Cast Formwork System

customised self-construction for local informal conditions

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Abstract

CAST Formwork Systems (CFS) is a concrete formwork system based on CNC milling technology. It enables self-construction in informal areas to build up safe, incremental housing up to four storeys high. Ordinary formwork systems are complex to use, often too expensive for the low- to mid-low income group and only suited to one shape of building plot. The CFS-system is not only cheaper, it can be customized to all shapes of building-plots and is both safe and easier in use.

Keywords

concrete; CAST Formwork Systems (CFS); concrete formwork system; CNC milling technology; housing

 Remmerswaal, N., Bilow, M., Moonen, F., Blok, R. (2017). Cast Formwork System: Customised self-construction for local informal conditions. SPOOL, 4(2). doi:10.7480/spool.2013.1.624

The problem

We live in an urban era; the Global Health Organization estimates that in 2050 almost 75% of the world population will live in cities. The biggest urban growth will take place in 'informally built parts of the city', often known as slums. These areas are formed when the government can no longer deal with the rapid growth of the urban population and city inhabitants start constructing their own living quarters. While densification in these ever growing mega-cities is sorely needed, the inhabitants often lack the building knowledge needed to construct safe housing over two stories high. Dangerous situations occur since these self-constructed houses are often not able to withstand the earthquakes and yearly flooding these poorly situated areas are exposed to.

The goal

The immediate objective is to provide a safe building method in the informal areas of Indonesian cities. These informal areas are called 'Kampung' and are an excellent example of self-build areas, 80% of Indonesian cities consist of these kampungs. They are more than just places to sleep, these Kampung thrive on a very close knit community and are full of economic activities. A governmental top-bottom approach in handling these areas often consists of tearing down the whole Kampung and build high rises in its place. This 'block attack' destroys not only the community but also denies the city inhabitants their economic opportunities. The CAST Formwork System proposes a bottom up approach where the inhabitants can independently build up safe housing in accordance with local practice.

Origins

The company CAST Formwork System (CAST) came forth from the thesis 'Tra-Digital Hybrids' written by Nadia Remmerswaal. In July 2015 she graduated from the Faculty Architecture at TU Delft as best graduate of her year with this thesis. In her graduation project, she delved into enabling safe, self-build constructions in informal neighborhoods, the Kampungs of Bandung, Indonesia.
Research shows that 80% of the build environment of Indonesian cities is self-build, in Indonesia this results in 100 million Kampung inhabitants, and it is expected that before 2050 we will see 50 million more Kampung inhabitants. This enormous city growth is not limited to Indonesia, but will happen in mega-cities worldwide. These DIY areas are prone to earthquakes and flooding, and residents often do not have enough building knowledge to build sustainable structures to withstand these natural disasters. After witnessing this in the cities of Indonesia, Remmerswaal tried to find a technical solution in her architectural graduation to enable safe self-construction in these areas.
After graduating Remmerswaal sought funding in the form of scientific financing and participated in several competitions to develop the project further. The project won the ASN Bank World Prize

"Veiligheid & Sociale cohesie", prize money €8000, the STW Open Mind funding, €50,000 and the 4TU Lighthouse funding, €50,000. The project has been renamed 'CAST Formwork System', CAST an abbreviation of 'casting concrete' and Remmerswaal started developing the project in February 2016.
The objectives of the project are to create both a workable prototype and a workable revenue model. Both are be completed in February 2017 when the project financing ends.

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The formwork is specifically designed for self-build areas, to be used by residents themselves.

FIGURE 1

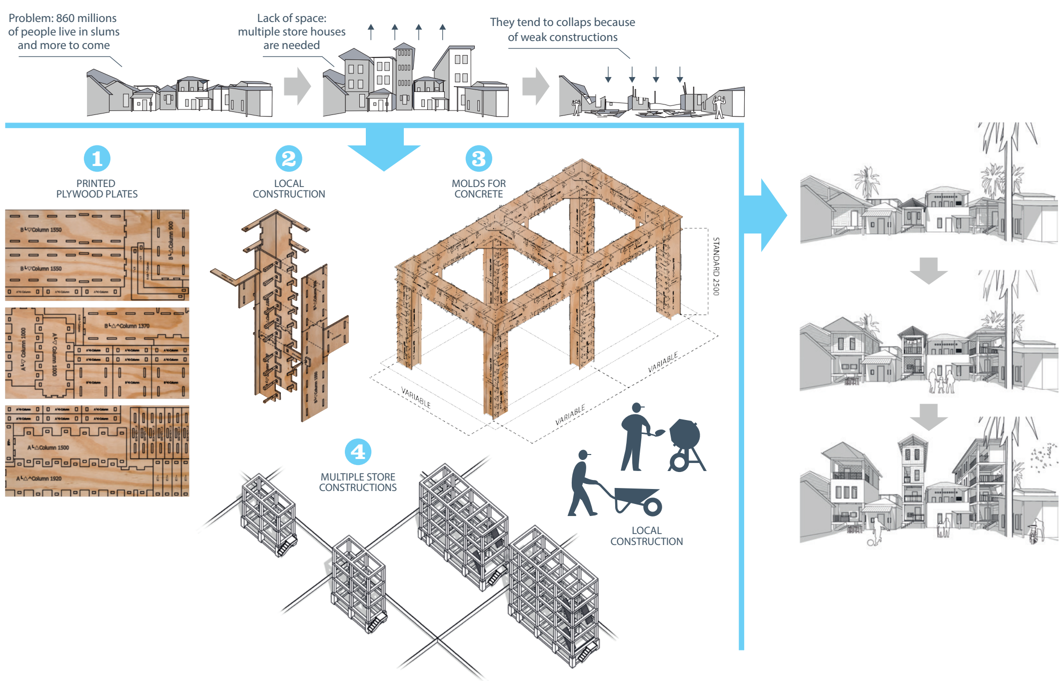

FIGURE 2 Graphical abstract

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A concrete frame of 3 x 7 x 3 meter was realized within two weeks.

The technique

CAST Formwork System is a formwork system based on CNC milling technology. The CAST system makes up the mould in which the concrete can be cast. The resulting concrete frame forms a durable structure and safe concrete skeleton. The formwork is specifically designed for self-build areas, to be used by residents themselves. The system is made from special wood: Betonplex, this hardwood triplex has a smooth, very durable coating that makes de-casting the formwork easy. Betonplex is being produced locally in Indonesia. The elements are never bigger than 1,5 meter, and can be easily transported into the Kampung using a handcard. It is designed to be as simple as possible, so that it can be put together by people with limited construction knowledge.

After the assembly of the formwork, the concrete is cast and when dry the formwork can be reused a minimum of 8 times. Normal formwork systems are often complex to use, need cranes or trucks to be transported or assembled, are too expensive for the low to middle-low income group in self-construction areas and only suitable for one form construction plot. CAST strives to be an inexpensive alternative that is easily adapted to multiple building plot configurations. Since not a single house in the Kampung, or self-build areas around the globe for that matter, are equal, this is an essential important aspect of the system.

With CAST Formwork System it is safe to build up to multiple levels, right now this is often impossible, inadequate construction knowledge prevents the buildings to reach over 2 building stories. With the CAST-system, it would be possible to expand the dwelling in an incremental manner: the first year the foundations and first story is constructed, and when inhabitants have gathered sufficient funding a second story can be constructed several years on. This incremental building method is essential as these informal neighborhoods often lack the financial resources to construct a four-story house all at once. This incremental construction method makes it possible for a household to spread the investment over several years.

The next step

In December 2016 a CAST-Formwork prototype has been tested at the Green Village in Delft. A concrete frame of 3 x 7 x 3 meter has been realized within two weeks. While some technical adjustments have to be made, the team considers the test a great success. The next step is to do more local testing in Indonesia in January 2017, and to present the formwork at the 'Week van de Bouw' in February 2017. A pilot project is being developed in Bandung Indonesia, if sufficient funding is found, 6 pilot homes will be built with the CAST Formwork System in May 2017.

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Support

- Jongeneel B.V.
- Cementbouw
- Van Gelder Group
- The Green Village
- Riset 8 kota Indonesia

FIGURE 3

FIGURE 4

FIGURE 5

Convective Concrete

additive manufacturing to facilitate activation of thermal mass

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Abstract

Convective Concrete is about a research-driven design process of an innovative thermal mass concept. The goal is to improve building energy efficiency and comfort levels by addressing some of the shortcomings of conventional building slabs with high thermal storage capacity. Such heavyweight constructions tend to have a slow response time and do not make use of the available thermal mass effectively. Convective Concrete explores new ways of using thermal mass in buildings more intelligently. To accomplish this on-demand charging of thermal mass, a network of ducts and fans is embedded in the concrete wall element. This is done by developing customized formwork elements in combination with advanced concrete mixtures. To achieve an efficient airflow rate, the embedded lost formwork and the concrete itself function like a lung.

Keywords

concrete; thermal storage capacity; thermal mass; Additive Manufacturing

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To accomplish this on-demand charging of thermal mass, a network of ducts and fans is embedded in the concrete wall element.

The use of thermal mass is usually considered as an effective strategy for achieving energy efficient building designs with high thermal comfort levels. This is normally done by applying construction types with high thermal storage capacity (e.g. concrete) on the inside of the thermal insulation layer. Such heavyweight constructions have a slow response time. This thermal inertia helps to flatten temperature peaks, but the slow response is not advantageous at all times. Due to a lack of control possibilities regarding when and how much energy to exchange between interior zones and the constructions with thermal mass, these dynamic effects may actually also increase heating and cooling energy demand during intermittent operation or can cause unwanted discomfort, either due to too cold surface temperatures when the building is already occupied on winter mornings, or because the accumulated heat can sometimes not be sufficiently released, leading to potential indoor overheating issues in summer. Another shortcoming of thick concrete slabs is that actually only a small part of the heavyweight material (usually the first few centimetres) effectively plays a role in storing thermal energy. This forms a missed opportunity.

Convective Concrete initially targets the residential building market. The goal is to mitigate residential overheating during summer periods by reducing the temperature of constructions through active heat exchange between the building construction (hollow-core concrete slabs) and cool outside air at night. Even though air has a relatively low volumetric heat storage capacity compared to e.g. water, it is used as a transport medium in this project, because of:

- Its widespread availability at favorable temperatures;
- Can be combined with earth tubes;
- Easy construction and installation process: plug-and-play;
- Provides standalone elements that do not need to be connected to additional systems;
- Can function passively without mechanically forced convection due to the buoyancy effect;
- No risk of leakages, punctures or frost damage;
- Low weight and therefore less structural requirements.

To accomplish the on-demand charging of thermal mass, a network of ducts with attached fans, needs to be embedded in the concrete wall element. The fans act as back-up to the buoyancy effect to ensure a sufficient amount of air flowing through the wall. This is done by developing customized formwork elements in combination with advanced concrete mixtures.

Additive Manufacturing (AM) is researched, because it is a good method for this kind of rapid prototyping. Customized and free-form parts can be produced easily. AM of lost formwork differs from the approach of direct concrete printing, but allows for a traditional processing of the concrete itself. To benefit most from AM as production technology, the free-form and customized parts needed for the Convective Concrete are printed in wax, using Fused Deposition Modeling (FDM), an AM process based on material extrusion, that can be melted after the concrete is hardened. The building volume and resolution of FDM printers can be adapted to the desired size and layer thickness easily. However, for the first prototypes wax casting was used.

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Additive manufacturing of lost formwork differs from the approach of direct concrete printing, but allows for traditional processing of the concrete itself.

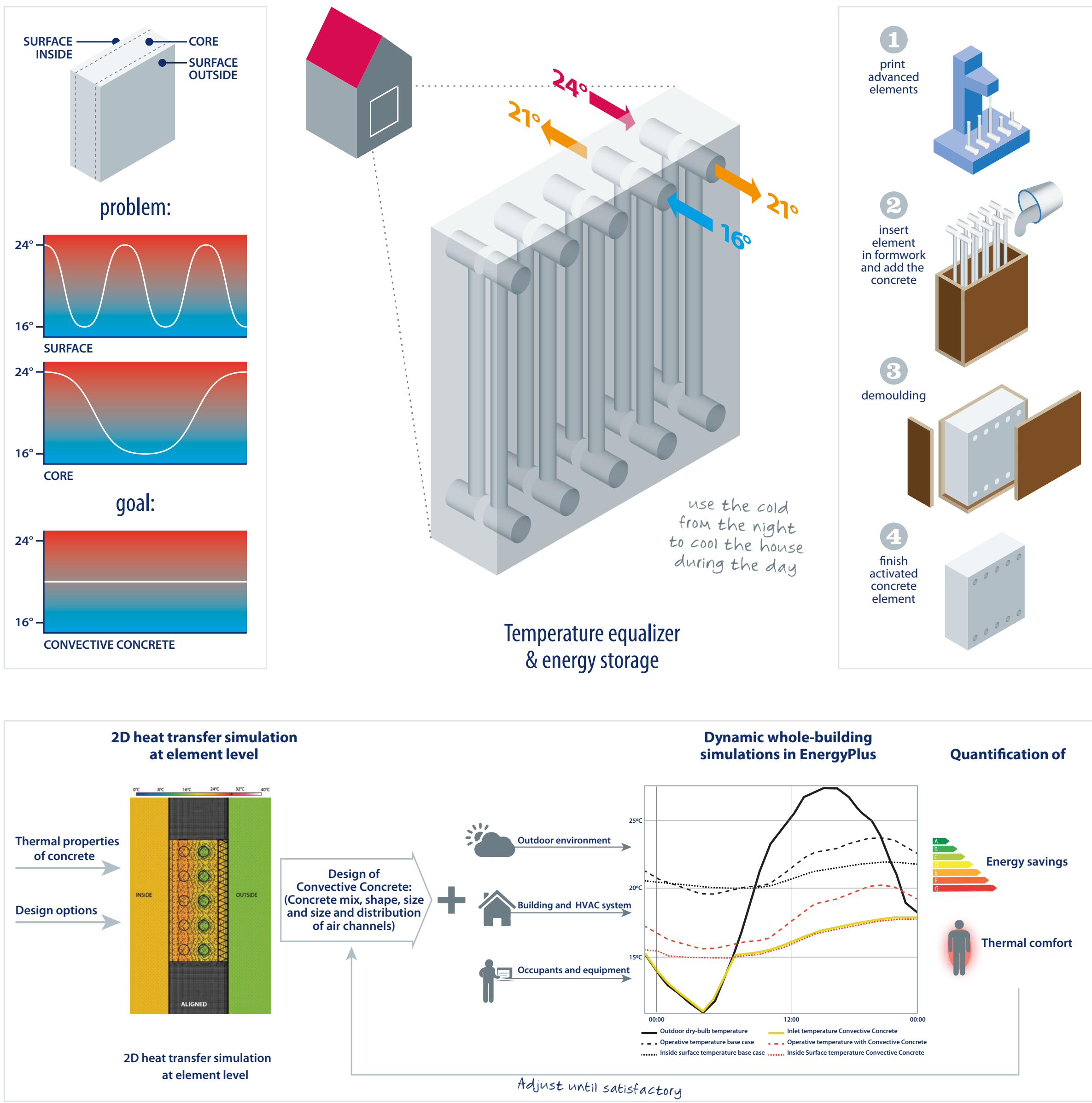

FIGURE 1 Graphical abstract

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To achieve an efficient convective flow, the embedded lost formwork and the concrete itself should function like a lung. The convection takes place with separate pipes on both sides of the concrete's core to increase the charge/discharge of the thermal storage process with help of fans, in the event of lack of buoyancy effect and with the help of valves, to control when the slabs are ventilated. There will not be any openings through the slabs themselves, because that would cause thermal bridges. The concrete mixture with matching characteristics (density, porosity and lambda value) will be fabricated on the basis of input from computational simulations.

As soon as the outcomes of the simulations match the physical models, parametric models can be designed, after which optimized internal formwork for the Convective Concrete can be printed and the façade and internal walls can be applied in the built environment. The final product can be in the form of a prefabricated concrete slabs, but also in the form of the inserts itself that is are placed embedded in the on-site built formwork.

FIGURE 2

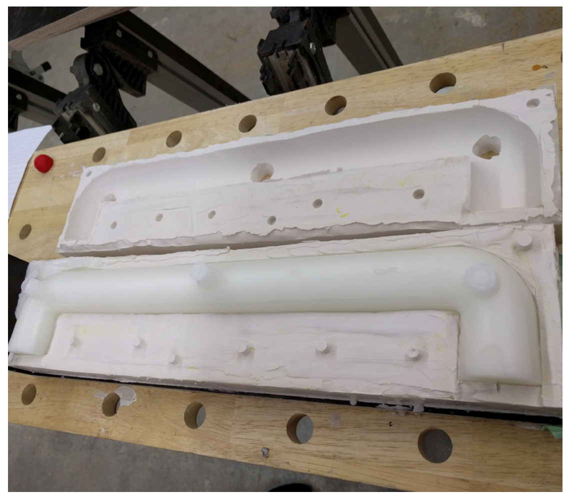

FIGURE 3

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