Concrete Mix

Mortar Recipe

A simple concrete mortar is not pumpable because the water will be expelled from the mix under the pressure that builds up in the pump. This is why we added a gelling agent which facilitates water retention and which gives the mix the desired plasticity so it can be pumped and extruded. The final mix consists of the following components, in mass percentages:

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51.1% dried sand
34.7% Portland cement CEM I 52.5 R
13.2% water
0.8% water retention agent: Cugla Viscosmart Pure P-50
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From our tests we observed that both the ratio of the ingredients in the mix and the preparation method are important. The fraction of water normally present in sand forms a strong bond with the water retention agent. After these bonds have formed, it is difficult to achieve a reproducible homogeneous mix because the component used does not gel through easily when water is added. The solution to this is allowing the agent and the water fraction to interact in a single step in the proces. This can be achieved by working with dried sand, or by adding the water retention agent to an already mixed wet mortar. The latter carries with it the disadvantage that an extra step is added to the printing process, namely premixing the wet mortar.

further work

This proces can be made more efficient when the premixed dry mortar is mixed with water in the pump mixer. This removes one treatment step from the proces, thus creating a simpler continuous proces. This approach also entails less cleaning of the machine. It appears that the gelling agent slows down the hardening of the cement, which reduces the number of layers that can be printer in a single go. When reaching a certain height, the print becomes unstable, falling over or buckling under its own weight. Suggestions for further research and development:

- searching for a test to measure plasticity, important for pumping and printing
- searching for a test to measure hardening speed, important for layer stacking
- measuring load capacity of the final result
- further examining the influence of variables in the used mixture on the printability, or an optimum combination of plasticity and hardening:
    - sand grain distribution
    - cement speed
    - type of gelling agent
- examining additional measures to improve the printability:
    - injecting a hardener/catalyst in the flow of mortar right before the nozzle
    - spraying/misting a hardener/catalyst on the print right after extrusion
    - using hot water / heated print head
- measuring the influence of micro-reinforcement on load capacity:
    - plastic fibres
    - elephant grass

- metal fibres

Extrusion

Extruding the mortar was realised by means of a simple, round nozzle, without shut-off valve, with a constant flow of material.

further work

An important limit of the current proces is the flow of material which cannot be regulated. Because of this, it is not possible to incorporate variable printing speeds during printing. Additionally, printing is confined to one continuous shape at a time, which entails serious limits for topology and construction methods of the shape to be printed. We see the following possibilites for further research:

- using the extrusion parameters from the gcode for real-time adjustments of the pump speed through the frequency regulator
- testing other nozzle diameters and shapes
- testing other materials: clay, loam, ceramic

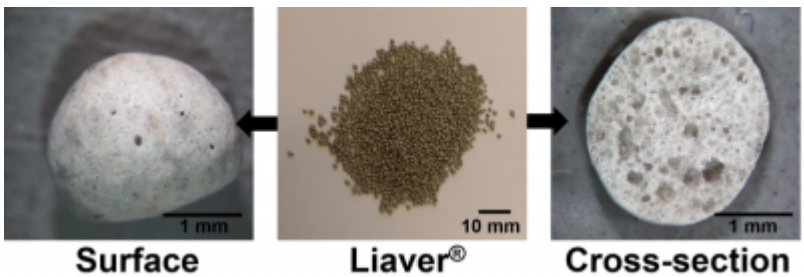
Support material

The basic mix will only stack layer on layer to about 30cm of height before collapsing. In order to make higher objects we employed sand in our early tests to support the material. The Technical University showcased an optimisation replacing sand with a much lighter support material, namely expanded glass beads.

In order to build up our early objects, we would build a box around the object and we would add this expanded glass to support the print.

PLEASE NOTE: creating a box and printing inside it results in a restrictive work area and is therefore more DANGEROUS! Please take extra precautions to work safely and NEVER run in automatic mode in such a confined space.

We used Liapor glass granulates and recommend the larger grain size. These can be reused after each print. http://www.liapor.nl/



In this manner, we were able to produce these columns, design with the Technical University of Eindhoven.

You can avoid using this support material by making objects that are less than 30cm tall, and perhaps thick and standing them upright. This can still create impressive prints. Please see a print we made designed by the Saxion Hogeschool.

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