Geopolymer Concrete as 3D printing material: advantages & challenges

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RENCA Inc
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

- Faster project’s implementation
- Decreasing the volume
- Reduction of the weight

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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. Tixothropy, 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 geopolymer technology available for commercial application.
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

Cost per ton in EUR

<table>
<thead>
<tr>
<th>1 ton</th>
<th>10 tons</th>
<th>20 tons</th>
<th>70 tons</th>
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<tbody>
<tr>
<td>733 EUR/t</td>
<td>133 EUR/t</td>
<td>82 EUR/t</td>
<td>42 EUR/t</td>
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Cooperation with local institutes

TEST REPORT

COMPRESSIVE STRENGTH OF HARDENED MORTAR

<table>
<thead>
<tr>
<th>REPORT NO.</th>
<th>REPORT DATE</th>
<th>PROJECT NO.</th>
<th>PROJECT NAME</th>
<th>CONSULTANT</th>
<th>CONTRACTOR</th>
<th>LOCATION</th>
<th>SOURCE</th>
<th>SAMPLE DESCRIPTION</th>
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<tbody>
<tr>
<td>EMTX-2017-021167</td>
<td>05/04/2017</td>
<td>EMTX-2017-021167</td>
<td>TESTING SERVICE FOR RENCA RUS</td>
<td>RENCA RUS</td>
<td>DUBAI</td>
<td>NOT GIVEN</td>
<td>MORTAR</td>
<td>TESTED</td>
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</table>

TEST RESULTS

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE OF MORTAR</td>
<td>RENCA 3D GEOPOLYMER CONCRETE</td>
</tr>
<tr>
<td>PRODUCT NAME</td>
<td>RENCA 3D GEOPOLYMER CONCRETE</td>
</tr>
<tr>
<td>SPECIMEN DIMENSION (mm)</td>
<td>40</td>
</tr>
<tr>
<td>WATER RATION (VOL/WT)%</td>
<td>SEE REMARKS</td>
</tr>
<tr>
<td>PRODUCT MANUFACTURING DATE</td>
<td>05/04/2017</td>
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<tr>
<td>AGE AT TEST (DAYS)</td>
<td>28</td>
</tr>
<tr>
<td>MEAN COMPRESSIVE STRENGTH, N/mm²</td>
<td>46.3</td>
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To verify this document please go to [http://login.dm.gov.ae/wps/portal/documentverification](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.
Logistics Challenges
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

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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:**

<table>
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<tr>
<th></th>
<th>Al$_2$O$_3$</th>
<th>SiO$_2$</th>
<th>Fe$_2$O$_3$</th>
<th>TiO$_2$</th>
<th>MgO</th>
<th>MnO</th>
<th>K$_2$O</th>
<th>Na$_2$O</th>
<th>CaO</th>
<th>LOI</th>
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<tbody>
<tr>
<td>%</td>
<td>28.27%</td>
<td>59.00%</td>
<td>6.32%</td>
<td>1.25%</td>
<td>0.68%</td>
<td>0.12%</td>
<td>0.60%</td>
<td>0.62%</td>
<td>1.76%</td>
<td>2.14%</td>
</tr>
</tbody>
</table>

**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
H$_2$O content — less 0.1%
Specific area (BET) — 4500-5000 cm$^2$/g
Bulk density — 1.14 t/m$^3$

**Chemical composition:**

<table>
<thead>
<tr>
<th></th>
<th>Al$_2$O$_3$</th>
<th>SiO$_2$</th>
<th>Fe$_2$O$_3$</th>
<th>TiO$_2$</th>
<th>MgO</th>
<th>MnO</th>
<th>K$_2$O</th>
<th>Na$_2$O</th>
<th>CaO</th>
<th>LOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>12.27%</td>
<td>38.18%</td>
<td>0.67%</td>
<td>1.63%</td>
<td>10.34%</td>
<td>0.67%</td>
<td>0.76%</td>
<td>0.44%</td>
<td>34.92%</td>
<td>&lt;0.10%</td>
</tr>
</tbody>
</table>
Developing new recipes
Based on our expertise in geopolymers, we are developing new or adjusting existing 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 GEPOLYMER CONCRETE

After 28 days in 10% Sulphuric Acid Solution:

- OPC
  - 40% weight loss
  - 70% Strength loss

- GPC
  - 0% weight loss
  - 0% strength loss

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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

Verification in external lab and certification

When needed we do verification of our test results in external laboratories and certification centers.
RENCA products
Ready to Use RENCA Products Supply

gopolymer cement and geopolymer reagent geosilicate

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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.

Depending on the request the recipe can be adjusted according to technical requirements of the customer.
RENCA equipment
Equipment Manufacturing and Supply

RENTA 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.
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
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