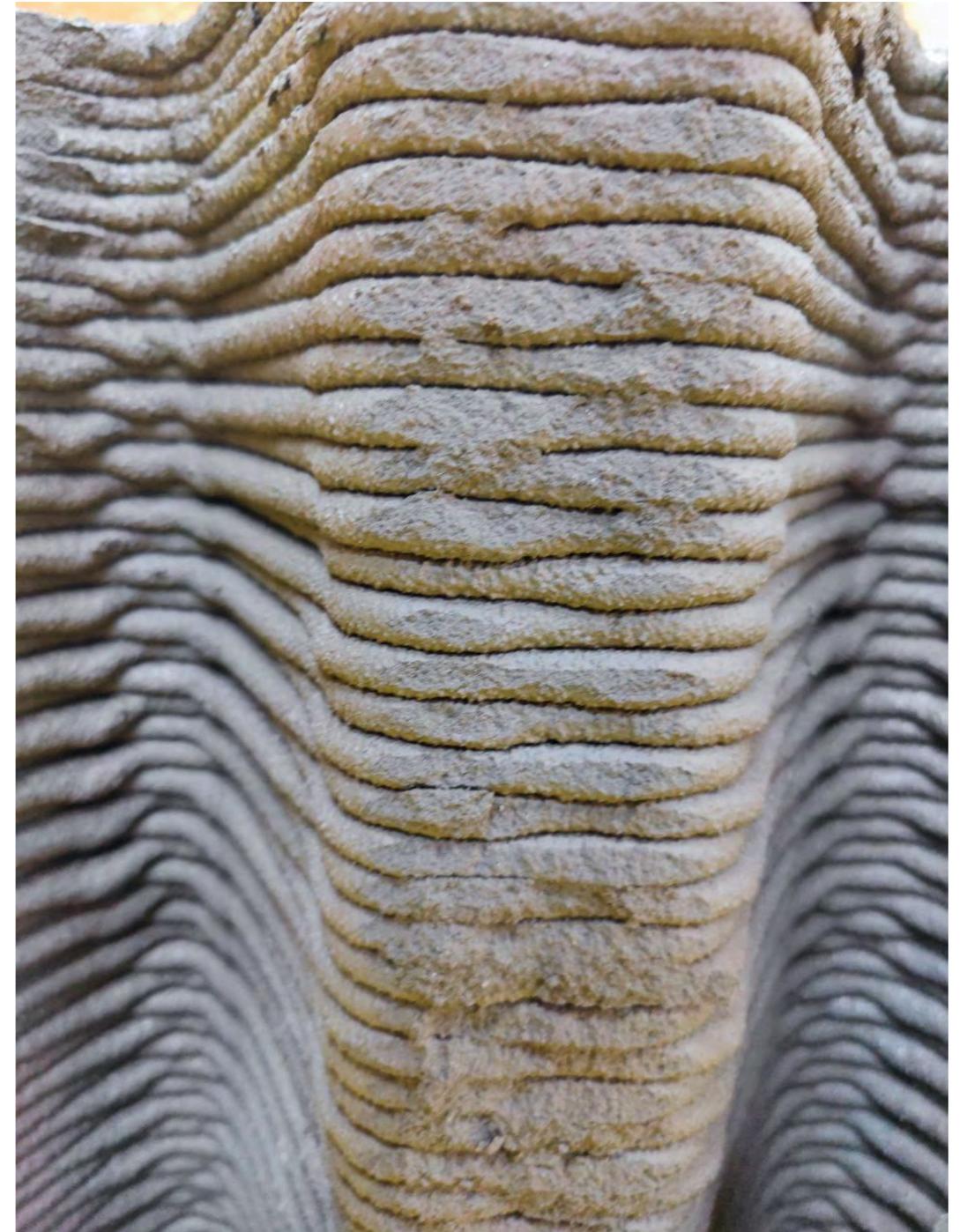
3 days:  $R_c = 16,6$  MPa;  $R_f = 3,2$  MPa;  
7 days:  $R_c = 24,2$  MPa;  $R_f = 4,1$  MPa;  
28 days:  $R_c = 57,6$  MPa;  $R_f = 6,2$  MPa;

# Failures

# Wall Failure



# Side Connections and Overlapping



# Cracks Caused by Disturbance of Concrete



# **Why Geopolymer Mortar is Perfect Material for Construction 3D Printing?**

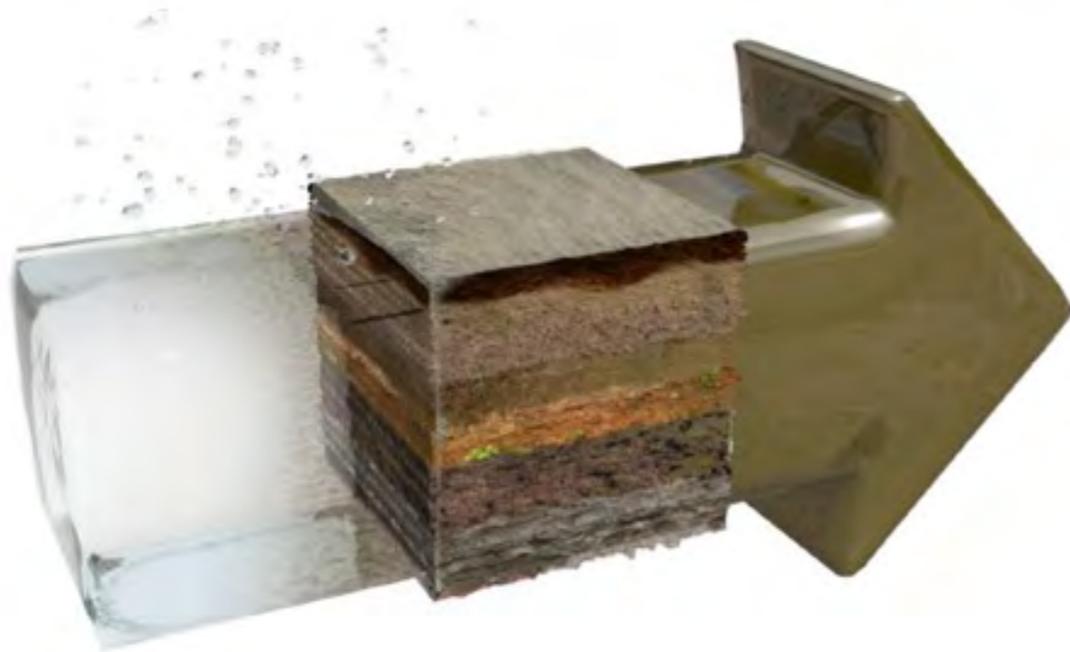
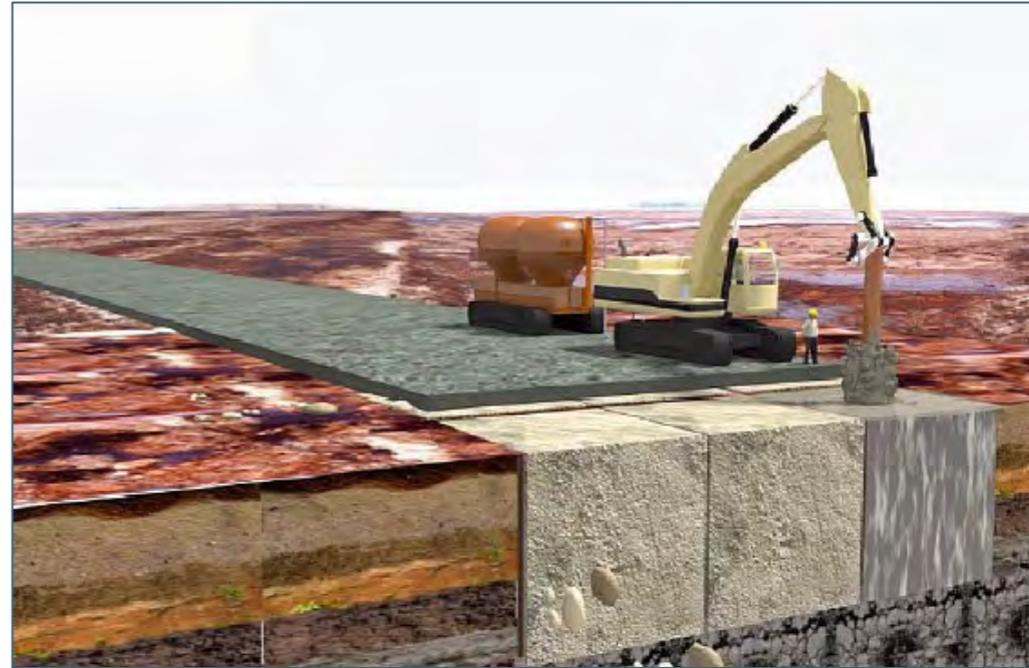
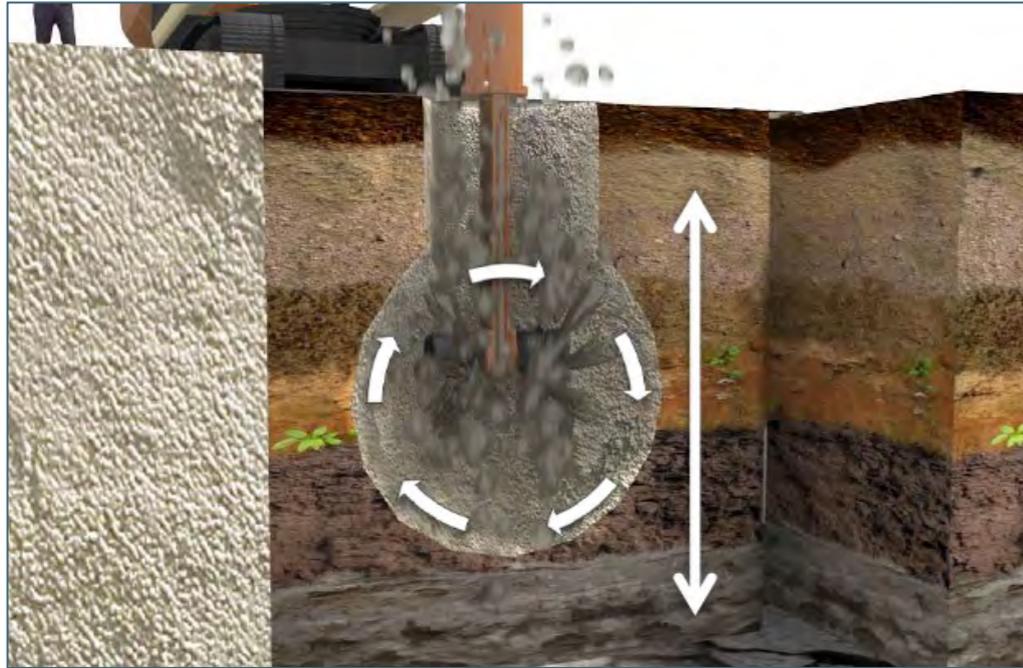
# Advantages of RENCA 3D ink

The only ink for construction 3D printing based on green and eco-friendly geopolymers technology available for commercial application.



# Recent Projects

# Chemical Waste Entrapment



# Chemical Waste Entrapment



# Chemical Waste Entrapment



# Chemical Waste Entrapment

Defined element	Before stabilization	Stabilized sample
<b>Benz(a)pyrene</b> , mg/kg	0.079±0.022	<0.005
<b>Aluminum</b> , mg/kg	89466±23261	56932±14802
<b>Sulfur</b> , mg/kg	12269±3681	8933±2680
<b>Cadmium</b> , mg / kg	<0.05	<0.05
<b>Manganese</b> , mg / kg	576±173	274±82
<b>Copper</b> , mg / kg	79±16	7.1±1.4
<b>Nickel</b> , mg / kg	<b>22.3±7.8</b>	<b>&lt;0.1</b>
<b>Lead</b> , mg / kg	<b>11.1±2.8</b>	<b>&lt;0.1</b>
<b>Chromium</b> , mg / kg	<b>51±10</b>	<b>&lt;0.1</b>
<b>Zinc</b> , mg / kg	102±20	18.5±3.7
<b>Magnesium</b> , mg / kg	4436±1331	5959±1788

Defined element	Before stabilization	Stabilized sample
<b>Mercury</b> , mg / kg	<b>0.298±0.095</b>	<b>&lt;0,02</b>
<b>Hydrogen index (pH) of water extract</b> , Unit , pH	7.66±0.10	10.8±0.10
<b>Mass fraction of moisture</b> , %	87.57±6.13	14.0±1.4
<b>Volatile phenols</b> , mg / kg	0.31±0.6	0.29±0.6
<b>Ammonium nitrogen</b> , mg / kg	259±28	12±1
<b>Nitrate nitrogen</b> , mg / kg	2.8±0.9	23±5
<b>Nitrite nitrogen</b> , mg / kg	<0.037	0.40±0.16
<b>Oil products</b> , %	0.30±0.13	0.054±0.023
<b>Chlorides</b> , mg / kg	133±13	102±10

Based on the results of the data obtained as part of the tests, it can be concluded that toxic substances are reliably encapsulated. Thus, the content of benzo(a)pyrene decreased 15 times, copper - 10 times, nickel - more than 200 times, lead - 100 times, chromium - 500 times.

# RENCA services

# HOW WE WORK?

If you are interested in developing of geopolymer products based on local raw materials, RENCA can provide you *various services*:



## ✓ Studying raw materials

Thanks to our geologists-mineralogists we study locally available raw materials, that has potential to be used in geopolymer cement and concrete production. We collect samples and do research: we check chemical and mineralogical composition, particle distribution and other physical and mechanical properties.

### Fly-ash type F

#### Mineralogical composition:

The mineralogical composition of fly-ash is presented by amorph phase (63-65%), the crystalline phase is represented by mulite (31%), graphite (3%), hematite (1%) and quartz (2%).



#### Particle distribution, $\mu\text{m}$ :

Median diameter  $d_{50}$  less than 21  $\mu\text{m}$



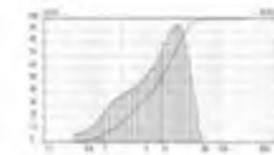
#### Chemical composition:

$\text{Al}_2\text{O}_3$	$\text{SiO}_2$	$\text{Fe}_2\text{O}_3$	$\text{TiO}_2$	$\text{MgO}$	$\text{MnO}$	$\text{K}_2\text{O}$	$\text{Na}_2\text{O}$	$\text{CaO}$	LOI
28,27%	59,00%	5,22%	1,25%	0,68%	0,12%	0,60%	0,62%	1,75%	2,14%

### GGBS ground granulated blastfurnace slag

#### Mineralogical composition:

The mineralogical composition of GGBS is presented by amorph phase (97-98%), the crystalline phase is represented mainly by melilite (2.0-3.0%).



Particle distribution,  $\mu\text{m}$ :  
Median diameter  $d_{50}$  less than 11  $\mu\text{m}$

#### Properties:

Beige powder  
H<sub>2</sub>O content — less 0,1%  
Specific area (BET) — 4500-5000  $\text{cm}^3/\text{g}$   
Bulk density — 1,14  $\text{t}/\text{m}^3$

#### Chemical composition:

$\text{Al}_2\text{O}_3$	$\text{SiO}_2$	$\text{Fe}_2\text{O}_3$	$\text{TiO}_2$	$\text{MgO}$	$\text{MnO}$	$\text{K}_2\text{O}$	$\text{Na}_2\text{O}$	$\text{CaO}$	LOI
12,27%	38,16%	0,67%	1,63%	10,34%	0,67%	0,76%	0,44%	34,92%	< 0,10%

## ✓ Developing new recipes

Based on our expertise in geopolymers, we are developing new or adjusting existing recipes to current raw materials.



“ new recipes  
to current  
raw materials ”

## ✓ Testing new products

When the recipe is ready and has passed initial tests, we start the series of testing, such as:

- compressive, flexural, tensile and bending strength;
  - freeze-thaw cycles;
  - water resistance;
  - acid resistance;
  - heat and fire resistance;
- and other types of testing, that are particular for specific type of product.

### ACID RESISTANT GEOPOLYMER CONCRETE



After 28 days in  
10% Sulphuric  
Acid Solution:

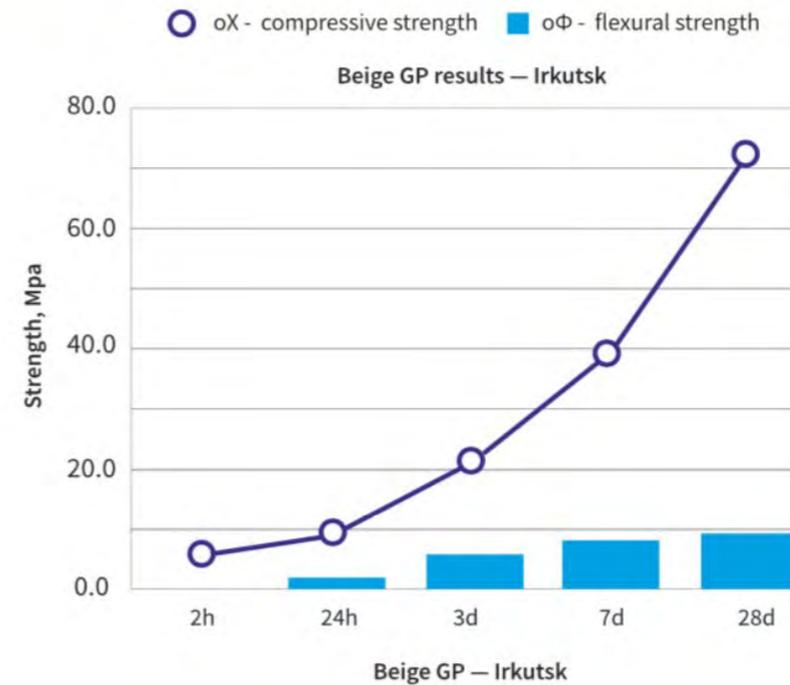
**OPC**  
40% weight loss  
70% Strength loss

**GPC**  
0% weight loss  
0% strength loss

## PROPERTIES OF BEIGE MK-750 BASED GP CONCRETE:

### Properties:

- Setting time: from 90 to 115 min. (at 18 °C in Irkutsk warehouse)
- Viscosity – thixotropic (shock table test)
- Density 2,0 g/cm<sup>3</sup>.
- Ability to harden at - 20 °C (after defrost for 2 hours in 20°C):
- 24h flexural strength: 1,0 MPa;
- Compressive strength: 5,2 MPa
- Freeze-thaw resistance: 500 cycles
- Water resistance: W16



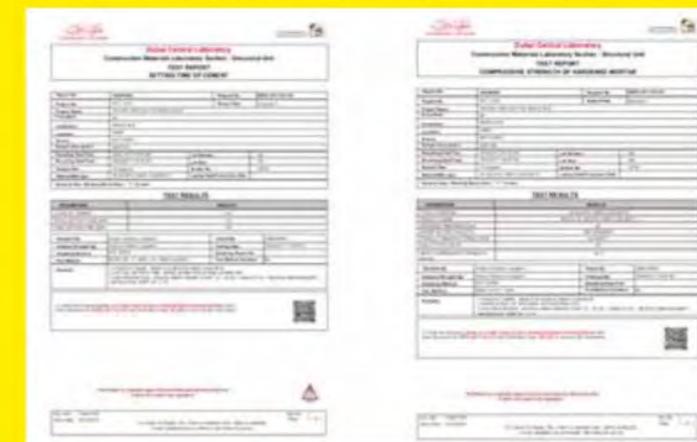
Age	oX, HPa	oΦ, MPa
2 h	4,2	0,0
24 h	9,2	2,1
3 d	21,1	5,8
7 d	39,7	8,8
28 d	72,3	9,6

## ✓ Verification in external lab and certification

When needed we do verification of our test results in external laboratories and certification centers.



### DUBAI CENTRAL LABORATORY CERTIFICATION TEST RESULTS:



# RENCA products

# Ready to Use RENCA Products



**geopolymer  
cement and  
geopolymer  
reagent  
geosilicate**

# Repair Mortars

RENCA GP Repair mortars can be used for various applications:

- airport tracks repair;
- road repair;
- wall repair;
- structural repair.

RENCA GP Repair mortars have high performance with improved properties for higher thickness of layer (more than 2 cm) and designed for both hot temperatures +25°C and above and severe cold temperatures down to -20°C.

These recipes reduce shrinkage and increase mechanical properties in terms of flexural strength and traction. Thanks to unique adhesive properties of geopolymer concrete – it can be applied almost on any surface. Some compositions provide fast setting time and, in few hours, can hold the load.

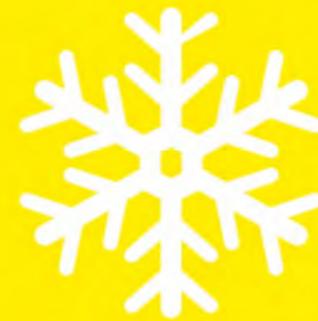
” reduce shrinkage and  
increase mechanical  
properties “



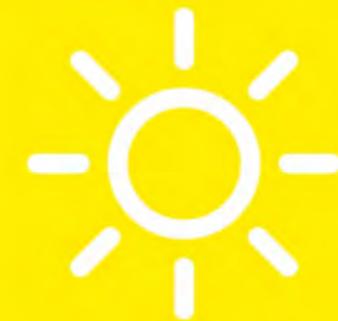
# 3D Printing Mortars

RENCA 3D GP cement is a batching type of mortar for construction 3D printing with fixed setting time and has two basic modifications:

- winter for temperature + 10°C;
- summer for temperatures +28...+35°C.



+ 10°C



+28...+35°C

*Depending on the request the recipe can be adjusted according to technical requirements of the customer.*

# RENCA Local Stocks



# RENCA equipment

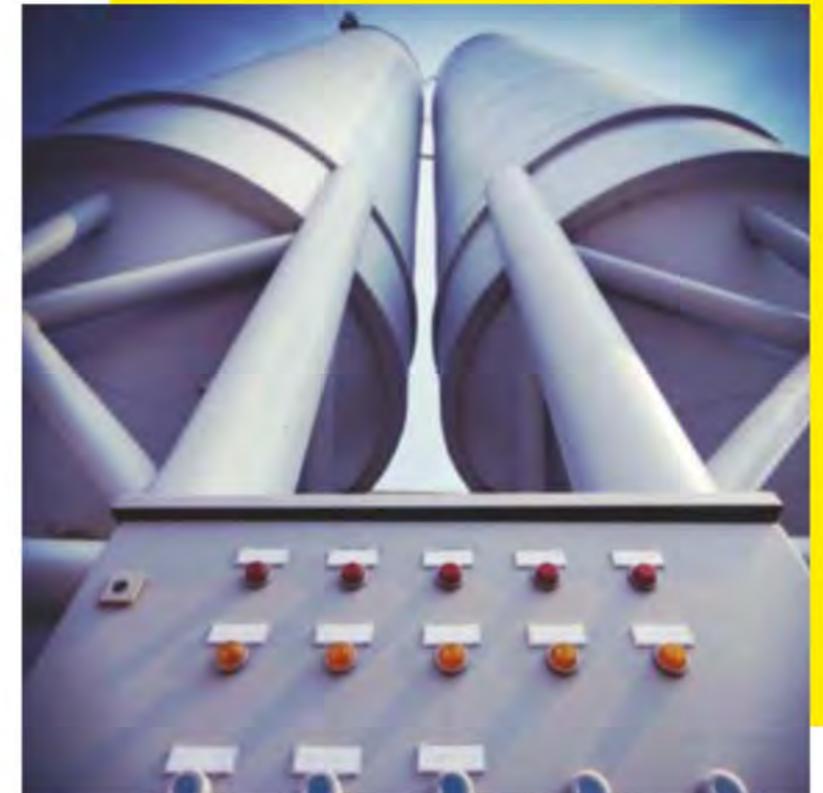
# Equipment Manufacturing and Supply

RENCA in cooperation with its Italian partners is ready to provide a range of equipment for full-scale production of geopolymer cement, geopolymer concrete and construction 3D printing.

## Geopolymer cement production plant

Geopolymer technology completely corresponds to the concept of green building by optimizing energy efficiency of the buildings, preserving natural resources and at the same time utilizing the by-products of other industries, thus decreasing the CO<sub>2</sub> emissions.

Amount of investments in geopolymer cement plant is 10 times less in comparison to Portland cement production plant. RENCA supply turn key solution for geopolymer cement production depending on the desired capacity of the plant. We adjust standard recipes for geopolymer cement production based on local raw materials.



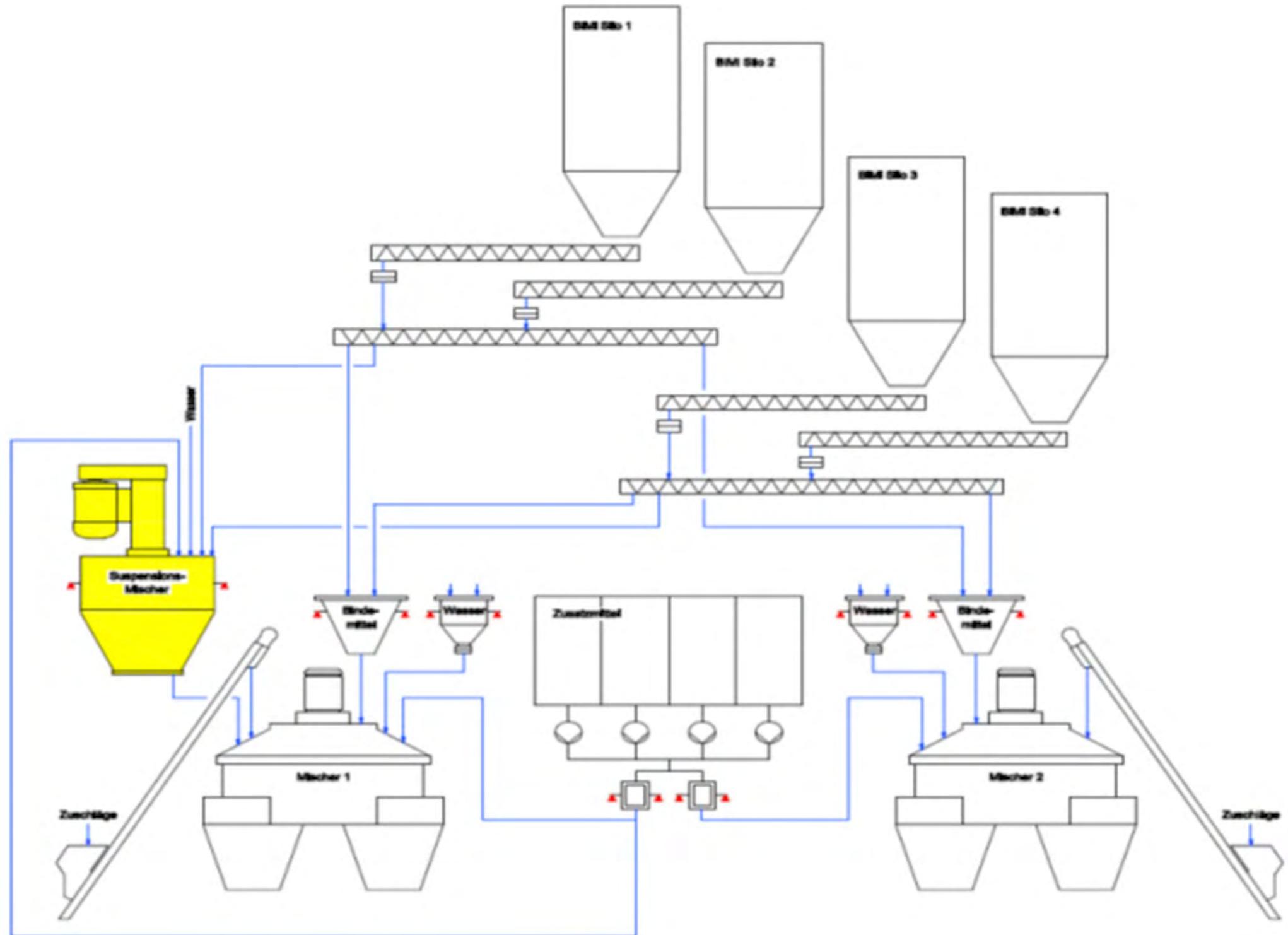
# Mobile Concrete Plants



# Laboratory mixers



# Integration of geopolymer binder mixing unit into existing concrete batching plant



# 3D Printing Solutions



# Partners and Clients

# PARTNERS AND CLIENTS



# CONTACTS

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