New and flexible formwork materials

Introduction
A larger part of the concrete architecture of today demands the use of non standardized formwork. In addition the complexity of the formwork has increased over the last few years due to the development of the digital design tools used to shape the concrete. Almost all non standardized formwork used today is processed manually, and is as such very expensive to use. Many interesting projects are never realized simply due to the fact that the production of the formwork is too expensive to produce or not possible to fabricate at all.

In this project robot technology has been used in the manufacturing of new formwork materials. The robot is equipped with a milling tool which enables a processing technique where material is milled out from a block material leaving the wanted shape. Thus the research in different block materials used as new formwork materials has been in focus. The formwork materials is assessed regarding flexibility, sustainability, robustness, reusability and cost effectiveness.

Earlier experiments have shown that different kinds of foam products have been very suitable for producing formwork for concrete by milling. Especially expanded polystyrene has a big potential, mainly because of the low price. This formwork material has been used for the demonstration tests in the present project.

Moulding sand as formwork material for concrete
Beside expanded polystyrene, an alternative formwork material has been chosen for further research and used for small scale experiments. It is molding sand which is used in the casting industry.

Molding sand is a completely new material to the concrete industry and there is a great potential in using moulding sand as formwork material for future concrete structures due to the great advantages regarding easy de-moulding, easy milling, reusability and homogeneous concrete surfaces.

Knowledge from the casting industry has been used in order to choose the casting sand which is most suitable for milling and casting of concrete. Thus a list of moulding sand materials and processes has been made. The chosen materials and processes chosen for assessment were:

- Clays
- Sodium silicate binders
- Alcalic resol binders
- Acid catalysed furane binders
- Vacuummethod
- Epoxy, “croning”, phenolic urethane binders etc.

On basis of the list above two types were chosen for laboratory experiments. These were alcalic phenol-resol and furan-sand. For the tests a number of samples were prepared. Moulds for concrete were milled out on the robot from basic sand-blocks. Before casting one half of each mould was covered with ‘black’ – a material used in the casting industry to seal the surface of the sand.

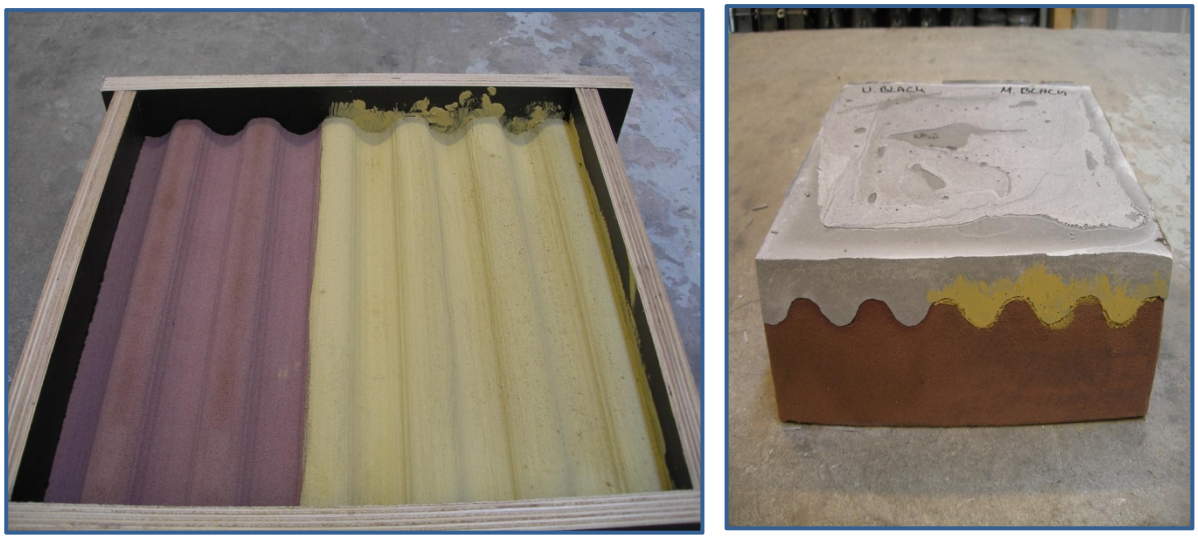

Fig. 20: Experiments with furan-sand where the one half of the mold was covered with 'black'.

Fig. 21: De-molding was quite easy in the areas with the 'black' coating but it stuck to the concrete.

The experiments showed that de-moulding was very difficult. Add to this that the 'black' material stuck onto the concrete. Thus another type of sand was tested. This was a chemical bounded filter-sand which showed some more promising results.

First of all the sand was assessed as concerns how easy it was to mill it into shape with the robot. Tests with different speeds – both spindle speed on the tool and the robot speed – were performed and showed some interesting results. With both high speeds on the spindle and the robot movement the sand was milled easily and perfectly. This indicates that moulding sand compared to a number of other potential formwork materials can be processed both faster and cheaper.

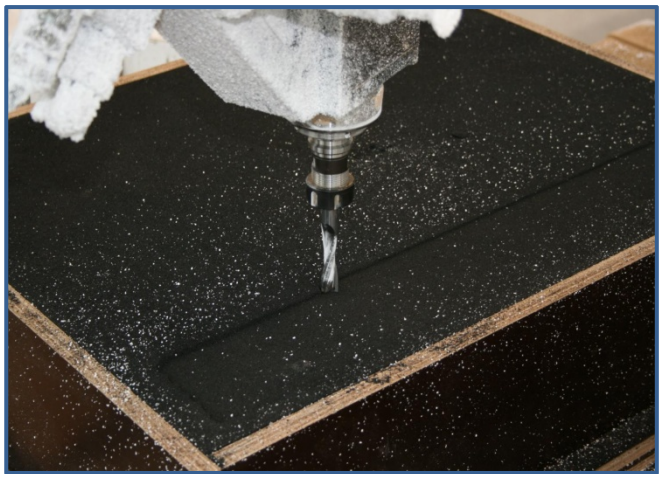

Fig. 22: Milling in moulding sand can be performed with very high speeds on both spindle and robot movement.

Also the quality of the sand after milling was promising. Tests with very fine details showed that the sand could hold the shape without small pieces breaking off
De-molding has shown very different results. Tests with two different fractions of molding sand has shown that the compacting of the sand has great influence on how easy the de-molding after casting with concrete can be performed. In the first test the sand was compacted better than in the second and the de-molding was thereby much more easy. De-moulding of the second, less compacted sand was on the other hand very difficult and tools for the de-molding process were needed.

Fig. 23: On the left: Easy de-molding without the usage of heavy tools. On the right: Difficult de-molding even with the help of heavy tools

Regarding the concrete surface quality it was very acceptable. The surfaces were homogeneous and there was hardly any air bobbles on the concrete surface.

Creation of reliefs in concrete using moulding sand
A number of experiments with reliefs in moulding sand have been performed. The aim of these experiments was to utilize the possibilities with digital fabrication in order to create patterns in concrete which are not possible to produce manually.

The basis for the experiments was pictures in black and white with a high level of contrast. These pictures were imported to a 3D modeling software where each level of gray was given a specific height lifting the picture up to 3 dimensions. Then a pattern of straight lines were projected onto the picture emphasizing

the shadows from the 3D picture. This final 3D model was then milled out in moulding sand on the robot creating a mould for concrete. And in these experiments the form-stability of the moulding sand was very crucial for the success.

The experiments showed that it was possible to create 3D pictures using this technique, and that the moulding sand was very suitable.

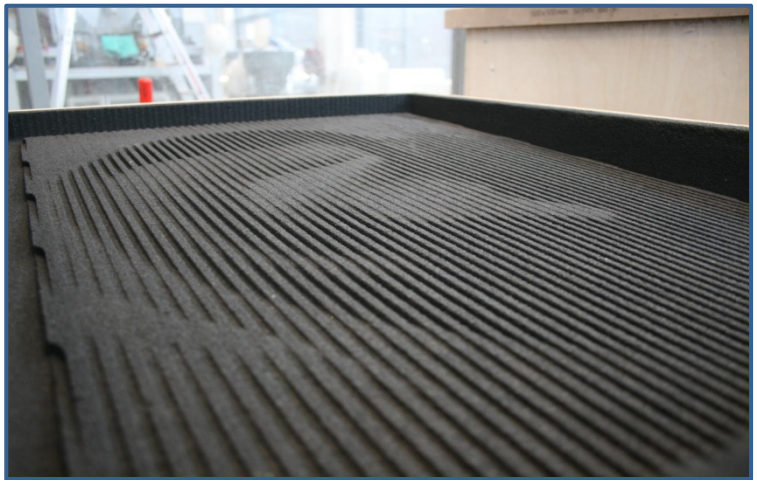

Fig. 24: Very fine details creating a 3D picture - milled in moulding sand without small pieces broken off.

Conclusions on experiments with moulding sand

Based on the tests performed, molding sand can be concluded as a very interesting formwork material for the future. The conclusions are:

- Molding sand can be re-used. This is a great advantage compared to other known formwork materials for singular concrete elements.
- The choice of the correct molding sand is very important – add to this the need for proper compacting of the sand before use. This is especially necessary to be able to perform easy de-molding after casting with concrete.
- Due to the firmness of the molding sand it is possible to create very fine details in the concrete surface. This gives some new opportunities for designers, architect, artist etc.
- The surface of concrete cast against molding sand is very homogeneous and without air bobbles.