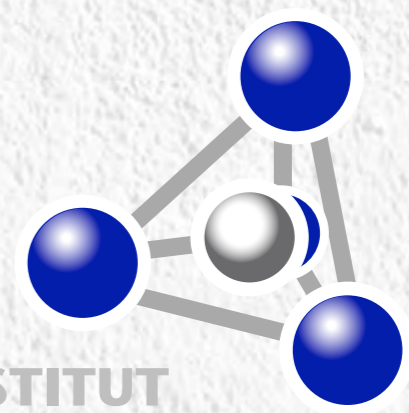


Geopolymer Concrete as 3D printing material: advantages & challenges

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Andrey Dudnikov & Alex Reggiani

RENCA Inc



INSTITUT
GÉOPOLYMÈRE



Construction 3D printing



Advantages of Construction 3D Printing

Today there are two main tendencies that become more and more popular: customized solutions and innovative materials with low environmental impact.

1 Eco-friendly

2 Integrated supply lines

3 Low costs



Advantages of Construction 3D Printing

4 No need for expensive molds

5 Automatization

6 New markets



Advantages of Construction 3D Printing

7 Faster project's implementation

8 Decreasing the volume

9 Reduction of the weight



Requirements towards materials for 3D printing can be challenging for OPC or gypsum based systems

3D printing mortar **MUST** have the following properties:

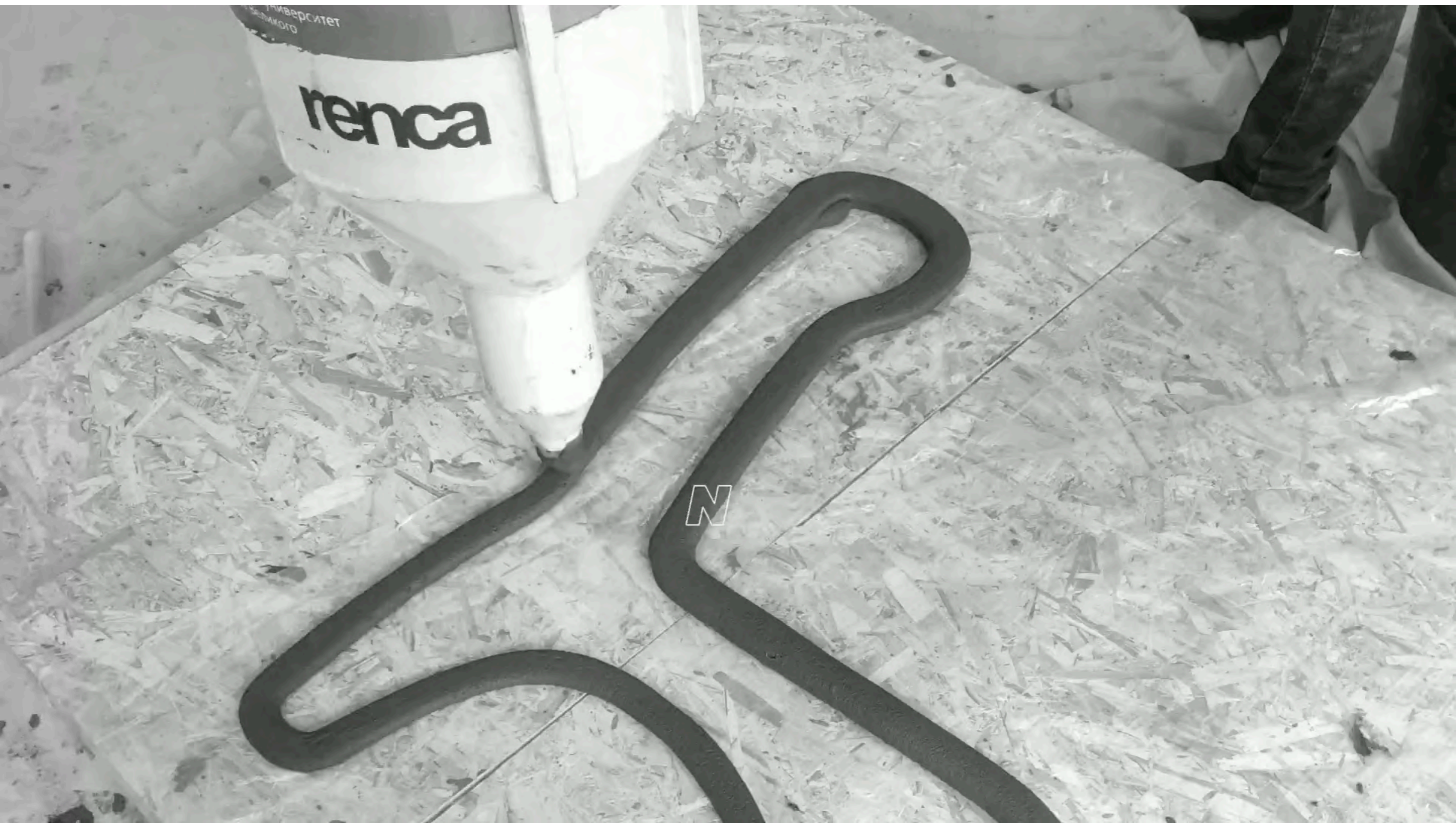
1. Fast hardening and strength grow
2. Tixotropy, shape hold
3. No shrinkage, no cracks
4. No cold joints between layers even after hardening
5. Structural final strength
6. Compatibility with steel reinforcement
7. Pumpability
8. Neutral carbon footprint

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.

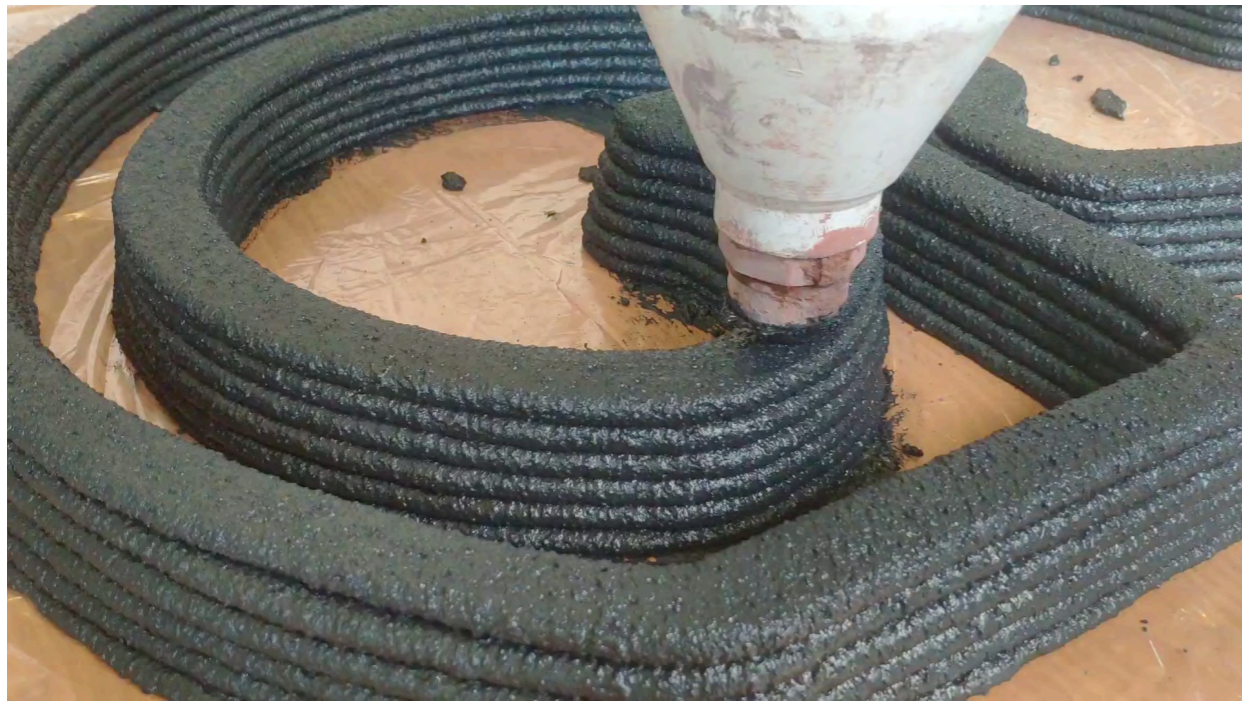






POLYTECH

Peter the Great
St. Petersburg Polytechnic
University



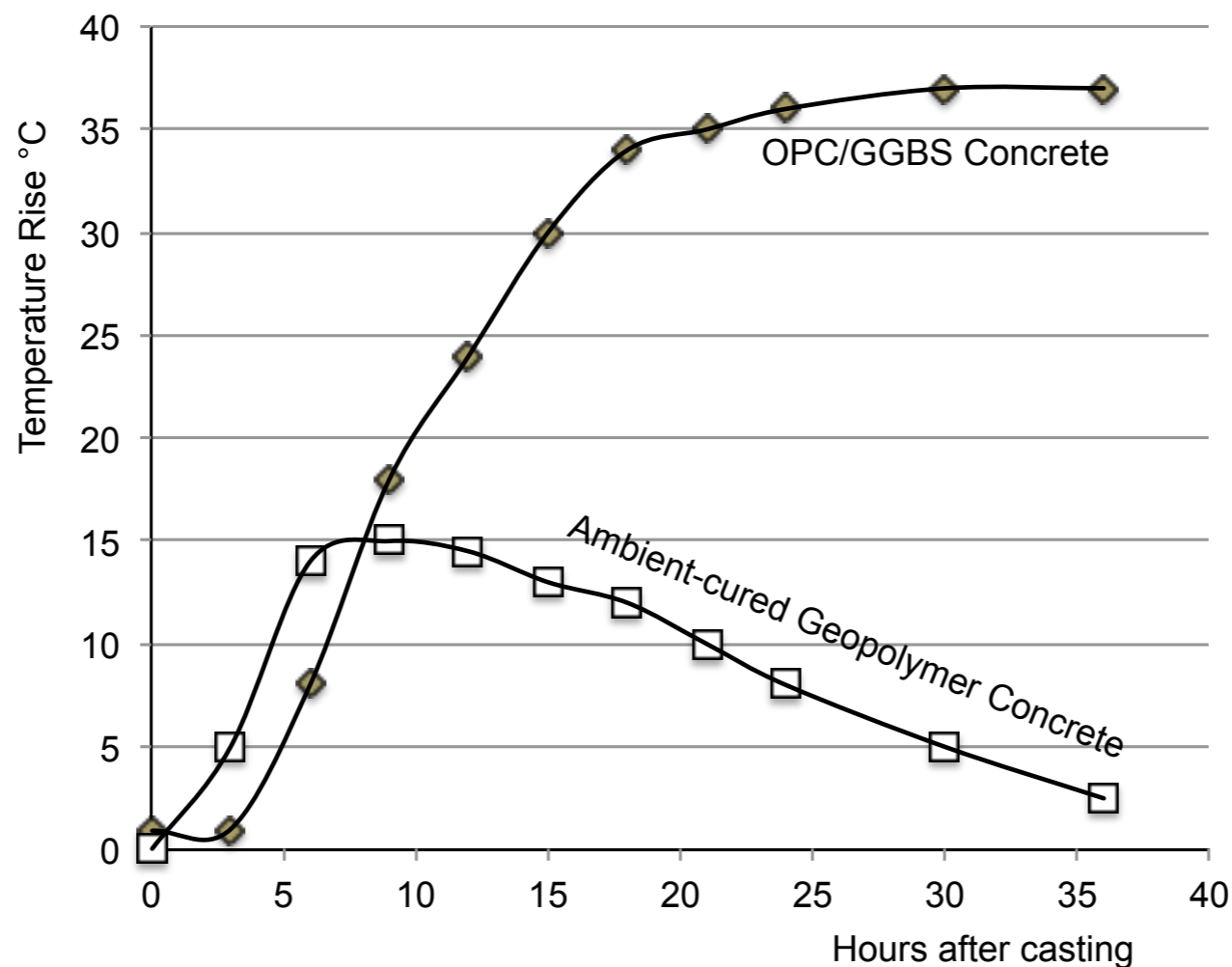
Recent Projects

Geopolymer precast railroad ties



Preserving the permafrost in Siberia

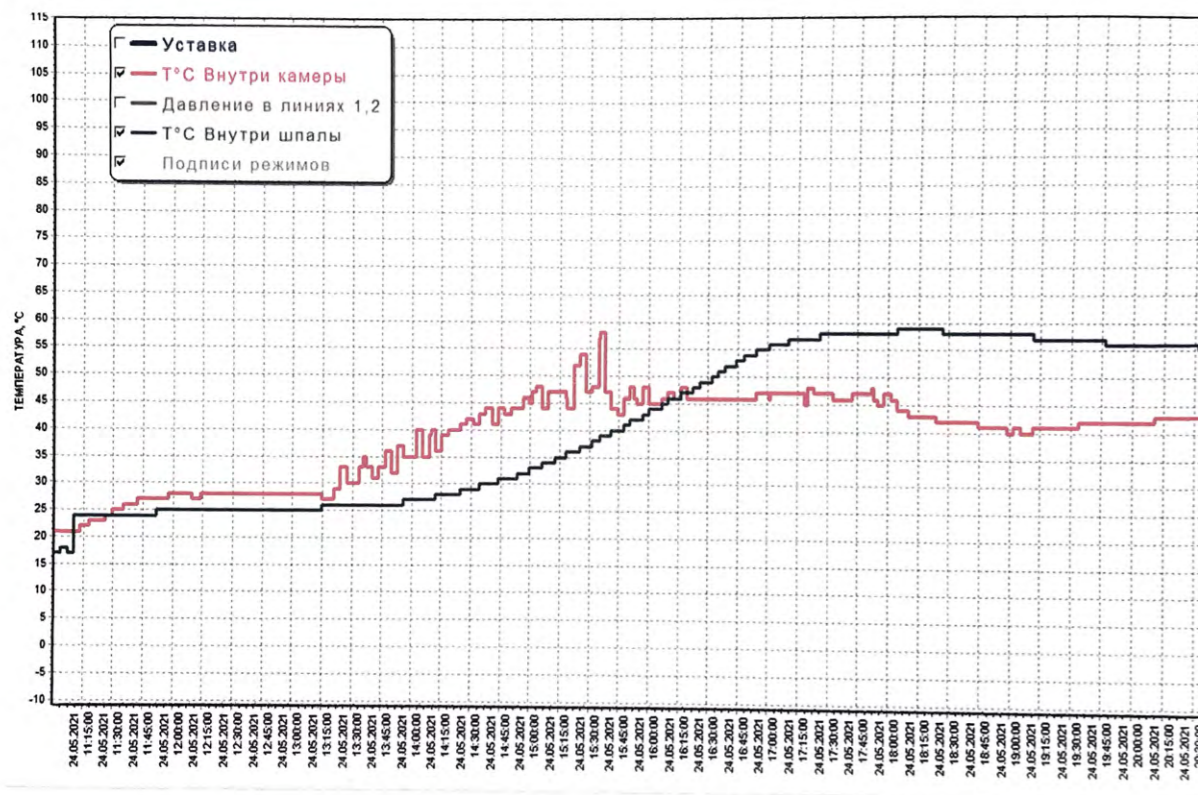
Cooperation with the Institute of Permafrost science, Yakutsk, Russia for studying the heat of reaction of geopolymer concrete.



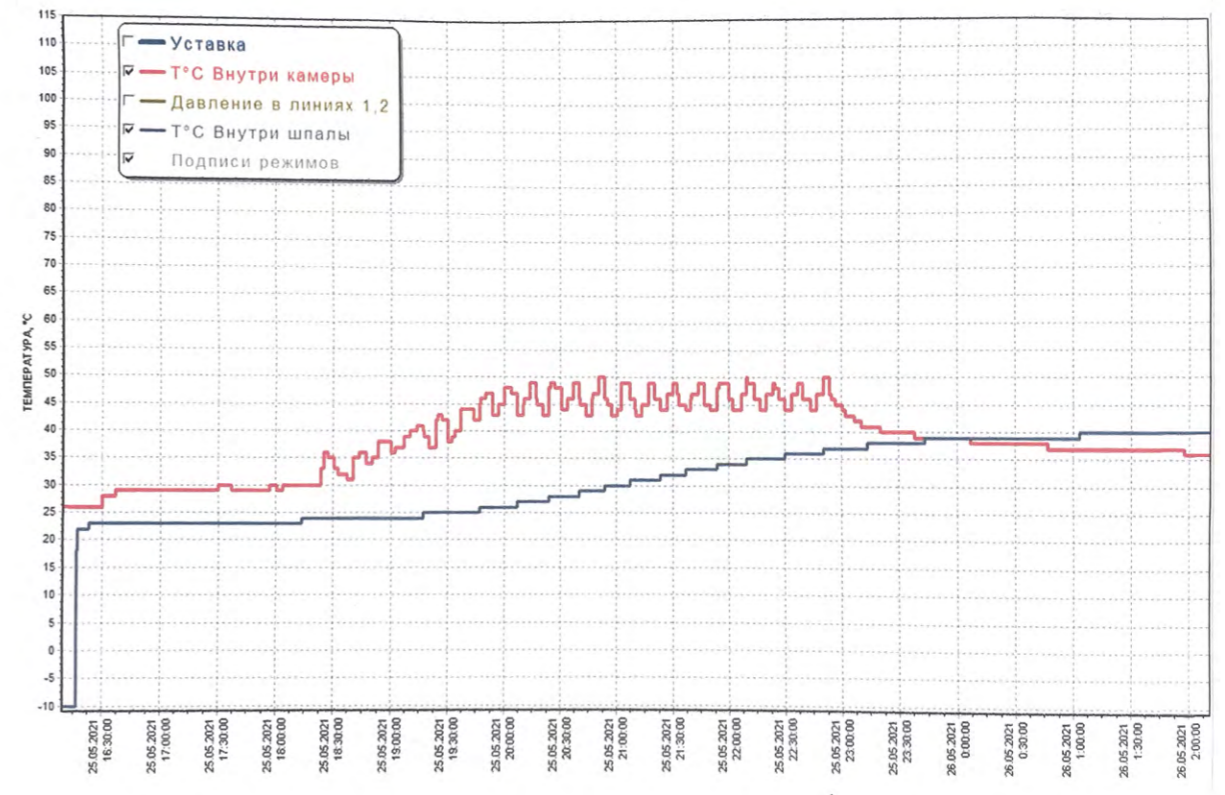
Chapter 25. Geopolymer Chemistry and Application - J. Davidovits

Heat of Reaction of Geopolymer Concrete

Heat of reaction inside OPC based concrete (to the left) and Geopolymer cement based concrete (to the right) in the steam curing chamber



OPC Based
Total temperature increase 40°C

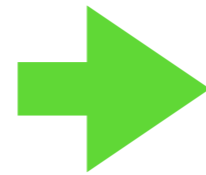


Geopolymer Cement Based
Total temperature increase 15°C

Chemical Waste Entrapment



Salts and gypsum



Building blocks

Promoting Geopolymer Science

Russian edition of the Geopolymer book by professor Joseph Davidovits



Available next year



Challenges of scale

Materials for small-scale and laboratory mixing

Binder components:

White Metakaolin	0,6-0,7 EUR/kg
Pure Al ₂ O ₃	2-3 EUR/kg
MgO	5-10 EUR/kg
White microsilica	1,0-3,0 EUR/kg
Microsilica	0,3-0,5 EUR/kg
Fly-Ash	0,2-0,8 EUR/kg
GGBS	0,3-0,5 EUR/kg

Fillers:

Fillite (microspheres)	1-2 EUR/kg
Pure sand with specific granulometry	0,5-1 EUR/kg
Dry sand	0,15 - 0,3 EUR/kg

Silicates:

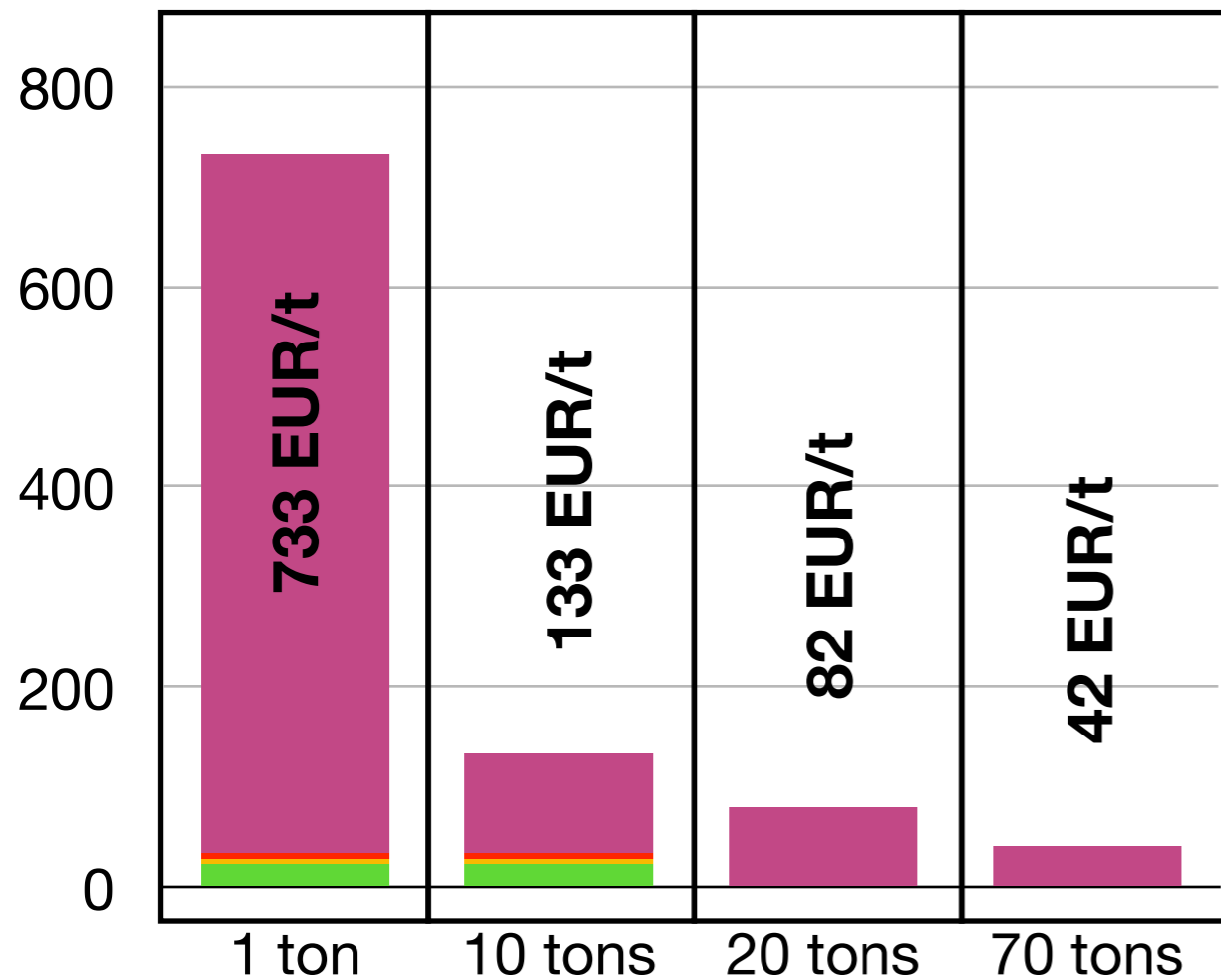
Extra-pure soluble silicates K, Li, Na based 2,2 - 5,0 EUR/kg

TOTAL cost of geopolymer mortar: 3-10 EUR/kg

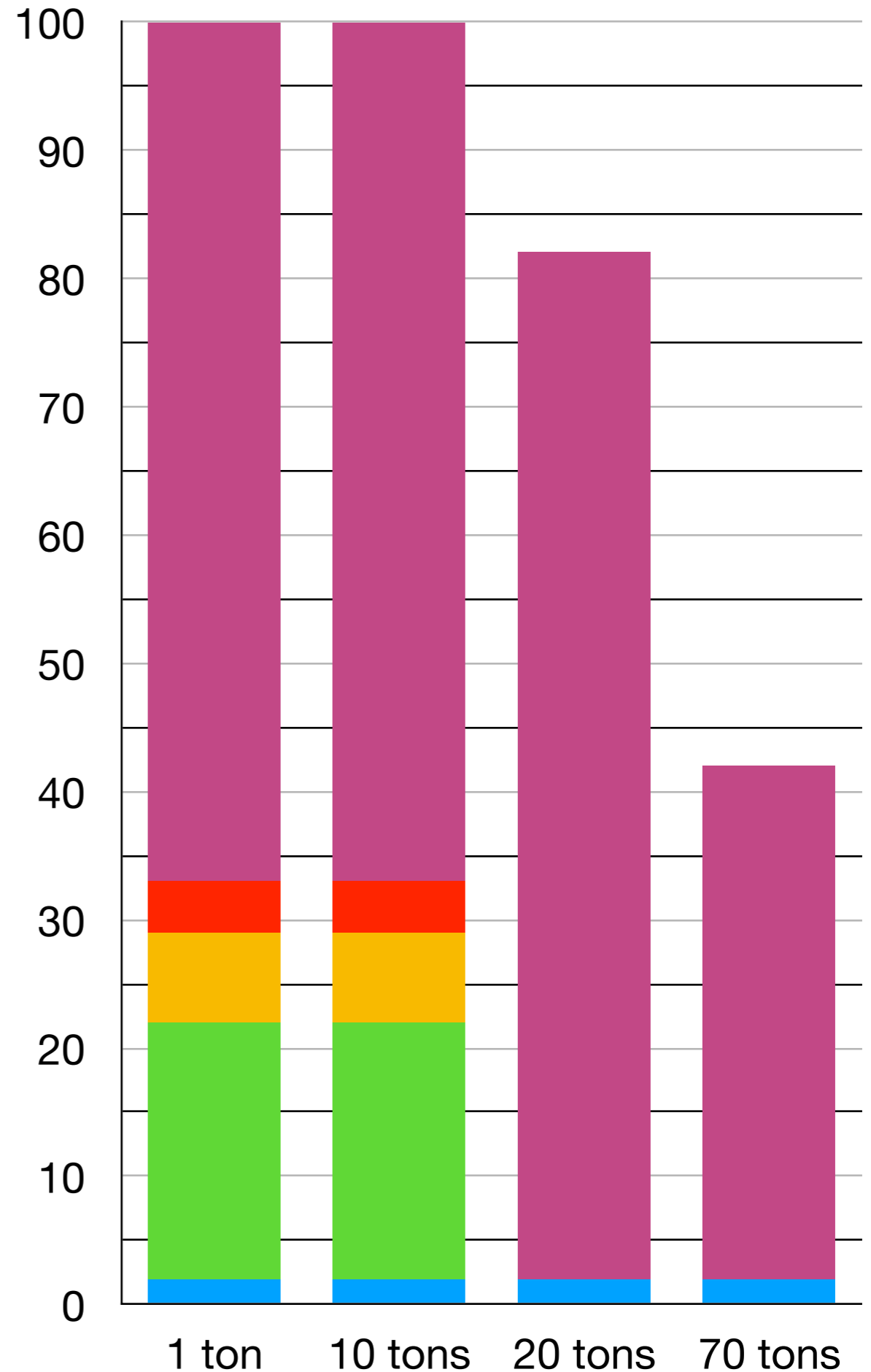
Transportation costs

- Delivery to production site
- Profit of P&H Partner
- Delivery to P&H site
- Packing and Handling (P&H)
- Cost of Fly-Ash

LAB SMALL MED. IND.



Cost per ton in EUR



Certification of Products

Cooperation with local institutes



Dubai Central Laboratory
Construction Materials Laboratory Section - Structural Unit
TEST REPORT
COMPRESSIVE STRENGTH OF HARDENED MORTAR

Report No:	100064593	Request No:	EMTX-2017-021167
Project No:	PS17-1076	Report Date:	06/05/2017
Project Name:	TESTING SERVICE FOR RENCA RUS		
Consultant:	NA		
Contractor:	RENCA RUS		
Location:	DUBAI		
Source:	NOT GIVEN		
Sample Description:	MORTAR		
Sampling Date/Time:	05/04/2017 08:00 AM	Lot Number:	NG
Receiving Date/Time:	05/04/2017 08:00 AM	Lot Size:	NG
Sample Size:	16 kilogram	Sender No:	GP3D
Material/Mix type:	3D GEOPOLYMER CONCRETE	Laying Date/Production Date:	

Nominal Size / Working Block Size L * T * H (mm) :

TEST RESULTS

PARAMETERS	RESULTS		
TYPE OF MORTAR	3D GEOPOLYMER CONCRETE		
PRODUCT NAME	RENCA 3D GEOPOLYMER CONCRETE		
SPECIMEN DIMENSION (mm)	40		
WATER RATION (VOL/WT)%	SEE REMARKS		
PRODUCT MANUFACTURING DATE	05/04/2017		
AGE AT TEST (DAYS)	28		
MEAN COMPRESSIVE STRENGTH, N/mm ²	46.3		
Sampled By:	Andrey Dudnikov (supplier)	Tested By:	JVBRIONES
Samples Brought By:	Andrey Dudnikov (supplier)	Testing Date:	05/04/2017 09:00 AM
Sampling Method:	NOT GIVEN	Sampling Report No:	
Test Method:	BSEN 1015-11:1999	Test Method Variation:	NIL
Remarks:	1- PRODUCT NAME : RENCA 3D GEOPOLYMER CONCRETE 2- DEMOULDING OF SPECIMEN AFTER 60 MINUTES 3- MIX PROPORTION : GEOPOLYMER CEMENT (PART A) - 30.9% + SAND 57.4% + GEOPOLYMER REAGENT - GEOSILICATE (PART B) 11.7%		

To verify this document please go to <http://login.dm.gov.ae/wps/portal/documentverification> and Enter Document ID: **EMTX-2017-021167** and Verification Code: **091-287** or scan the QR code below.



This Report is computer approved and authorized by Structural Unit
It does not require any signature

Logistics Challenges

RENCA international sales



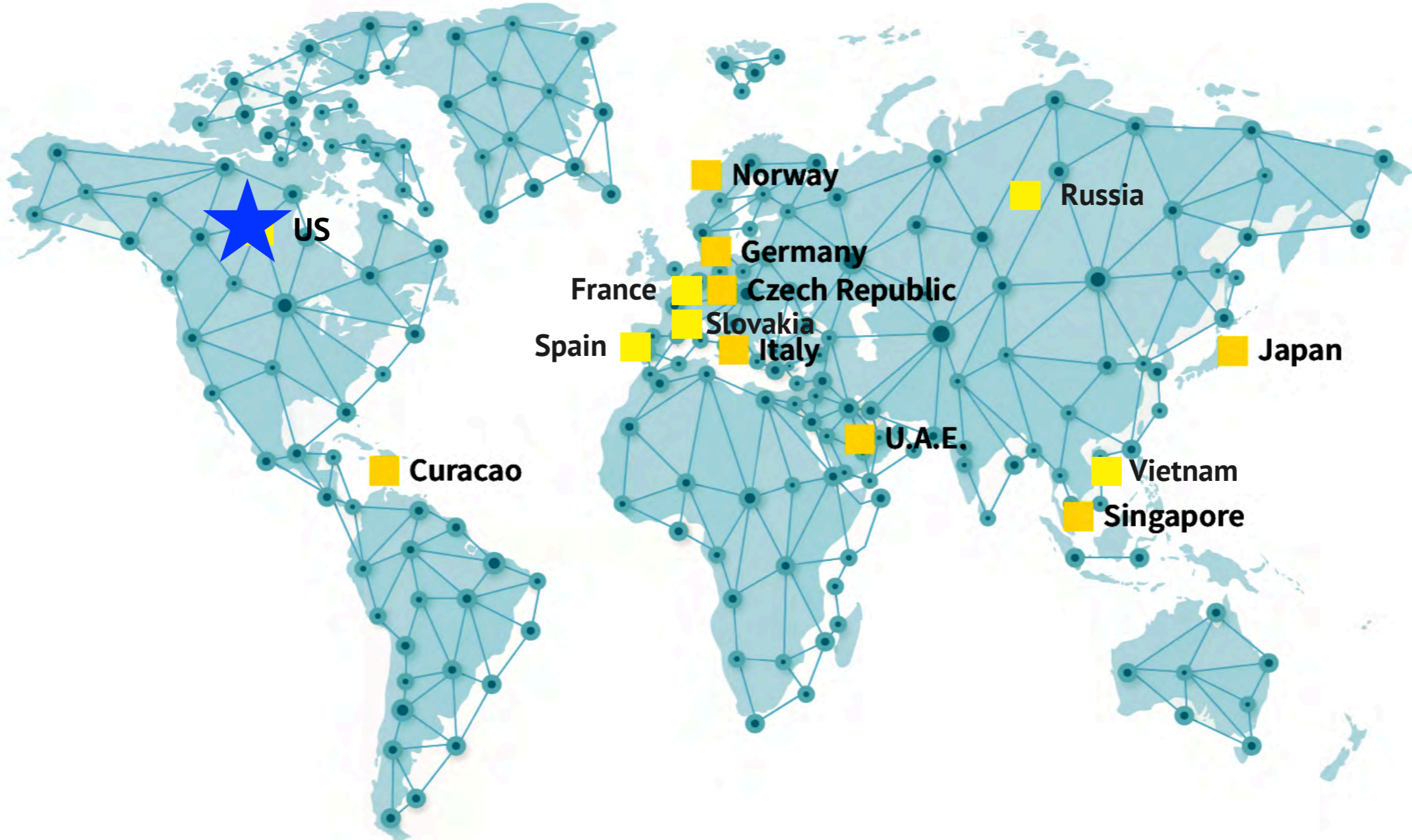
Logistics Challenges

- High cost
- Long time of delivery
- Import / export taxes
- Geopolitical issues
- Not in comply with LCA

There is a need for local production!

Franchise network!

RENCA franchise network



RENCA franchise network

RENCA DELIVERS THE ALL-IN-ONE SOLUTION:

The complete system for **geopolymer cement** production **3D printers** and automatic mixing system for concrete.

Technology for production a wide range of **sustainable products** based on local raw materials.

RENCA franchise network

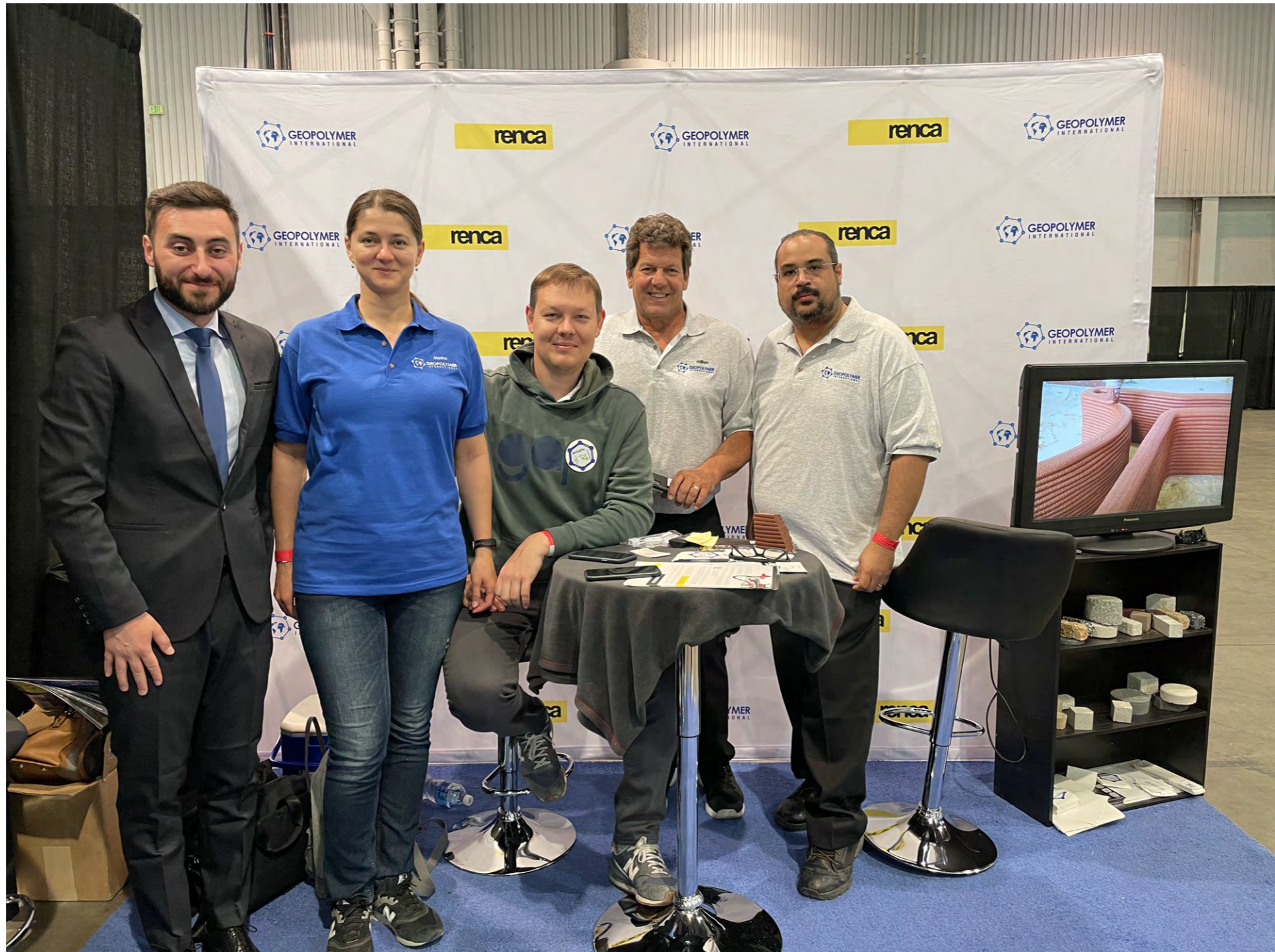
- Raw materials R&D
- Development of products
- Technical support
- Initial/ongoing training
- Equipment supply
- Marketing



RENCA local stocks



RENCA is available in the USA



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

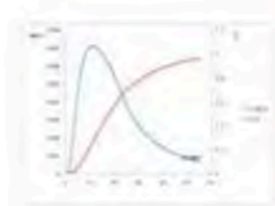
Mineralogical composition:

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, μm :

Median diameter d_{50} less than 21 μm



Chemical composition:

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	MgO	MnO	K_2O	Na_2O	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, μm :
Median diameter d_{50} less than 11 μm

Properties:

Beige powder

H₂O content — less 0,1%

Specific area (BET) — 4500-5000 cm^3/g

Bulk density — 1,14 t/m^3

Chemical composition:

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	MgO	MnO	K_2O	Na_2O	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:

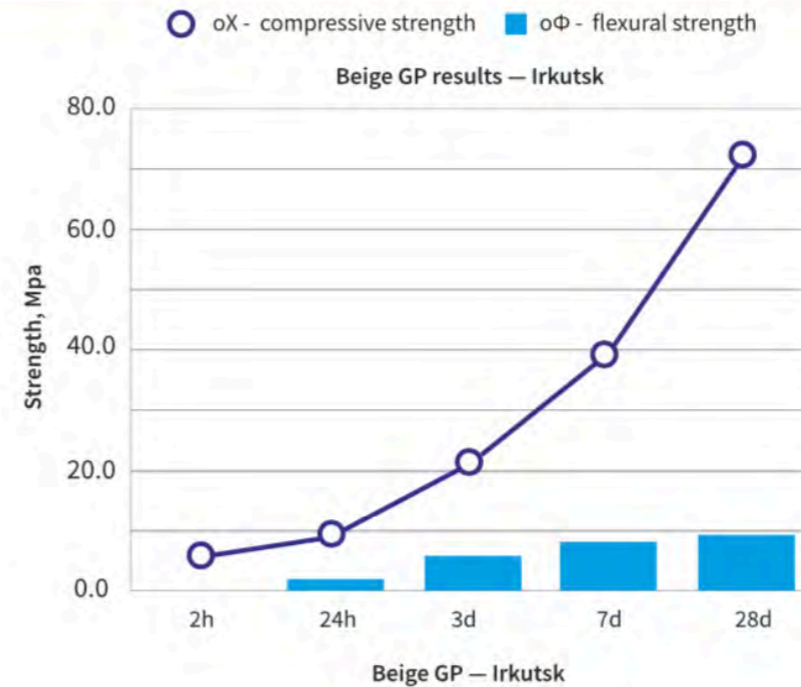
OPC
40% weight loss
70% Strength loss

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/cm³.
- 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 Supply



**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 “



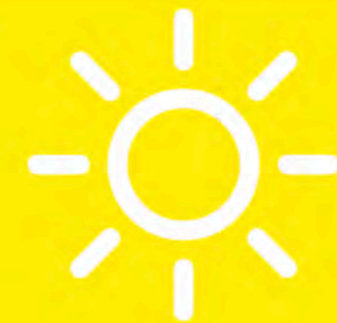
3D Printing Mortars

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 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 CO₂ emissions.

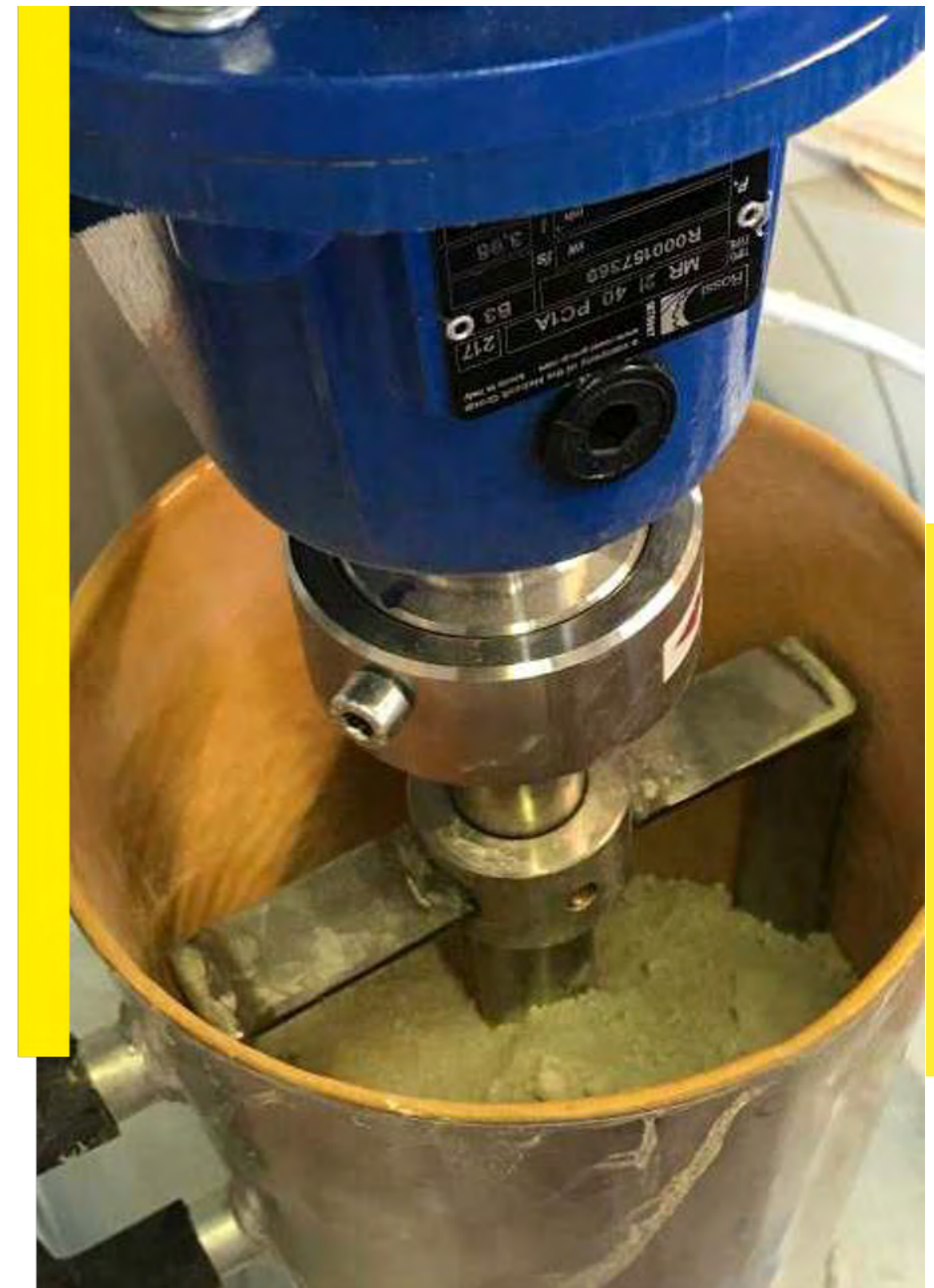
Amount of investments in geopolymer cement plant is 10 times less in comparison to Portland cement production plant. RENCA supply turn key solution for geopolymer cement production depending on the desired capacity of the plant. We adjust standard recipes for geopolymer cement production based on local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



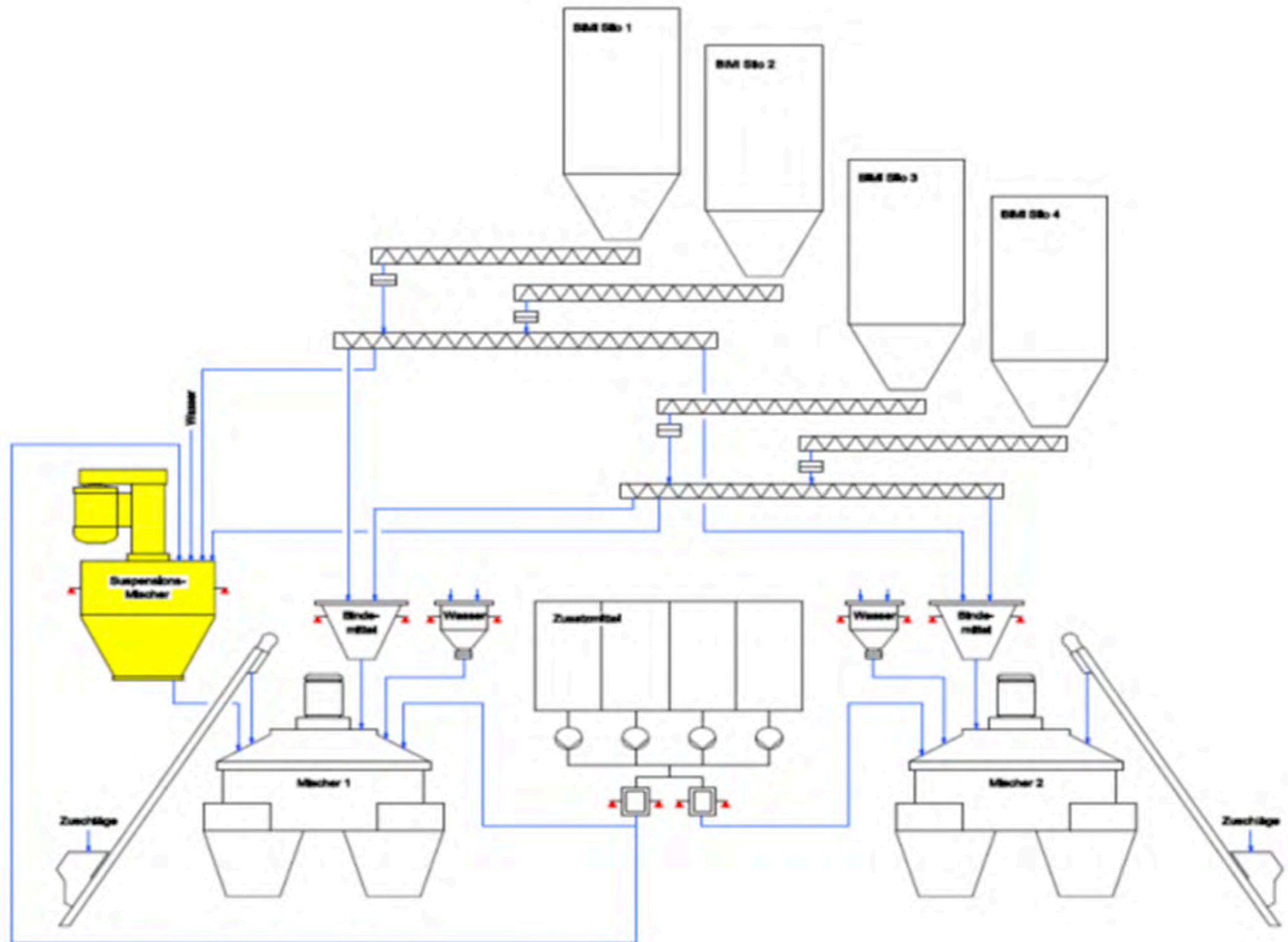
Mobile Concrete Plants



Laboratory mixers



Integration of geopolymer binder mixing unit into existing concrete batching plant



Construction 3D Printers



Extruders



Linear rails for 3D printers



Continuous tracks



Partners and Clients

PARTNERS AND CLIENTS



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