Re-inventing mixed fabric and cable-net formed morphology in practice

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This paper showcases three recent projects from the design practice of Zwarts & Jansma Architects: an entry for the ARC Wildlife Crossing Design Competition, a design executed for the Extended Waal Bridge in Nijmegen, the Netherlands and HiLo pavilion under NEST which is a flagship project of Empa and Eawag a collaborative effort to contribute to the future of construction. In all the three cases, the design has been informed by the construction method of using a large cable-net formwork with a secondary system of geotextiles. This new concept builds upon existing architectural vocabulary, ideas and advantages found in fabric formwork technology, cable-nets and tensioned membrane roofs, to allow for variable-scale, long-span structures. The resulting designs demonstrate the computational tools developed to imitate and inform physical realities and validate how both thin shell volumetric concrete structures can be made with this system. Both physical and digital, parametric design models were used during development of these designs. Insights into the feasibility and viability of this method have been discussed based on experiences during the design process leading to construction and realization in real world.

Keywords: fabric formwork, form-finding, optimization, lightweight structures, parametric modeling, computation design

1. Introduction

Architecture’s relationship with textiles has traditionally been of peripheral interest in the central theories of architecture. It is therefore timely that this neglect of textiles in architecture is now in reversal. Architects, theorists, engineers and designers are now making bold claims for the importance of this disciplinary confluence and its increasing centrality in architecture. Textiles now offer a significant, unique and expanding range of possibilities for innovation.

Apart from tents and tensile structures, which have a perfectly reasonable architectural history of their own, using the textile, as a metaphor for the structural concept is relatively recent. We are now considering textiles exactly because they bend and curve, and can mould themselves to form as the skin does to the body. The seamed and tailored textile surface can continue uninterrupted, and link the inside with the outside (Garcia, 2007). Today we are able to realize a wide range of structural performance and functionality in responsive and interactive ways. Fabric formwork has the potential to develop interface with built structures on many different levels, resulting in a whole new paradigm of lightweight structure and architectural vocabulary.

In three recent designs for concrete structures by ZJA, in cooperation with BLOCK Research Group at ETH Zurich and Iv-Groep structural engineers, the use of fabric formwork was considered and investigated as a construction method. In this paper, the designs of all the three projects have been discussed and how each of them being so different is interconnected at the same time. The role of digital parametric models and computational optimization strategies during the design process will be discussed as well as how they were cross-informed by physical models to determine highly optimized performative geometries.

In the first project, the Landshape Wildlife Crossing, an entry for the ARC competition, the proposed method was developed and executed. This resulted in a detailed technical design and construction strategy. For the second proposal, the Extended Waal Bridge, the method was proposed by ZJA, however an alternate method was adopted by i-Lent and it's already halfway its construction. In the last project in this line, HiLo pavilion, research string was pushed forward to a totally new level where extremities of this method were employed in the form of an ultra-lightweight roof construction.

2. Cable-net supported form-works

The architectural shapes that seemed appropriate for all the three projects overlapped with the forms that are naturally being generated by membrane structures. This suggested using such membranes as their formwork. To date, there has been only handful large-span structures realized using fabric formwork. The largest of such examples was perhaps the Chivas Distillery Warehouse in Paisley, Scotland, featuring three ca. 100m spans. However, the main load-bearing structure relied on steel arches with the fabric only spanning the distance of ca. 2.5m between the arches (Anon., 1959). However, to cope with larger scales we propose combining fabric formwork with a cable-network. The cable-net not only adds strength to the fabric mold but also means to control the geometry.

Recently a broad range of software tools have been developed that can predict the geometry and behavior of such cable network. At the same time the interface between design and manufacturing has seen a paradigm shift towards digital workflows. This allows for rapid prototyping of designs and more freedom to use components tailored for specific projects. These developments combined might eliminate some of the practical limitations for using such cable-nets.

We are convinced that the combination of these two technologies into a hybrid structure of cable-nets that support a fabric form-work can make it economically feasible to create large-scale free flowing curved structures and surfaces. It has the potential to reduce waste of materials and energy. It opens up new doors towards a repertoire of vocabulary and shapes that would otherwise be hard to imagine and construct. This form language has the flexibility to adapt to a wide range of contexts.

3. Landshape Wildlife Crossing

The objective was to design a wildlife crossing in the Southern part of the Rocky Mountains near Vail, United States, as part of a more generic design strategy for the construction of 25 crossings at other sites in the surroundings. The designs had to be technically innovative while being constructible, efficient and cost-effective. They had to be context-sensitive, attractive and ecologically responsible.

Figure 1: Artist impression of Wildlife crossing

3.1. Design Concept

A hypar surface was chosen as the main theme for the design solution (Fig. 1). Seen from the road it creates an inviting arch spanning 81.5m for the traffic passing underneath while extending the flowing lines of the landscape. In cross section the upward facing arc protects the wildlife against noise and lights from the highway. Together these two perpendicular organizing curves define a double curved, anticlastic surface, the hyperbolic paraboloid, or hypar. The hypar as a thin shell structure and has very low stress. Applied in the non-symmetrical and irregular nature of the site topology, this idealized geometry is transformed into a shape that is context specific (Fig. 2).

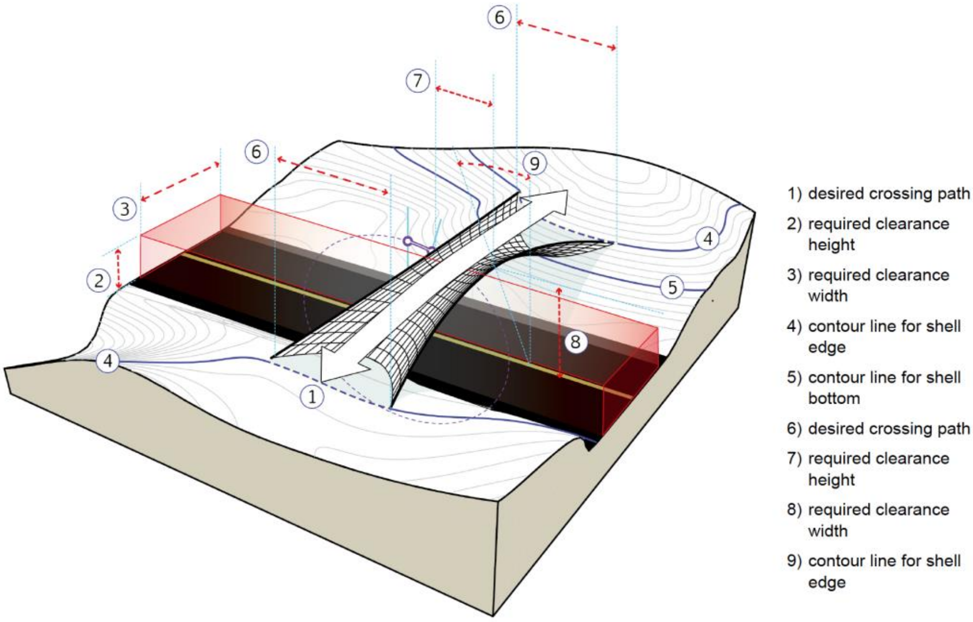

Figure 2: Interlinked design parameters taken into account for developing parametric model

3.1.1 *Physical modelling*

A physical model was made by pouring gypsum over a latex sheet to validate our thesis. It was soon clear that the tensions in the membrane during casting would become too high for the fabric on its own.

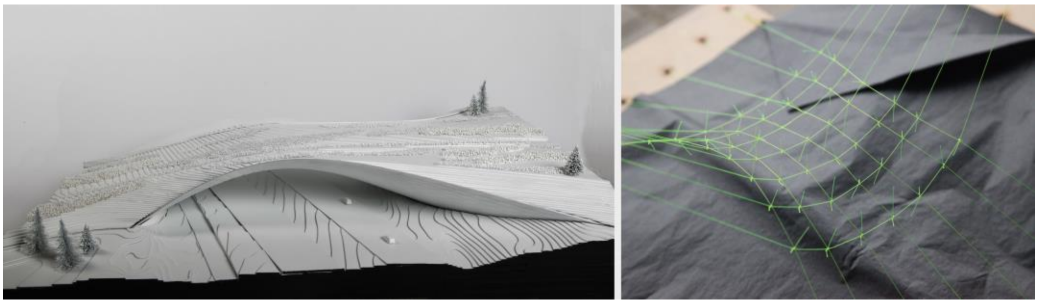

Figure 3: Site context model and wire model prototype of the cable net

To solve this a temporary supporting steel cable-net structure was developed that carried the fabric formwork along with its supports, thus splitting the formwork in a primary, steel network and a secondary fabric layer allowed for greater control over the geometry of the bridge (Fig. 3).

3.1.2 Digital modelling

For the purpose of form finding, performing initial structural calculations and communicating the results, a parametric model of the proposed solution was developed, using Grasshopper (Grasshopper, 2012) and a custom component written in Visual Basic. In this digital model the physical behavior of the cable net and fabric are being simulated with a particle spring system with a 4th order Runge-Kutta solver. The final shape of the crossing (Fig.2) results from the interplay of the boundary conditions (local topography of the landscape, traffic requirements etc.) and from the physical properties (grid size, stiffness, static loading, etc.) of the proposed structure. The user does not directly define the form of the hypar shell, but controls it by picking the location in a 3D terrain and setting parameters like the required clearance, the width of the crossing and an initial geometry of the cable-net. All these parameters are being fed into the model, which then uses a physics simulation to come up with the resulting shape. It can thus be said that a specific design is an 'emergent property' of the input conditions. This design methodology allows the designer, once the parametric model has been set up, to quickly investigate different design alternatives by changing the input parameters. Secondly, it implements a generic strategy that can easily be applied to different sites and conditions. This is an important quality because the design brief asked for a family of potentially 25 crossings.

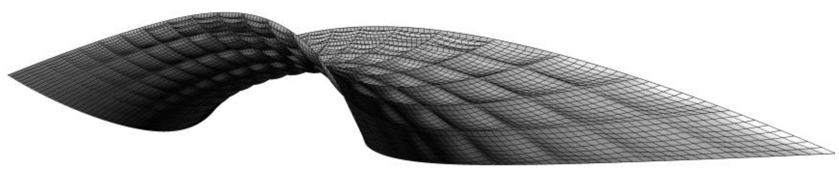

Figure 4: Digital simulation of the hybrid formwork, showing typical sagging behavior of the fabric

3.2. Structural Concept

The idealized hypar is a shape in which loads on the structure are transformed into forces parallel to the plane of the shell (membrane forces). Because of the near absence of bending moments it would be possible to use a very thin (<200mm) concrete shell as load-bearing structure. However, imperfections in material and asymmetries in the shape and loading lead to certain bending forces and instabilities. Therefore the shell was increased to a more substantial but still lightweight structure with an overall structural depth of 500mm, with the ability to carry uneven loading and reduce local bending stresses to an acceptable level.

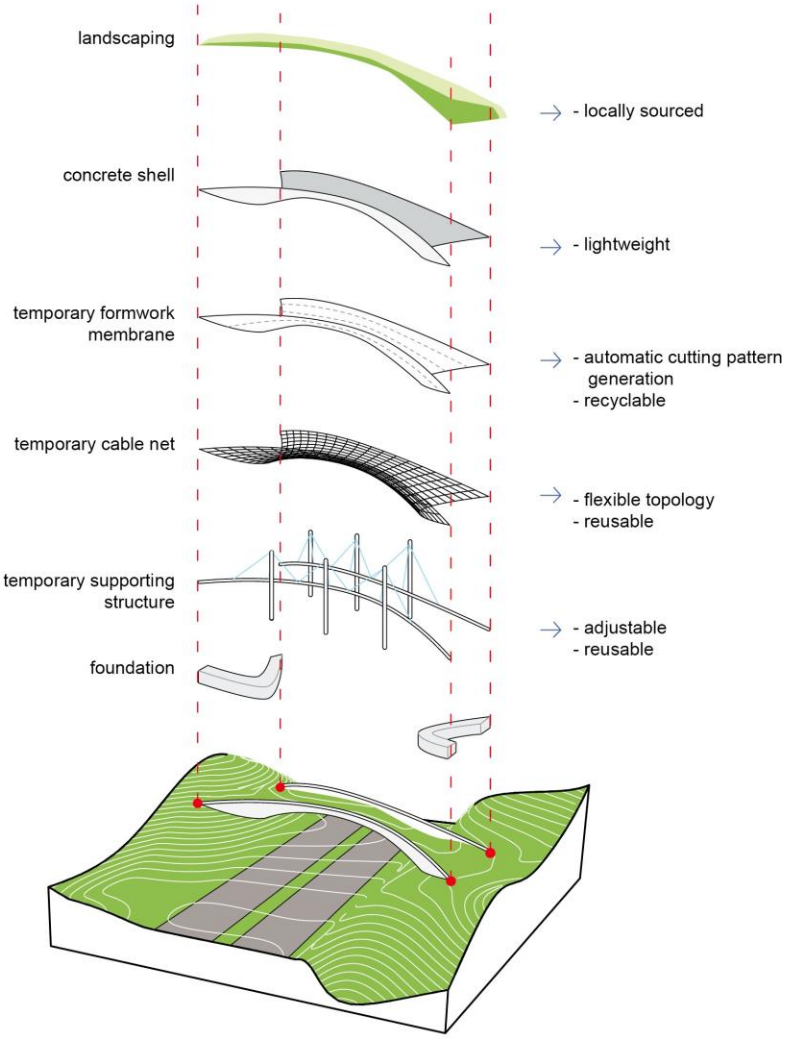

Figure 5: Exploded view of the construction elements

To support the fabric formwork a temporary support structure will be built. It consists of a grid of pre-tensioned steel cables spanning the length and the width of the shell. The longitudinal supporting cables are attached to the concrete basements on both ends of the structure, the crosswise cables are attached to temporary steel arches running along the two edges of the shell.

The formwork will be made of a geotextile, supported by the grid of pre-tensioned steel cables. It is cut and sown to the desired shape, specific for the particular crossing. This geo-fabric is covered with a non-adhesive coating to avoid bonding with the concrete surface while hardening. While applying the first 100mm layer of shotcrete the fabric will sag between the supporting cables, thus giving the surface its characteristic pillow-like look (Fig. 4), the sagging will range between ca. 30 to 300 mm, or about 1:33 to 1:20 of the span. After the concrete girders have set, the temporary support structures can be taken away and the superstructure is ready to be covered with soil and vegetation (Fig. 5).

To reduce the building costs of the superstructure and minimize material waste, the temporary supporting structures will be designed to be reused. This spreads the costs for these elements over more crossings

3.3. Results

The Landshape structural concept works out to be a cost effective solution for the wild life crossing. The architectural design is based on a double curved hypar shape. In addition a construction method has been developed that enables flexible formwork to be made of prefabricated customized elements. This reduces the execution time and thereby the costs. The design method is further optimized in the following projects through advanced form finding (form follows forces).

4. Extended Waal Bridge

The following project is an invited design for an extension of the Waalbrug in Nijmegen (Fig. 6). Along the existing run of the Waal River, a secondary, shallow channel will be dug to carry excess water in case of extreme water levels. To cross this secondary fairway an extension to the existing bridge has been proposed. Designing the extension to the Waalbrug is part of a much bigger project initiated by the municipality of Nijmegen and the Dutch government. The overall project aims to improve the water management of the Waal River and develop the city and infrastructure surrounding it.

The original Waal Bridge, a steel arch, was built in the 1930’s and was considered a high point of engineering in its days. The central idiom behind the design was allowing water and river bypass the obstacle, which in this case was the vehicular traffic; water has become the new actors driving the design principle. Inspiration came from “canyons” often carved landscape by the erosive activity of a river over geologic timescales (Fig.7). Another aim was to come up with a design that would be informed by the curved forms of the original. This was achieved by designing the bridge as a series of supporting ca. 80m arches. The monolithic arches will mirror the construction of the main bridge, while at the same time having its own distinct morphology and material.

Figure 6: Artist impression of Extended Waalbrug

It was clear from the outset that, the design should be based on modern engineering principles. The appearance of the bridge should be a reflection of the construction method that was used. The experience of the Landshape Wildlife Crossing suggested that a similar visual language of smooth surfaces, created by stretching fabric, might be used for this project. And possibly also a similar construction method could be employed. The initial design of the bridge was based on the bending moment diagram along the span (Fig. 8).

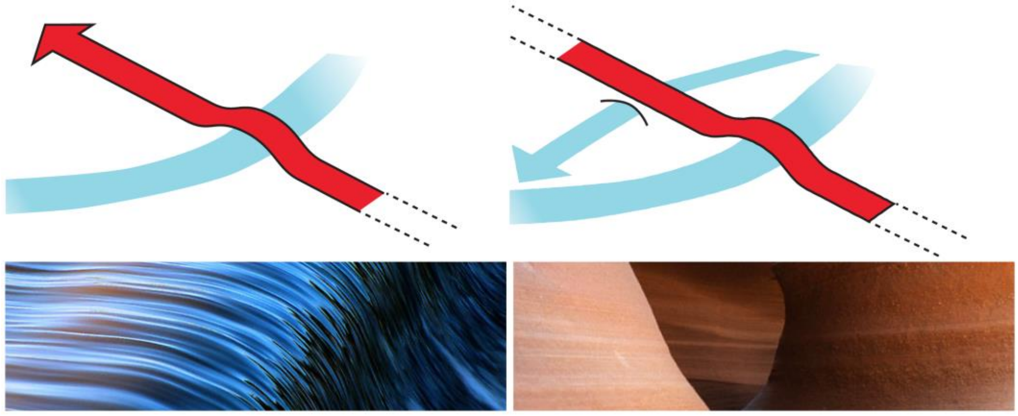

Figure 7: New extended Waalbrug acts as caved landscape by flowing river inspired by canyons

4.1. The design process

Designing the bridge has been a process of switching back and forth between physical and digital models. A physical model was the first step in the design process, but to optimize the design and communicate with other parties involved a digital, parametric model was developed which acted as a key in further developing the design. Still, in all stages of the design small physical models have been made (and will be made in the ongoing process). Rapid prototypes made from plaster, nylon fishing wire, or

CNC milled from foam and wood provided an important spatial and tactile experience that a computer screen cannot deliver.

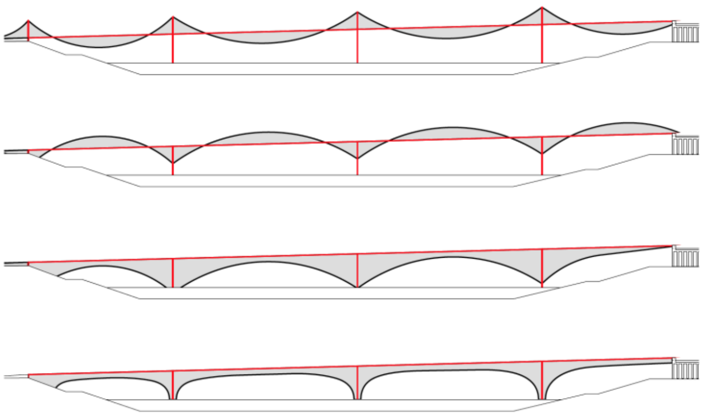

Figure 8: The overall shape of the bridge is derived by rotation and translation of bending moment

4.1.1 Physical modelling

The first sketch of the design was a physical model. A piece of latex, tightly stretched over a wooden framework was pulled down in three places (Fig. 9). It was assumed that tension forces in the fabric would correspond to compression forces if the resulting shape were built as a thin shell structure. This process created a mold, from which a plaster model was cast, the first in a long series of physical models that would be made throughout the various stages of the design process. They serve to check the physical qualities of different designs, as well as to inspire solutions.

Figure 9: Exploration of mesh geometry using physical models

4.1.2 Digital modeling

The physical model indicated that stretching a single sheet of material with constant stiffness results in supports that are too massive. To accommodate the flow of water under the bridge, the supports can have only a certain, limited dimension. As a consequence the transition from support to the deck would need to have a smaller radius.

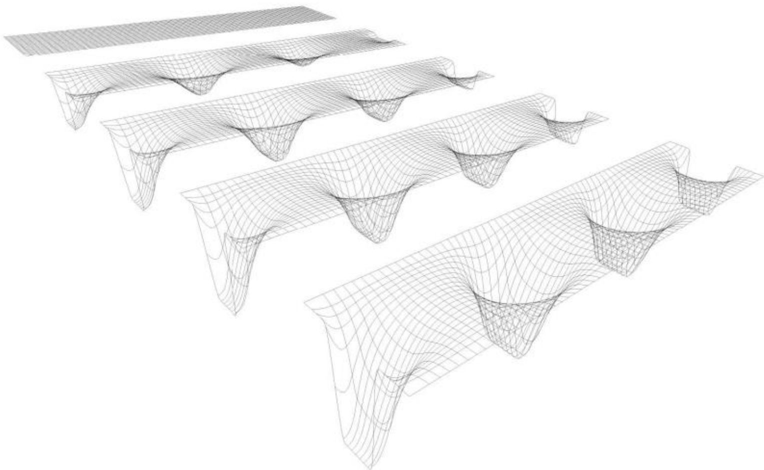

Figure 10: Schematic representation of the iterations for form finding

To test designs, a parametric model was set up in Grasshopper, and used Kangaroo plugin for form-finding instead of the earlier custom component. It takes boundary conditions, such as the alignment, the width of the road and number of supports and physical parameters such as grid size, stiffness of the material and vertical loading as input parameters. Given these conditions a mesh was stretched between the fixed edges (Fig. 9). The important difference however was that instead of using one single rectangular mesh, meshes were considered that consist of multiple panels, 'sewn' together. The topology of such a mesh is, in its unstressed initial state already a coarse approximation of the intended final shape and would overcome the limitations of the initial model (Fig. 10).

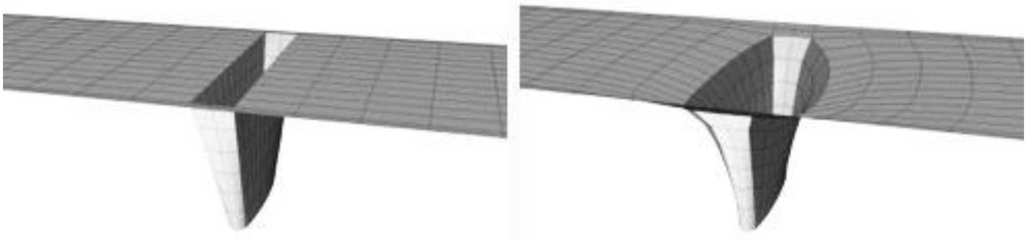

Figure 11: The modified/ tailored mesh before and after relaxation

Most of the vertices have four edges coming together, but some have five (Fig. 8). These are the points where multiple panels of the composite mesh meet. Additional forces were introduced in the digital model to arrive at the required profile of the supports and the associated sharper corners. Using this method it proved possible to interactively shape the bridge by fine-tuning the input parameters. The resulting, relaxed mesh was then subdivided and smoothed to arrive at the final shape (Fig. 11).

It should be mentioned that in order to arrive at the desired shape some parameters (e.g. static loading, stiffness) had to be set to values that were no longer physically meaningful. This liberal use of variable settings has implications for the role of such a tool in the design process. Instead of approximating the behavior of an actual physical structure, it is now used to help arrive at predetermined visual appearance.

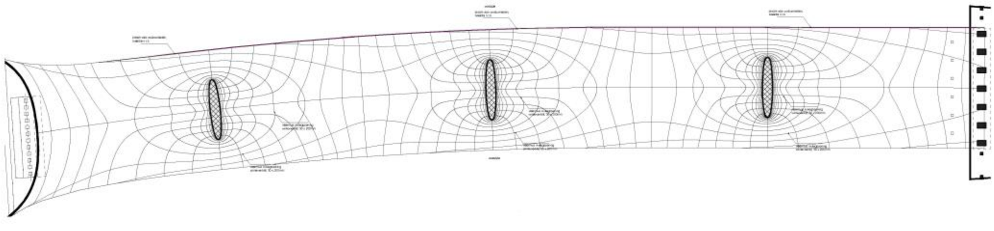

Figure 12: Field lines accentuating water lines under the bridge

The parametric model does have some shortcomings as a true simulation tool, it means that additional analysis or extension of the tool is required to obtain meaningful structural quantities. That a realistic cable-net with the same shape can be obtained is certain because the form finding problem is material-independent and the process guarantees a tensioned structure in static equilibrium. However, having altered the shape to fit certain projects constraints, does mean that cable forces and therefore shell forces will vary significantly, which influences both the structural response (susceptibility to bending and ultimately shell buckling) and structural design (local dimensioning and stiffness of cables, shell thickness and reinforcement). These were tackled in the HiLo pavilion to a greater extent, which accentuated the computation to an all-different level.

4.2. Construction method

The ambition was to achieve unison between the shape, design and constructability of the design. Apart from a cable-net and fabric formwork, three other alternative methods for constructing a formwork were investigated. Due to the smooth, doubly curved surfaces it seems appropriate to investigate the use of fabric formwork supported by a cable grid. A cable-net and membrane formwork will sag between the supporting cables and might show wrinkles at the corners.

Second approach was by shaping the mold from the existing earth body, i.e. excavating the formwork from the existing ground body taking advantage of the special circumstances. The building site is unique in the sense that the bridge will replace an existing road that sits on top of a dike. This method has been used for the Teshima Art Museum in Japan by architect Ryue Nishizawa and engineer Mutsuro Sasaki. Other alternatives considered were CNC milling of the formwork from polystyrene (e.g. the Spencer Dock Bridge in Dublin, Ireland) and subdividing the design in panels with single curvature coupled with a sophisticated way of computer-controlled optimization of the quantity of formwork material, and ease of build up by the pre-fabrication of the formwork parts which would allow the use of bent plywood to create the mold (e.g. the Mercedes-Benz Museum in Stuttgart, Germany).

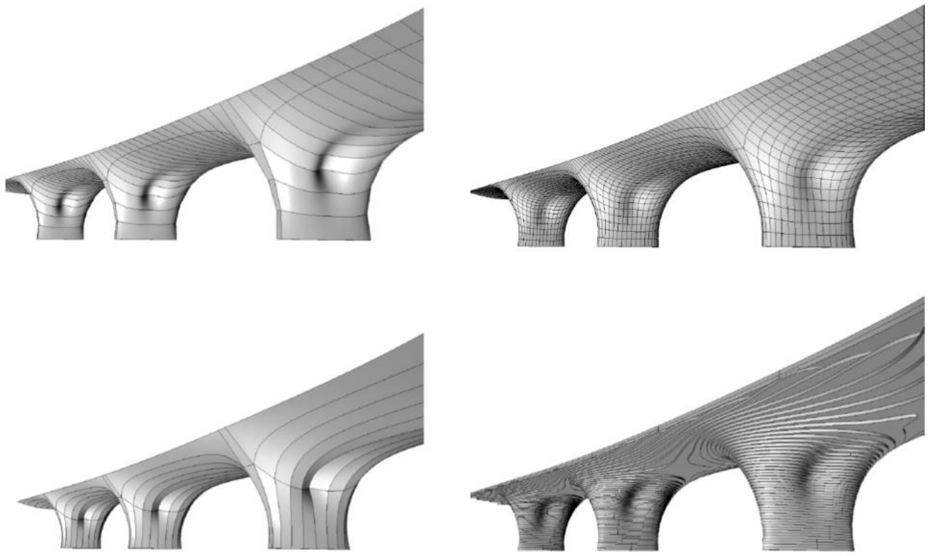

Figure 13: A schematic representation of possible outcomes in terms of appearance based on formworks

Each construction method (Fig.13) has its own implications for the final appearance of the bridge. It has been proven to be difficult to arrive at a satisfying geometry by using just the tension in a cable network as driving force to generate the desired span and shape of the bridge. The contractor tried to minimize the associated risks and finally the explicit visibility of the subdividing surfaces as building method was considered a feature and guided further elaboration of the design and construction.

Figure 14: The timber formwork produced by Verhoeven Timmerfabriek for the supports of the bridge which is in the stage of realization by i-Lent

4.3. Result

In the case of the Extended Waal Bridge the use of this method is not self-evident. Possible reuse of parts is limited in this project. Also, the conditions imposed on the shape of the bridge by the required water flow may have pushed the design beyond what is still natural to build using this method (Fig. 12). Beyond this, use of traditional formwork for curved concrete structure using custom timber bended formwork was adopted as a final solution. The wooden formwork was prefabricated at the factory before it was transported to site to be re-assembled and casted. All the reinforcements follow the double curvature of the formwork, given the complexity of the surface geometry. BIM model acted as basis for the structure generation and clash detection operatives compared with original design to monitor deviations (Fig. 14). In figure 15, you can see the formwork on site. Beyond this project, an additional research is needed on detailing of the formwork, in particular adaptable joints for reuse and connections between fabric and cable-net. Furthermore, methods to translate data from the digital design model to the workshop or site need to be developed. These research strings are taken into account the forthcoming project of HiLo pavilion, thus the evolution of this method prevails.

Figure 15: Formwork and work in progress at the site

5. HiLo_NEST

HiLo is a research & innovation unit for NEST in the domains of ultra-lightweight construction and smart and adaptive building systems, planned as a duplex penthouse apartment for visiting faculty, to be built in 2016. NEST – a flagship project of Empa which is the building material testing center and Eawag which is the aquatic research center. It is located on the Empa-Eawag campus in Dübendorf, Switzerland. ZJA's role was limited to HiLo pavilion (Fig. 16).

Figure 16: Artist impression of the HiLo pavilion

It is a collaborative effort between ZJA, Supermanoeuvre (Australia) and the Institute of Technology in Architecture at the Swiss Federal Institute of Technology in Zurich (ETHZ), represented by the Professorship of Building Structure (BLOCK Research Group) and the Professorship of Architecture & Sustainable Building Technologies (SuAT).

The main motivation of this applied research project is to severely reduce material, and hence weight, both for the formwork and its resulting shell roof structure. If we look at a broader picture transcending beyond the scope of roof structure research, a very lightweight building extension opens up possibilities to address vertical densification of cities.

5.1. Design process

We collaborated closely with BLOCK Research Group at ETH Zurich to develop the thin shell roofing system and contributed to other innovations related to the roof in collaboration with SuAT. It is a very lightweight and extremely thin, less than 70mm. The roof attains its slenderness by developing and optimizing the shape based on a flexible parameterization of the shape of the roof.

The use of a doubly curved shell roof at a domestic scale is largely unprecedented and as such so are the possible spatial qualities it offers: smooth, free-flowing and loosely demarcated spatial territories. The strategic deployment of a doubly curved roof relative to the arrangement of rooms yields a sophisticated dual spatial condition that supports and celebrates the at times competing needs for: privacy and communality; work and living.

Concrete shell structures, if properly designed and constructed, are able to cover large spaces at minimal material cost through efficient membrane action. However, they are challenging to construct, since they have to be customized for a specific doubly curved geometry. Due to the amount of work involved, these structures are generally not competitive in a contemporary building environment.

It is possible to reduce the amount of material, especially of the formwork, by introducing a flexible formwork. In this case, a fabric replaces the shuttering, and formwork, such as scaffolding, is replaced by a cable net, supported by an external frame at its boundaries. The challenge is then to design the flexible formwork such that the resulting shape is as designed.

The formwork system offers a degree of control over the shape such that it can be easily optimized for improved structural behavior and other criteria compared to traditional geometries. Key research areas dealt with developing a range of highly sophisticated digital modeling, simulation and advanced construction techniques to massively reduce the amount of traditional building materials (steel and concrete) and therefore the embodied energy used.

HiLo pavilion is a unique example in itself, where one cannot treat the digital computation model and construction as separate entities. They form an amalgamated entity; both are interrelated to one another where one informs another and vice-versa. The proposed integrated shell layers, starting from base construction outward, consist of the lightweight concrete shell with PU pads, radiant heating/cooling tubes with infill aerogel insulation, vacuum insulation layer, aerogel insulation, plywood substrate, waterproofing layer, thin film photovoltaic layer (Fig. 17).

5.2. Digital model and Construction

The choice of insulation is based on the low u-value ratings of aerogel and vacuum insulation. Only by using such high performing materials, it is possible to keep the integrated shell as thin as possible while maintaining a sufficient insulation capacity.

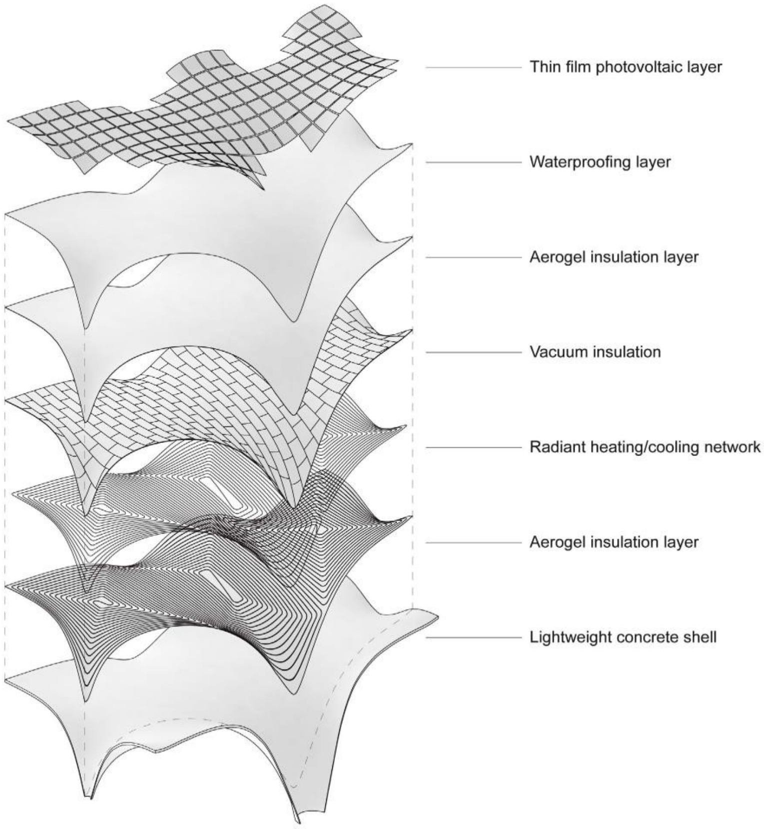

Figure 17: Taxonomy of the lightweight roof structure

In the initial situation the backbone has been constructed and is ready for arrival of the research & innovation units. As HiLo pavilion is part of the first wave of these units, the adjacent plots are still empty. The thin-shell roof is then constructed through a sequence of ten stages (Fig. 18). A parametric model has been developed to design and visualize the formwork system and it's supporting structures in each of these steps. This model can accommodate changes to the shape of the shell based on continuing structural shape optimization.

The thin shell roof touches down at several points along the perimeter of the HiLo pavilion. At these points it is connected to the structure of the backbone or through intermediate steel structure. After these permanent supports have been constructed, additional temporary supports are needed to support the roof and its formwork. These temporary supports consist of a perimeter structure of supports with adjustable length and an adjustable head. They will take the vertical load from the roof and the horizontal load from the pre-stressed cable net in stage 6. As the roof shell is a key component of the innovation strategy, it is preferred that the lower surface of the shell is not directly insulated.

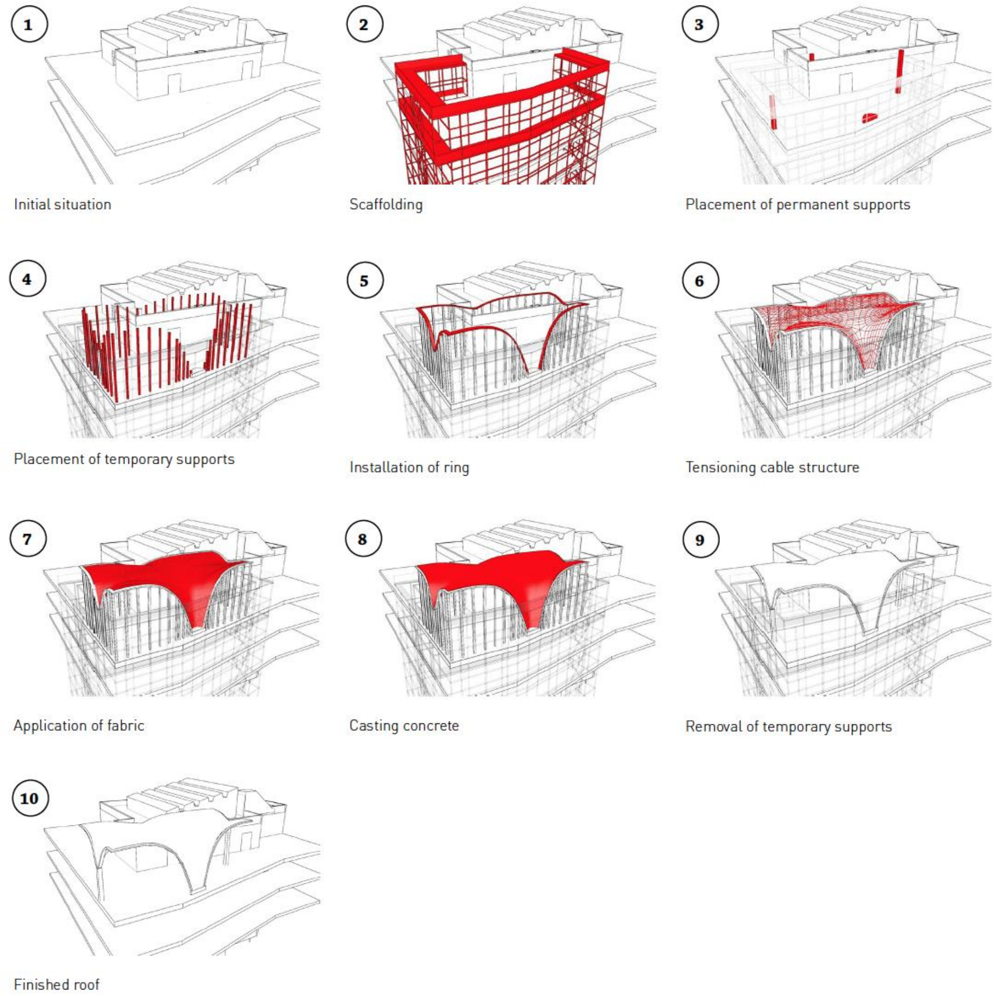

Figure 18: Sequence of construction of the roof structure

The perimeter consists of a T-shaped profile consisting of a continuous metal flange with a welded web. The profile is a complex three-dimensional shape, bent and rolled into shape. The profile serves both as the frame for the cable-net formwork, as the final edge detail for the finished roof. Though it is important to mention that this solution is still under investigation because of the issue of “thermal expansion”. It is not a major problem in case of conventional reinforcement bar but since in our case steel is outside the concrete it might undergo thermal expansion.

The cable net is prefabricated with fixed nodes. The geometry is obtained by mapping a cable-net topology onto the optimized shape of the roof. This mapping is carried out such that the cable net allows for convenient pre-stressing, accommodates cutting patterns for an additional fabric layer that supports the fresh concrete and behaves well under live load. Pre-stress forces within the cable net before and after casting are calculated using computational strategies developed by us and BLOCK Research Group. For different iterations generated for the roof structure and topology, each variant indicated differential characteristics. Some showed excessive tension that led to a change in the mesh topology used for form finding; as a result once an optimal form has been achieved, the initial cable net used to inform and generate the form in the first place might become useless. Due to this deformation, a better cable network could be fitted to the final shape thus validating the evolutionary nature of the computational run where offspring show different behavioral traits than their parent and new behaviors are adapted. The new cable net will not just be informed by performative parameters, but will also address aesthetic considerations. In the next phase, both the shape and topology were considered to find most feasible cable-net layout.

The fabric is patterned, sown or welded, and placed over the cable network. The fabric is not tensioned like the cable net, but is likely to be fixed to the nodes of this network, depending on the angle of the surface and the friction between fabric and cables (fig.20).

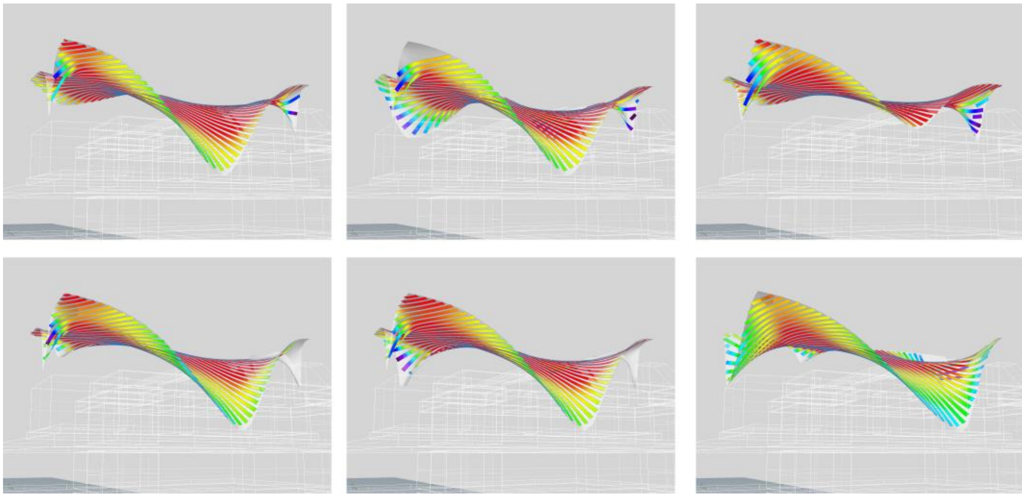

Figure 19: Solar PV Panel arrangement and optimization using customized script

The outermost layer of the integrated shell will be composed of high efficiency thin film photovoltaic cells. An initial study of the integrated shell has been carried out to propose the placement of the thin film PV elements. A computational algorithm was developed to proliferate the shell surface with PV panels optimized to the double-curved shape and maximizes solar radiation impact. Various alternative options were explored considering arrangement and orientation of panels to select the most efficient and practical solution (Fig. 19).

The thickness of the high strength concrete will have to be measured or monitored during its application. Photogrammetry has been used as a simple and cost-effective method of measuring the formwork prototypes and can easily be used for HiLo. Methods like 3D scanning are becoming increasingly available and affordable. To apply the concrete an overhead contraption may be used for easy access, visual inspection and quality control during application.

Figure 20: Various iterations of the roof geometry 3d printed and prototyped

Several prototypes have been built by BLOCK Research group in order to identify challenges in both computational and constructional aspects. It also validates the concept, a complete workflow for the structural design of an anticlastic thin concrete shell taking into account the fabrication constraints of a hybrid cable-net and fabric formwork.

6. Conclusion

The use of cable-network supported fabric, as a flexible and adaptable formwork, is promising as an economically viable method for construction of large-scale, large-span concrete structures. The concept consists of a cable-net and supporting structure at the same scale as those of built tensioned cable-net roofs, combined with a geotextile formwork at the scale of the cable grid size, the same scale as those of existing fabric formworks. It is therefore a combination of technically proven construction techniques. It is also economically feasible, especially so when concerning series of structures with similar geometries. For a single, unique design such as the Waalbridge and HiLo pavilion, economic feasibility remains to be a bone of contention. It does remain on the higher end if compared to conventional construction methods owing mostly to the design research which goes into it. Though it definitely promises economic and construction advantages in a longer run. There have had been estimation from contractor for the formwork, which gives it a competitive edge over conventional woodwork for instance. It is noted that the Wildlife Crossing project required continuous use of the freeway during construction. None of the other three methods would allow this, as they each require substantial formwork, whereas the cable-net and fabric formwork has a clear span with lightweight material with an entirely external support structure.

The design of these formworks is possible by constructing physical models and facilitated by recent advances in digital modeling, computation simulation and file-to-factory fabrication, respectively allowing for integration in traditional software in the building industry and offering an economically viable method of manufacturing the doubly curved geometry. Using these methods has the potential to reduce waste of materials and energy both for construction and the resulting structure. It provides a vocabulary of shapes that would otherwise be hard to build under current economic conditions. This form language has the flexibility to adapt to a wide range of sites and circumstances.

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