Tectonic Prototyping

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Tectonic Prototyping CINARK Perspectives

The Royal Danish Academy of Fine Arts
Schools of Architecture, Design and Conservation
School of Architecture

CINARK

Centre for Industrialised Architecture

www.cinark.dk

CINARK

CINARK BACKGROUND

Danish architecture and the Danish building industry need to develop clear strategies in order to take advantage of the architectural potential linked to industrialised production from a perspective that concerns environmental
responsibility. This in order to rank Denmark in a leading position, when it comes to developing contemporary sustainable architecture based on the design and knowledge based building industry.

CINARK TASK

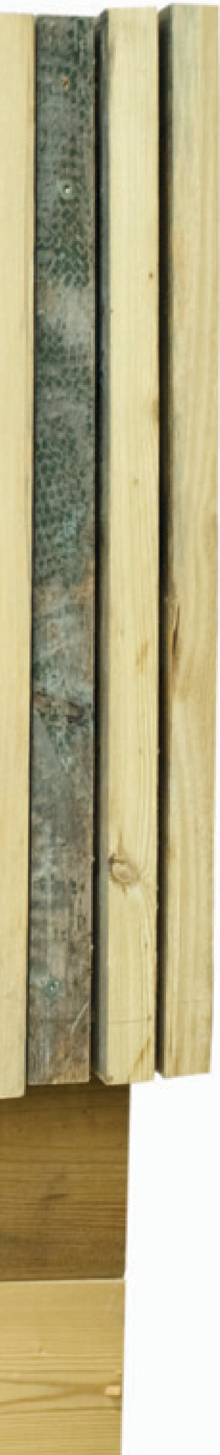
CINARK develops, accumulates and coordinates research and education activities concerning the production of industrial architecture from a sustainable point of view. As a central activity - the centre outlines and revises those specific concepts, characteristics, methodologies, processes and products that define the field of sustainable Industrialiesed Architecture. The object is to clarify essential, as well as present-day
problems and potentials. The centre aims at close collaborations with the building industry and related businesses.

CINARK OBJECT

Through increased research and teaching it is CINARK's aim to strengthen the school, the architectural education and the architectural profession when it comes to the use and understanding of the architectural potential in the industrialised building industry.
The question at stake is how to develop the building industry towards advanced sustainable solutions. These efforts include a new organisation of the building industry, new processes of manufacturing as well as new design of building components. The centre strives to build up and communicate current knowledge in order to improve the dialogue between architects, manufacturers and users of sustainable industrial architecture.
Research and education focuses on the following themes:

• Architectural development of buildings and building parts through highly industrialised methods and materials.
• The changing role of the architect in new building processes, business organisations and co-operational set-ups.
• Focus on quantitative as well as qualitative potentials in mass production, new ways of delivery and increased attention to customer needs and expectations.

Reversible construction with wooden panels



THE PROTOTYPE AS ARCHITECTURAL RESEARCH

by Professor Anne Beim, Architect MAA, PhD

Due to the specific circumstance that architecture grows out of a practice based discipline architectural researchers continually return to questions of how to produce knowledge that link practice and theory within our field. By which means and methodologies can this knowledge be created, to what extend does the very approach influence the end results and how does a practice-led research inform thinking and new theories in architecture?

Focussing on a wide definition of practice-led research, CINARK has over the years studied, analysed and discussed how the practices of architectural design; its prototyping and building embody a particular set of knowledge types that inform architectural thinking. Architectural reflection is connected to its media. It is through the drawing, the model and the construction of the building that architecture is conceived and developed. In practice based research, working through design means reflecting through the fabrication of material evidence in its various forms. A central question for architectural researchers as well as practising architects must be; how the material evidence resulting from these practices comes to contain knowledge – how is it produced, what knowledge does it embody and last but not least by what means and methods can it be critically evaluated?[1]

When testing (research) ideas through full-scale mock-ups or completed buildings, the nature, complexity and resistance embedded in the various elements that shape architecture come into focus. These can be considered as constraints that contaminate the ideals of the designed, or they can be included as part of the material evidence for further examination. It is through these circumstances that the full-scale physical object, when built, opens for reflection, refinement, testing and development – and thereby offers matter for further theorisation.

[1] Beim, Anne & Mette Ramsgaard Thomsen. (2011). For further elaboration on the topic of prototyping, modelling and drawing see: "Material Evidence". Kunstakademiets Arkitektskoles Forlag, Copenhagen

However, the specific understanding of the prototype as part of architectural production is difficult to emphasise, as most buildings can be considered as prototypes – one-offs. The exhibited prototypes by CINARK attains their own value as a mode of architectural exploration. Through full-scale experiments they have systematically tested the material, building technology, structural and aesthetic properties of concrete, fabric, wood, and solid and layered constructions. The prototypes generate, direct and sharpen the research questions and in their own abductive manner produce new research questions, experiments and prototypes. It is a slow and laborious research practice that can be characterised as a tectonic reflection.

CINARK AND THE PROTOTYPE

From an architectural sustainable perspective - CINARK has over the years distinguished itself as research centre through an experimental practice and dissemination of architectural knowledge in regard of industrialsed products, systems and processes. The main focus has been on the quality aspects of the diversity and the culture-bound values by which architecture is rounded. CINARK's work can be characterized by the articles, projects and experiments that have deliberately been driven by a desire for close dialogue with partners from building practices, including architectural firms, building material manufacturers and contractors. This has led to a body of knowledge and a special understanding of technology's role in the development of architecture.


Fabric Formwork

Knowledge and examples of methods that we also disseminate further in the education of the architectural students.

We have seen that our many different initiatives and projects over the years have filled an important role in bridging the gap between architects' knowledge development (research / teaching, trial practice and technology understanding) and the challenges involved in modern Danish construction Industry. We are therefore pleased that our work now also meets the international attention and interest through this special event; The PROTOTYPING ARCHITECTURE EXHIBITION, Wolfson Prototyping Hall, Nottingham University, Oktober 2012.

CINARKs contributions are:

Learning from Autarki (self-sufficiency)
Is a full scale demonstration project, which explores the architectural potentials using cross laminated solid wood.
Initiated by Jesper Nielsen (former head of CINARK) under the auspices of CINARK - now under further development of employees / architects: Nikolaj Callisen Friis and Emanuele Naboni.

Fabric Formwork for Concrete
This project explores the architectural potentials by using textiles as formwork for concrete.
Recently completed Industrial project by Anne-Mette Manelius,
Industrial sponsors: Pihl A/S (contractor) and SHL Architects

Optical fibre concrete
This project challenges the common image of concrete - a homogeneous grey mass - by combining it with translucent and opaque components controlled by computer tools resulting in a new form of transparency.
Ongoing Industrial PhD project by Johannes Rauff Greissen
Partners: Dupont Lightstone, Danish Technological Institute (DTI)

Tectonics of Adaptability - which on the basis of concrete facade solutions look at the architectural implications of adaptive, life-cycle strategies, including flexibility and re-use.
Current Industrial PhD project by Soren Nielsen, Vandkunsten Architects

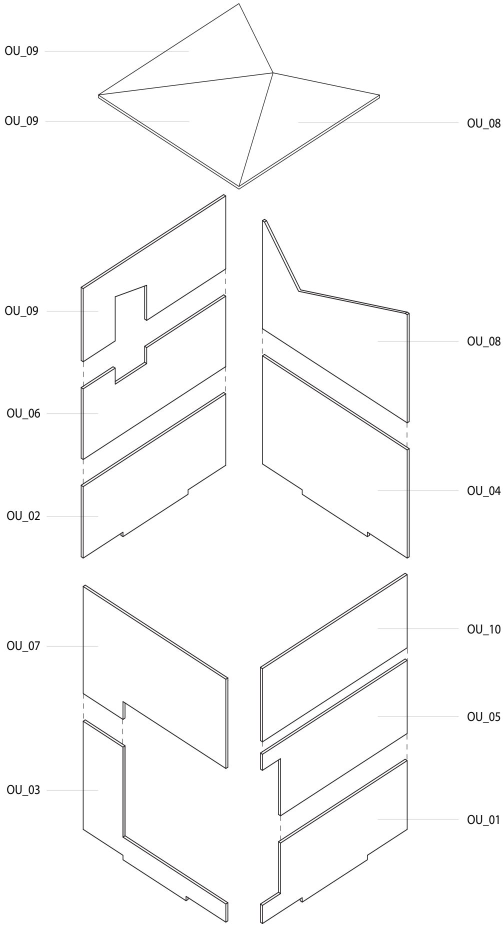
As part of the current demonstration project Autarki is running to first July 2013 and currently. listed in 1:1 on KADK's campus area which will be tested in terms of building physics and surface treatment (durability / aesthetics), it is intended to show the material also exhibited under the auspices of KADK - for students, colleagues and the general public.

AUTARKI 1:1

by Jesper Nielsen, Associate Professor, M. Arch
and Nikolaj Callisen Friis, Assistant Researcher, M. Arch

Autarki 1:1 is a pavilion in cross-laminated timber (CLT) which has been erected at the Royal Danish Academy of Fine Arts - School of Architecture in Copenhagen in the autumn of 2011. For the Prototyping Architecture Exhibition we have chosen to display a prototype section of the building unveiling the tectonic principles and the assembly joints for the pavilion. This prototype is accompanied with a 1:10 scale model displaying the building in its entirety and clarifying it's constructional logic.
The aim of the project is to investigate solutions which will improve recyclability and reduce the energy consumption of the building by optimisation both the processual and the technical aspects of CLT
Autarki (Greek for Self-sufficient) 1:1 is constructed as a passive house with the sun as the main source of heating and natural ventilation as a focal point.
By building with a double shell principle the thermal bridges has been reduced significantly, and the homogeneity of the building allows for a more simple and sustainable building process.
During 2012-13 we will conduct measurements of the building's thermal performance. This development can be followed in real time at www.AUTARKI.dk.

Concept
The project is not meant to be directly industry-related or demonstrating a proposed route for the CLT industry. It is a tectonic experiment, meant to generate, through an idealised statement, a discussion on wood, manufacturing, comfort and sustainability. The main criteria for the experiment are:
- Full visibility of the material itself. Like masonry and concrete, CLT is capable of being surface as well as structure, allowing us to use it a homogeneous building material.
- Mono-strategy. By allowing the panels to act both as façade and structure the building process is simplified and a number of part deliveries are eliminated. This makes it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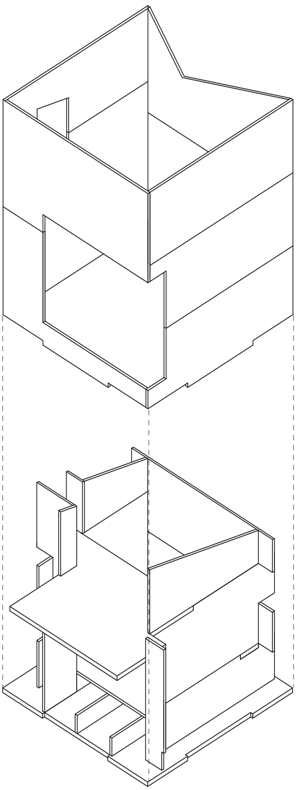


easier to go directly from design to production.

- Structural logic. To optimise the structural principle, potentially using the entire cross-section of the exterior envelope for carrying load and creating stability.
- Low-tech climate strategy. By building healthy and well-insulated and by implementing a natural convection driven heat exchanger the aim is to fulfill the German Passive House Standard. [1]
- Design for disassembly. As an added benefit from the mono-strategy to create a house, that could be taken apart again into its individual components and either recycled or re-erected elsewhere.

Process

The house was built with the help of carpenter apprentices from the Copenhagen Technical College. The CLT components were delivered pre-cut on site and was assembled using a crane. It was built from the inside out, with the panel layout planned, so that temporary bracing wasn't necessary, and due to the bonded connections, the next panel could always be fixed directly to the former.
The two shells are constructed so that they in principle are independent of each other. After the inner shell was erected the wood fibre insulation battens were mounted. The building was capped off with with the roof plates which was then covered with tar paper. Finally the glazing was delivered and mounted.

Materials

CLT panels has been used as a construction material during the last twenty years, but recently it's popularity has increased due to it's inherent sustainable properties, and one could argue CLT to be a legitimate alternative to concrete as a first choice industrial material.
In the Autarki 1:1 pavilion CLT is used both as the inner and the outer wall. This is more material consuming than a corresponding construction using frames and boards (gypsum, osb, and suchlike), but it opens up for some tectonic advantages that are tempting to explore:
By using only CLT panels you can build with fewer parts which again allows for a simple construction with less studs, fasteners, boards,screws, gaskets, foils, etc. What you see is what you get and there are no endless layers of glue, fiberglass, filler and paint.
Also by digitally crafting the CNC-manufactured laminated timber, the components are pre-fabricated to the architects/engineers specifications. This means that the designer has a much more direct influence on the components, in which the form is pre-determined. Additionally the whole process is much more material-saving as nothing is cut on site.
The building is insulated with wooden fibre battens from the German company Homatherm. Their product has the ability to distribute moisture more evenly

[1] "Passive House," Last modified September 7, 2012. http://www.en.wikipedia.org/wiki/Passive_house

than mineral wool, allowing us to build without a vapour barrier. In addition wooden fibres allegedly have a higher thermal capacity than mineral wool, which gives a more stable indoor climate with less temperature fluctuations.

Tectonics

The pavilion is constructed with a principle similar to masonry diaphragm walls. In masonry, A blockwork diaphragm wall is a wide cavity wall with two leaves of blockwork bonded together with cross ribs. But in our case the cross-laminated wooden leaves can withstand considerable amount of bending out of the plane and we can restrict the ribs to areas around the corners.
This double-skin principle leaves us with a house that is effectively a thermos bottle. Two only partially interconnected layers, creating a continuous void for insulation between them. The cold bridging between inner and outer layer is only a fraction of what they are in conventional construction. Apart from the ribs in the corners, the two layers are only connected at the windows.

Performance

The pavilion is placed on a site right in the middle of the campus of the School of Architecture. The openings in the box has been optimised in relation to sunlight, with the main opening towards the south, but twisted slightly to the east, as the heat gain in the mornings is important. On the outside the southern window is shaded in the summer by a projecting sheet, cantilevered from the

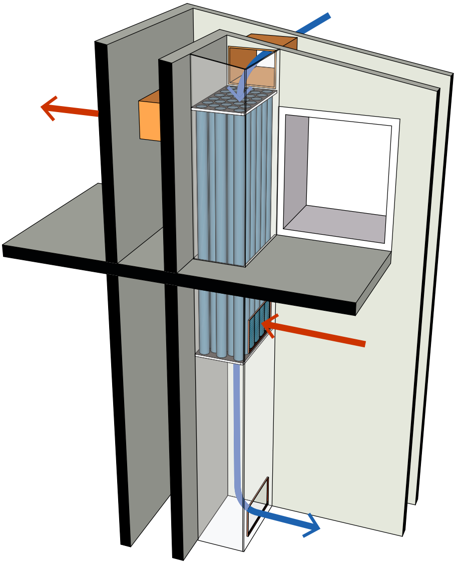


Fig. 1 - Heatexchanger: Airflow

inside balcony. The windows are newly developed (and sponsored) by Rationel Windows. They are 3-layer, argon-filled with an U-value of 0, 79.

The achieve the German passive house standard it is necessary to keep heat loss by infiltration (of air) on a very low level. The low natural infiltration again means, that it is impossible to sustain a reasonable air quality in the space without some kind of ventilation going through a heat exchanger.

For this we have built a heat exchanger driven solely by natural convection. It is based on an old research project at The Danish Technical University from the early nineties.[2]

The principle is shown on fig. 1. Cool air from the outside is drawn from the top part of the south facing façade (where the pressure is often higher due to the prevailing wind) into the top of the exchanger, where it is lead through a series of thin-walled aluminum tubes. Leaving the tubes again the air continues to the bottom of the room, where it leaves the device at floor level. This air flow is countered by a similar movement of warm interior air from just below the balcony into the exchanger, where it flows along the aluminum tubes in the opposite direction, delivering its energy to the incoming air through the tube walls. The whole system takes its energy from the differences in height and pressure of the two air flows.

[2] Jørgen M. Schultz, Naturlig Ventilation med Varmegenvinding, (Laboratoriet for Varmeisolering, Meddelelse nr. 249, Technical University of Denmark, 1993)

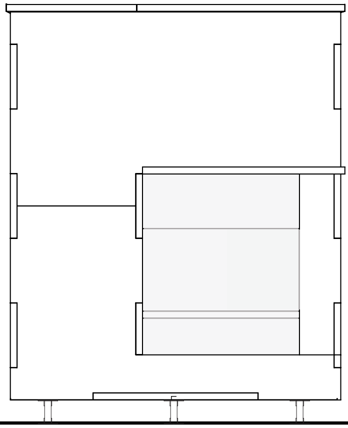
During 2012-13 we will conduct measurements revealing how well the building performs throughout the year. We have equipped it with loggers measuring temperature, light intensity and relative humidity, and by comparing simulations and models with our measurements we will be able to see how the building performs.

view the latest measurements

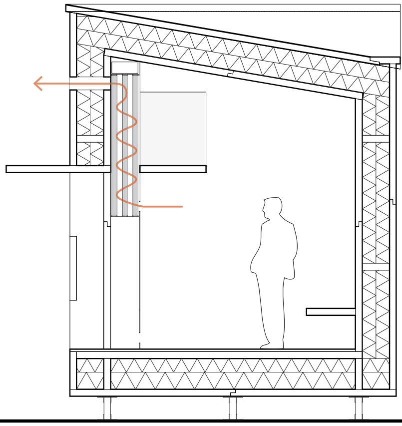
Potentials

We're optimistic that the project will demonstrate the tectonic potential of CLT panels as more than a technical option, and that it will inspire architects to challenge the boundaries presently set by the manufacturers. We also hope promote the idea of homogeneous construction, for the benefit of sustainable solutions and for architecture in general.

This experiment is not an attempt to present a build-able solution - it is meant to help promote a debate on how to build with CLT and what potentials lie therein. Some of our investigations might not be feasible in the real world but our hope is that by producing this architectural prototype, we can attempt to push the boundaries and hopefully pave the way for possibly seeing new solutions otherwise not considered.



east elevation



section

The project is sponsored by:

Rationel Auraplus
low-energy windows and door

Environmentally friendly
woodfibre insulation

Financial support and counseling

Construction of pavilion

Cross Laminated Timber

Roofing

Power tools

Asphalt flooring

Screws and brackets

Design Team: Jesper Nielsen, Associate Professor, M. Arch; Daniel Reinert, MSc.Eng.; Finn Ørstrup, Associate Professor, M. Arch; Svend Jacobsen, Associate Professor, MSc. Eng; Rikke-Julie Schaumburg-Müller, Assistant Researcher, M. Arch; Nikolaj Callisen Friis, Assistant Researcher, Emanuele Naboni, Associate Professor, M. Arch and Nina Belokonskaia, Stud.Arch

Research & Development Credits and Fabricators: Grontmij Carl Bro, KTS (Copenhagen Technical College)

Sponsors: Rationel, Homatherm, Moelven, Icopal, Dansk Støbe Asfalt, NKT, Bosch, KTS and Carl Bro Fonden

more information can be found at:
www.AUTARKI.dk and www.CINARK.dk

FABRIC FORMWORK – PROTOTYPING CONCRETE AS MATERIAL AND PROCESS

by Anne-Mette Manelius, Architect, PhD

Prototype description
Fabric formwork is a new construction method for concrete structures that utilizes sheets of fabric as flexible, lightweight moulds. Based on a recently completed PhD project about the architectural potentials of fabric formwork for concrete, the fabric-formed column is the investigation and material prototype of a lightweight, prefabricated fabric mould, which unfolds to be cast on site. The three-legged concrete column is form-optimized for stability and constructed with minimal means.
The principles of tensioning the fabric, of restraining it, and placing concrete have a direct formal consequence as a material dialogue between relaxation and control; thus the technique encourages an architectural understanding of concrete as material and as process. Essentially the prototype must then be understood as the formwork, the process, and the concrete object, and the contribution discusses the future of industrialized concrete architecture by emphasizing the prefabrication of intelligent, and lightweight moulds as an alternative to heavy and dumb concrete elements.
The mould is exhibited, hung next to the concrete object and details of the sculptural concrete object can be compared with its two-dimensional textile origin.

Fabric formwork has recently been defined as a “formwork that uses a flexible membrane for the structural support of fresh concrete or rammed earth.” (Veenendaal, West, and Block 2011) This definition includes soil, air or fluid pressure-supported formwork as well as the use of different types of fabrics such as non-woven membranes. It excludes the simple use of fabric as a form liner. The construction method is characterised by the development of catenary curves, a filter effect during casting, as well as an intense material dialogue during construction.

Catenary curves

The shape of a hanging chain is described as a catenary curve. Membranes deflect into catenary curves in all directions across the surface when exposed to an evenly distributed load such as hydrostatic pressure from poured concrete. This material negotiation between the concrete and the flexible membrane allows the latter to structurally 'organize itself' to a form that achieves equilibrium in relation to the load. The 'allowed' deflection of the surface under pressure makes the membrane an efficient formwork material.

Textile Filter Effect

The porous structure of woven fabrics acts as a filter that leads excess water and air through the formwork membrane. This happens immediately after fresh concrete has been placed, and the hydrostatic pressure is still high. The release of excess mix water from the fresh concrete mix lowers the ratio of water to cement in the concrete surface, reduces the amount of air bubbles and blowholes, and increases the surface strength of the cured concrete. (Lamberton 1980).

Special, often non-woven, fabric liners are placed inside rigid formwork systems to improve the water-cement ratio for concrete in harsh conditions such as salt water. With fabric formwork, the formwork itself has this effect.

Expressive construction

Besides formal geometry, concrete takes on the characteristics and details of any formwork surface. For fabric formwork, the pattern of the weave, the fibre used in the fabric, the direction or tailoring of the fabric, and the shape and method of restraining and tensioning fabrics become evident in the form and surface of the concrete. These formal consequences are very distinct in concrete cast in fabrics and demand a renewed understanding of concrete construction as well as the role of formwork. Where as the role of formwork technologies traditionally is to control a predetermined sculptural form, the roles of the formwork elements in fabric formwork deals with releasing fabric/concrete or restraining it. This entails that the technical role of the restraining form tie in fabric formwork also offers the architect a role of 'tying form' linking the designing with the processes of construction.

Stereogeneity – concrete as material and process

The material prototype is crucial in understanding and developing new methods of construction through making. For fabric formwork the details of construction are expressed directly as a formal consequence of construction. This entails that the formwork tectonics so related and readable in the finished fabric formed concrete, leads to a poetics of concrete. The relation between materiality and process for concrete is described in the concept of stereogeneity, coined by the author (Manelius 2012) Based on the Greek words stereos, hard or solid, and geneity derived from Gr. ginomai, to begin to be. Stereogeneity is the expressed manifestation into solid material form of a series of conditions from the construing and construction of structural formwork principles and concreting. In more general term, stereogeneous construction is concrete as material and process and is linked to a way of thinking concrete in architectural constructions.

Background

Pioneers in the field consist of three parallel practices in the 1980s and 90s. The built practice by the Japanese architect Kenzo Unno, the sculptural practice by the American architect, architect and builder Mark West, and the construction products patented by the Canadian business man Richard Fearn. CAST (Centre for Architectural Structures and Technology) at the University of Manitoba is the pioneering research centre founded in 2002 by Mark West. Here concrete columns, beams, walls, wall elements, shells, and rigid moulds have been cast and sprayed in fabrics. The exhibited prototype continues a practice at CAST of travelling with lightweight, prefabricated fabric moulds (West 2002) and West literally brought fabric formwork to Denmark in a duffle bag (Manelius and Beim 2007). Today, leading research also includes work in Britain undertaken at the University of Edinburgh and at the University of Bath. Architectural research and teaching is categorized by a material practice; research projects in engineering are categorized by a combination of digital simulations and empirical testing and iterative development of construction techniques.

Future

The question is not whether fabric formwork can be used in construction. The future of fabric formwork in industrialized architectural constructions is however yet to be determined, but the prototyping may be part of it. An examination of the development and the roles of the formwork in a form-optimized fabric-formed concrete beam produced in a PhD project (Sang-Hoon Lee 2010), suggests that fabric formwork has a future for simple adaptations of mock-ups with complicated geometric shapes. The potential is that it is simple and cheap to adjust and develop complex concrete elements in a number of prototypes for empirically testing. The production of large numbers of identical concrete elements may however be cheaper by making a rigid formwork and is discussed by comparing Lee's work with similarly shaped beams in projects by Harry Seidler (Manelius 2012).

On the other hand, a newly patented building technology combines ordinary and lightweight concrete in a sequenced mode of construction (Hertz). With both technologies still in their infancy, an increase in the possible scale of constructing fabric formed concrete is a benefit form the use of lightweight concrete because the lower density concrete has a lower formwork pressure during the concrete pour.

Fabric moulds and textile construction

The development in the low-tech fabric-formed construction of thin concrete shells by the engineers, the Irish James Waller and German Kurt Billig, inspired the Spanish-born Mexican engineer Candela and he used it to build his first concrete shells in 1956 (Faber 1963); but Candela moved on to other methods of construction when he adopted mathematically methods of design. A double-curved brick vault by the Uruguayan engineer Eladio Dieste (1974) displays a similar structural shape. Dieste did not apply fabric as formwork; instead the innovative use of reinforced brick can be categorized as a form of weaving and in this regard, the further developments of Dieste's corrugated brick structures are indeed very textile. Like any fabric formed concrete, Dieste's Gaussian vaults display a series of catenary curved sections. (Pedreschi and Theodossopoulos 2007). One can then speculate if a branch of the fabric-formed prototypes produced at the present time will also leave the fabric moulds behind and develop into more 'textile' constructions one way or another?

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Anne-Mette Manelius is a board member of the International Society of Fabric Forming (ISOFF)
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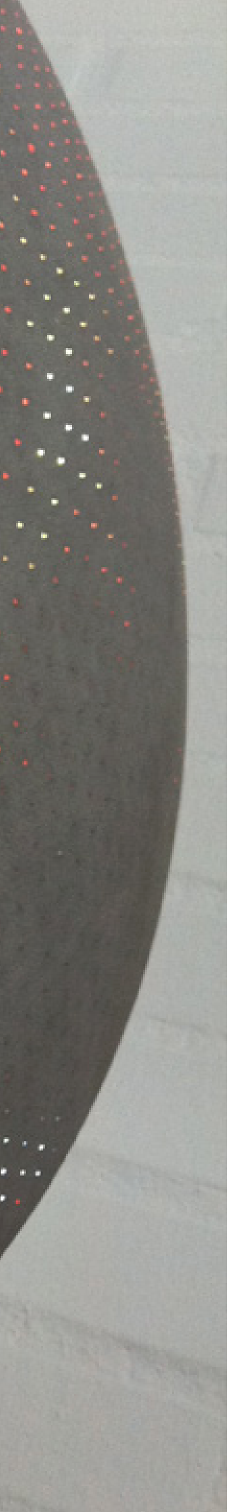


OPTICAL FIBRE CONCRETE

by Johannes Rauff Greisen, Architect and industrial PhD-student. Consultant at Danish Technological Institute

Description

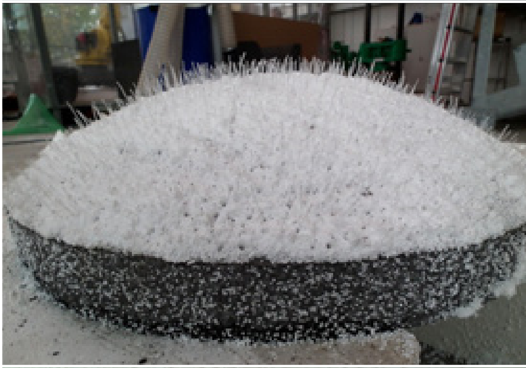
Optical fibres transmitting light through concrete can be used to show live images on concrete surfaces. The display technology has been developed for planar concrete screens by Dupont Lightstone. The display technology requires that the optical fibres are embedded precisely into the concrete; therefore the formwork must provide a high level of spatial control of the fibres during casting. Applying this display technology on double curved surfaces involves major challenges in achieving accurate fibre position and angle: Formwork rigidity is critical in order to maintain fibres orthogonal to the surface during casting and yet allow reasonable deforming. The research conducted at Danish Technological Institute solves these challenges by utilizing a new composite concrete formwork material and three and five axes robotic milling and drilling operations. The experimental work consists of five phases. The first three phases are 'Pixel-pattern', 'Formwork-system' and 'Concrete' and they cover the actual technology research and development. The subsequent two phases 'Demoulding and surface finish' and 'Interface and projection device' are of more practical ad-hoc nature.

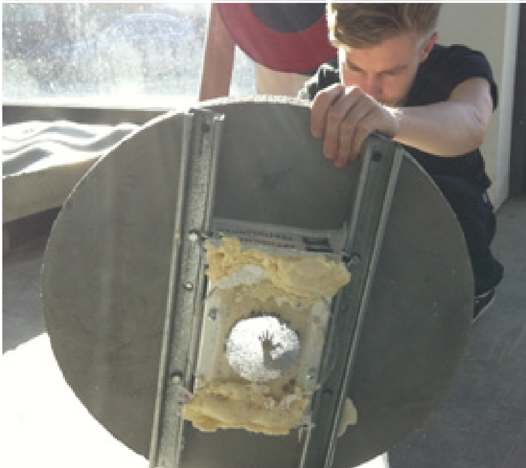
Pixel-pattern

The interface divides the input image into interface-pixels and each pixel is passed through its respective optical fibre becoming a surface-pixels. Pixels must therefore be placed in a pattern able to transfer the two-dimensional interface input correctly to the three-dimensional image output on the concrete surface. Various patterns were tested, and it is concluded that a triangular pattern offers a non-distorting concrete screen with a high degree of formal freedom.

Formwork-System

The metal sheet originally used for planar concrete screens must be replaced by a material allowing three-dimensional shaping and still is stiff enough, so the large amount of optical fibres could be fitted effectively with a tolerance of less than 1mm (position) and 2 degrees (angle), and kept

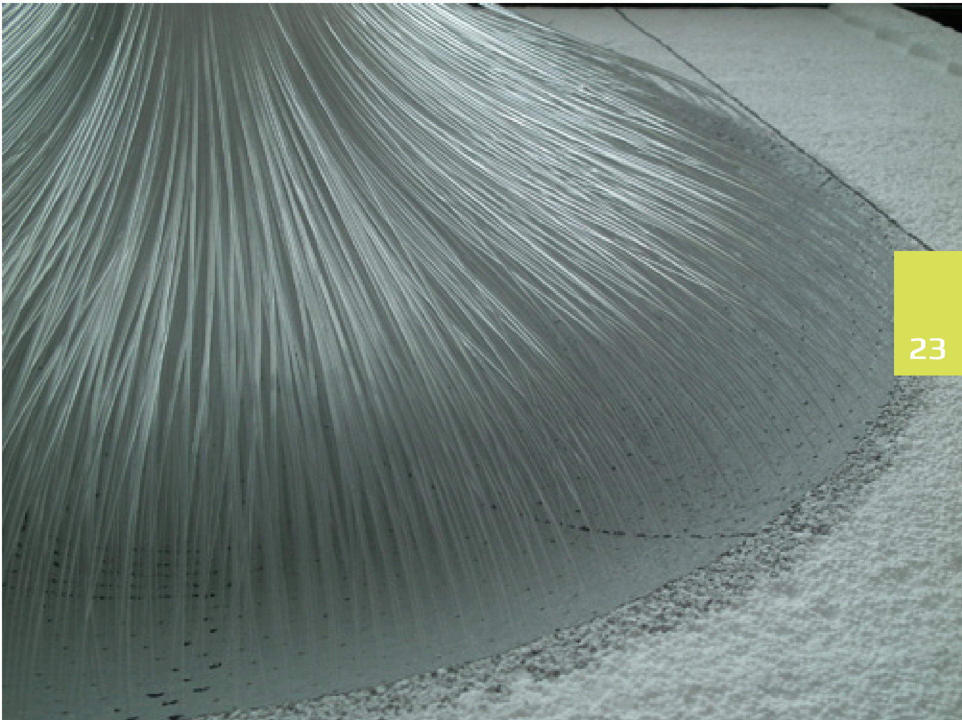




in position and angle during concrete casting. Various formwork materials were tested, and the conclusion is a formwork system based on epoxy resin coated expanded polystyrene. This formwork system can easily be fabricated by three axes milling and five axes drilling, and it proves to be rigid enough to control concrete and optical fibres during casting and yet relatively easy to remove after curing without damaging fibres and concrete.

Concrete
Low viscosity and small aggregates is necessary to ensure complete enclosure of fibres and to avoid blocking in between them. The concrete must be self-compacting (SCC) because experiments with vibration showed that air bubbles formed around the fibres. The final requirement was a concrete surface of high quality without blow holes, with uniform colour and no traces of the expected variations in casting pressure resulting from the variation in geometry. Various mixtures were tested, and a ready mix mortar proves to be useful in regards to form-filling, enveloping optical fibres, the even colour and final surface quality being suitable for subsequent grinding and polishing.

Demoulding and surface finish
A critical aspect is the interlocking between formwork and cast concrete, due to the different orientations of the optical fibres. The formwork must therefore be



cut away. Manual dry grinding followed by wet grinding and wet finishing using pneumatic tools with rotating diamond based abrasive discs.
Interface and projecting device

A light projecting device is used in the display technology of the concrete screen. This projector should be obsolete and regarded as interchangeable, according to needs and technology development. The presented prototype uses an of the shelf low emission, long life LED projector with a light intensity of 2000 lumens. The three first phases used iterative methods which are commonly known within product development, design, and artistic development. The aims of using them were problem solving and value creation. In the two final practical phases were used just plain skill and craftsmanship. Evaluation of casted concrete screens, were done by qualitative methods to assess the appearance of concrete surfaces and quantitative methods to evaluate the efficiency and accuracy in fabrication. These evaluations were made continuously informing the iterative development process.

The presented prototype is a final cast result of this research and development of the next generation of formwork technology for optical fibres. The research is an example of new digital tools being used to obtain durable, functional and beautiful architectural surfaces, by innovative use of traditional and inexpensive materials. The optical fibre concrete tends to have a highlight on the areas facing towards the observer. This highlight compromises the relevance as traditional screen, but shows new spatial, aesthetic and formal potentials. The conclusion is that utilizing robots within fabrication of concrete building, opens new perspectives: Controlling and embedding a hitherto unseen amount of delicate inserts is now technically possible, and when the efficiency of computer aided manufacturing is combined with the flexibility of craftsmanship the embedding can be customized and executed within a reasonable economy. Concrete as building material is a composite, but has sometimes nevertheless been conceived as a homogeneous grey mass. Optical fibre concrete is to be conceived as a true composite material with translucent and opaque components controlled by computer tools to a degree resulting in a new breed of transparency.

Organisation: Danish Technological Institute (DTI) in collaboration with CINARK – Centre for Industrialised Architecture

Design Team: Johannes Rauff Greisen, Lars Nyholm Thrane, Claus Pade, Christoffer Dupont

Research & Development Credits and Fabricators: Dupont Lightstone, Danish Technological Institute

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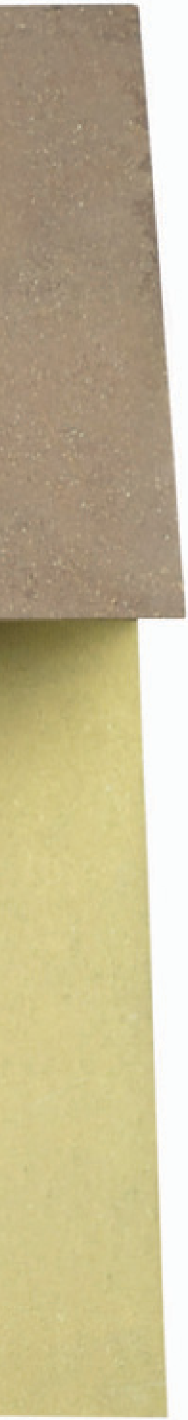
Prototype 1 - Principle: Pitching



REVERSIBLE CONSTRUCTION WITH WOODEN PANEL

by Søren Nielsen, architect and partner in the architectural office Vandkunsten, Copenhagen, Industrial PhD Student

Providing affordable homes for an increasing urban population is an important topical task for Scandinavian architects as people with ordinary incomes are challenged by the high market prices for homes in the growing cities. One of the most efficient tools for lowering production costs is low-tech industrial prefabrication and the demand has resulted in a growing number of manufacturers of wooden panel elements. Experiences from the last decade's Scandinavian low-cost residential projects have shown that it is possible to build in high technical and architectural quality with wooden panel elements.

Furthermore, from a resource preserving perspective timber based construction represents a significant improvement in building practice due to a carbon footprint which is low or even negative, as wood absorb CO_2. At the same time, the focus of resource saving is about to shift from energy for building operation to energy consumed in building lifetime processes. This implies the need for introducing constructive principles, which enable reuse of components.

On the one hand, wooden panel construction systems seem to be able to meet both the demand for low carbon and to constitute a suitable platform for reversible construction methods. On the other hand, it provides an atectonic structure as the load bearing members are usually disguised, all wrapped in skin components such as gypsum and chipboard. As when constructing with steel, the architectural expression is left to be performed in the more volatile layers of the building, and thus the detailing of the cladding comes to play the leading role in the exterior side of all four prototypes. The result can be described as an architecture of 'deep surfaces'.

1. Prototype for rapid on site mounting.
Principle: Pitching
The pitched boards reflect the on-site mounting process where boards are placed in position from a scissor lift. By using untrimmed, stock-measured board modules and frictional fixation

screws, instead of drilled penetrations, the cladding construction is designed for disassembly and salvaging for reuse. Rhythmically placed steel hooks generate a characteristic motif imparting an atmosphere of constructive openness by rendering visible traces of the assembly process as well as anticipating future dismantling.
The bent forks of stainless steel are not meant as a gimmick! Customised production of stainless hooks is costly and more functional specific than forks, which are apparently more versatile despite their strong identity.
The principle has been proposed for a major residential project in 2009 but was eventually rejected by the contractor as part of a budget revision. The boards ended up being mounted in the traditional destructive way by penetrating fixations, i.e. screws.
Interior detailing:
To enable easy access to joints between elements a grove has been made between the interior cladding boards. The grove is covered by a removable lid element held in place by moldings. A separate, demountable panel covers a zone for power installations, giving easy access for changes and replacements.

Design team: Vandkunsten by Søren Nielsen and Katrine West
Products: Rockpanel Natural, OSB-boards, reused timber, recycled stainless forks, plywood boards, rubber P-profiles, tarmac felt

Prototype 2 - Principle: Consoling

Interior: fabric or leather bands mounted with velcrostrips to cover element joints

2. Prototype for an adaptable façade.
Principle: Consoling

In order to separate the more volatile skin layer from the permanent structural layer non thermal-conducting intermediary consoles of recycled fibreglass are deployed, resulting in a gargoyle-like motif. Additional applications can be attached to the consoles such as balcony elements, sunscreens or windshields. The building becomes a paper-doll that can easily be dressed up in new ways. As background for the free configurable façade a cladding of fabric mounted on hard insulation boards are suggested. The coconut washers are not meant as a gimmick but as an example of a strong and durable organic alternative to synthetics.

The principle has been proposed in the competition for adaptable building typologies held by the Adaptable Futures research team at Loughborough University in 2011.

Interior detailing:

The cladding boards are separated by groves in order to enable access to joints between structural elements. A heavy quality fabric mounted with velcro-strips covers the groves generating a modular pattern in the interior.

Design team: Vandkunsten by Søren Nielsen and Katrine West
Products: Barsmark PD-1700 fiberglass board, Barsmark Glapor insulation board (foamed recycled glass), acryl-coated cotton fabric, OSB-boards, reused timber, Rigidur fiber-gypsum board, rubber P-profiles (for air-tight mechanical assembly), tarmac felt, velcro, leather

Prototype 3 - Principle: Wrenching (left: facade cladding, right: interior)

3. Prototype for façade renovation.
Principle: Wrenching

Façade cladding boards are mounted on battens. Instead of penetrating the boards by screws small pins are penetrated and used as clams to wrench the board in place. The mounting system allows easy dismantling and undamaged components suitable for reuse.
The principle has been proposed for a major renovation project and is currently being designed for realisation.

Interior detailing:
The structural members are rendered visible and the cladding boards are mounted as a filling. To enable easy dismantling and to avoid penetration by screws or nails the cladding is fixated with dowels of bamboo.

Design team: Vandkunsten by Søren Nielsen
Products used in prototype: Barsmark PD 1700 (recycled fiberglass), OSB-boards, reused timber, rubber P-profiles, eating pins of bamboo, tarmac felt

4. Prototype for plug-in panels.
Principle: Frame and filling.

The structural grid is constructed in advance and the prefabricated panels are additions, which fill out the framework of rough timber. The exterior gaps between the sides of the panel elements can be respected or ignored by demountable claddings, which can respectively reveal or hide the structural system.
The principle is well known from many projects, for instance KieranTimberlake's Loblolly house, but is here shown in a version with reused timber.

Interior detailing:
The structural grid appears as pillars at the inside of the façade wall. At the floor a board covers the gap between the floor elements indirectly revealing the structural system.

Design team: Vandkunsten by Søren Nielsen
Products used in prototype: OSB-boards, reused timber, Rigidur fiber-gypsum board, rubber P-profiles, tarmac felt, rope of hemp

Vandkunsten architectural office in collaboration with CINARK – Centre for Industrialised Architecture

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Prototype 4 - Principle: Frame and Filling

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2012-13 in Nottingham and London

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Engineering, Institute of Architecture.

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CINARK's prototypes:

AUTARKI 1:1

Fabric Formwork [Anne-Mette Manelius]

Optical Fibre Concrete [Johannes Rauff Greisen]

Reversible construction with wooden panels [Søren Nielsen]