An aesthetic approach to the use of textiles in architecture

Prof Tina Moor, Lucerne University of Applied Sciences and Arts, CC Products & Textiles
Prof Dr Andrea Weber Marin, Lucerne University of Applied Sciences and Arts
Janine Häberle, Lucerne University of Applied Sciences and Arts

Abstract

Current trends indicate that ways of living will change due to longer life expectation, urbanization, scarcity of raw materials and energy resources and increased mobility leading to a need for flexible housing. Using textiles in architecture can be energy efficient and economic: it is lighter to transport and easier to (dis)assemble.

We are interested in an aesthetic approach to using textiles in architecture: textiles can i.e. be soft, foldable, elastic and they are available in a variety of colours and textures. We want to play with the sensory capacity of textile to give architectural spaces a different touch and feel. Our team of designers, architects and engineers at the Lucerne University of Applied Sciences and Arts (LUASA) is currently working on the project ‘Stoffwechsel’ (‘textile change’) with the aim to disclose the aesthetic potential of textiles in architecture.

In this paper we focus on two sub-components within the ‘Stoffwechsel’ project: textile insulation and textile pavilion. We present the state of the art and key learnings from the project and end the paper with offering suggestions for further research.
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Keywords
Textile architecture; textile aesthetic; sustainability; insulation;

1. Introduction

The requirement to act in a sustainable way has reached all areas of life. In the field of construction, new requirements to use natural resources more economically are especially challenging. Textiles have already been applied successfully, both for temporary and permanent construction applications, mainly as membrane constructions, geotextiles, shading and reinforcement.

The use of textiles in construction is nowadays limited to applications such as lightweight constructions (e.g. tents and shelters), mobile and temporary constructions, membrane structures, weather protection membranes and façade structures. The typical use of textiles in architecture demonstrates, especially in membrane construction, the characteristically, mostly three-dimensional, organic forms, which result from tensioned membranes, as well as the spatial contortion of those membranes. The repertoire of forms is based on complex distortion and absolutely wrinkle-free tensioned laminated fabrics, which distinguish the straight lines and right angles of the usual architecture. This almost perfect surface, without any wrinkles, is the reason why typical textile properties are completely negated; i.e. softness, fall of the folds, crinkles, etc.

The starting point for the research project was the great potential for the composition of textile architecture, whilst delivering sustainable, functional and feasible solutions. Consequently, the focus in architectural application is not only on ecological, technical and economical functionality, but also on the aesthetic aspects of textile surfaces, as well as the designing of textile modules. In this paper, we explore the aesthetic use of textiles in architecture. First we describe textile design principles that can be applied to the use of textiles in architecture leading to the definition of five working hypotheses. We then introduce the ‘Stoffwechsel’ project and its sub-components ‘textile insulation’ and ‘textile pavilion’. We describe how we have tested the hypotheses in this project and provide
preliminary conclusions on the feasibility of using textiles in architecture. We end the paper with offering several suggestions for further research.

1.1. Textile design principles
This paper focuses on design considerations, although the functional principles are always kept in mind. We will be examining which of the following aesthetic principles from textile design can be transferred to the use of textiles in architecture.

- Material
  A huge variety of different textile materials, both natural and synthetic, could be used for buildings. Some are able to absorb or resorb humidity, others are flame-resistant, water-repellent and/or breathable. The textile finishing industry offers vast possibilities in treating textiles in order to enhance the functionality of the material or to achieve special properties. Examples are phase change materials, silver coatings and coatings for moisture elimination. The great advantage of textiles is at the same time the main weakness. Textiles are soft and adaptable and the tensile strength is paramount, but they cannot stand compression forces.

Figure 1 / 2: Magnificent spaces can be created with textiles. A good example is the ‘Big Air Package’ by Christo at the Gasometer in Oberhausen, Germany. This sculpture made of 20,350 meter of fabric is installed inside a former gas tank and is illuminated through the skylights of the gasometer and additional light projectors. Photographs Walter Tschopp, 2013
• Construction of Textiles
Various textile construction are possible for use in textile construction elements: simple weaving, double weaving, warp knitting, non-wovens. of the two surfaces. The techniques of weaving and warp-knitting allow to construct three-dimensional textiles, for example spacer fabrics. It is possible to determine different properties of the two surfaces, which are attached to each other with spacer threads. Furthermore one can decide either the distance of the spacer threads and of the two surfaces.

• Proportion and Surface:
Proportion is an important theme in surface (textile) design. The size of a repeat is always adapted to its final use, be it an accessory, a garment, wallpaper or whatever is created with the fabric. This must also be taken into consideration when it is adapted on a surface in an architectural context: if the repeat unit is too small, the whole surface is perceived as a plain pattern. If the aim is to put rhythm into the surface, much bigger patterns are required. Textile surfaces offer a wide field of creation while simultaneously dealing with functional challenges. Creating textile surfaces means to consider all the possible parameters: the relationship between figure and ground, abstract or figurative forms, the choice of colours, contrast or harmony of chosen colours, matt or brilliant material, structured or plain surface.

• Repeat:
Textile surfaces are characterized by the repeat of one unit, side-by-side and end-to-end. The size of the repeat depends on the use of the fabric. These repeats can be created in very regular or irregular orientation. When designing a repeat, different sizes, changes of direction and proportion must all be taken into consideration. I can name two famous examples of structured surfaces, built with ETFE, one more regular, the other with complex repeat: The Allianz Arena, München and the Water cube, Peking. The surface of the Allianz Arena seems to be quite regular with its rhomboids but has a strong movement that welcomes the
sight of the spectator and transports it around the building. The very complex outside of the Water cube, built with differently shaped polyhedron-“bubbles” seems to have no repetition. But in fact, the surface consists of 13 different cushions, which are repeated in a bigger module. Another example for a regularly rhythmised wall is made out of insulating rubber material. The black surface is fixed with anchors in a offset grid pattern.

1.2. Hypotheses

Based on design principles of the textile design, the following working hypotheses are studied in the “Stoffwechsel” research project:

a) Textile materials and their properties are suitable as building material in architecture.

b) Textile construction offers a high potential for surface design.

c) Textiles, in combination with insulating materials, offer high insulating performance - due to their confection in chamber systems - as well as a variety of aesthetically designed appearances.

d) Textile chamber systems, in combination with reinforcing materials, achieve high load capacity with low weight, whilst also changing the aesthetics of a building.

e) Textile junctions (sewing, welding, gluing etc.) can be design elements and simultaneously help to transfer loads.
2. The “Stoffwechsel” project

2.1. Introduction

In the project “Stoffwechsel” textile elements are introduced as insulating part of the building envelope for indoor and outdoor application as non-structural and structural application. Textile fabrics are also applied for temporary structures where they have structural purposes. Thereby multi-layer textile designs could replace conventional walls, ceilings and roof systems. There are several reasons for this:

• Textiles are complex constructions, whether woven, warp-knitted or non-woven. The properties and characteristics can be pre-determined by choosing the right fibres, threads as staple thread, monofilament or multifilament, and by deciding on the construction of the fabric surface and its finishing, where supplementary functions can be introduced.

• Textiles are very robust, durable and lightweight, and have high tensile strengths. Textiles can be created according to their specific use, by employing high-precision processing technologies. Moreover, ready-made textile components may be transferred to the construction area, where they can be positioned and filled with insulating material.

• Textiles can be more adaptable to the requirement of the system, due to their specific properties, and because textile components allow for a customized construction.

• Textiles have different properties ideal for use inside, outside, and even as a house.

Applying textiles as new construction materials will result in a new and aesthetically appealing innovation, which can be seen, and evaluated, as having additional architectural value. Similarly, textiles used in an architectural context can be highly aesthetic, as well as being able to fulfil constructive, functional, insulation, acoustic and hygienic functions. For example, when textile materials are used externally, or as a façade, they provide opportunities for designing the surface. Moreover, when textiles are used together with insulating material and compression elements – but designed to be smooth and limp rather than high tension – the combined effect will have visual and tactile properties, showing natural folds and curves, resulting in new aesthetic opportunities. Solutions need to be found as to how to influence the forms of such constructions, by using appropriate material assembly, as well as woven or warp-knitted fabric constructions. Last, but not least, the overall impact of using textiles, on the building as a whole, needs to be clarified.

The LUASA School of Art and Design in collaboration with the LUASA School of Engineering and Architecture, is pursuing the application of textile material (woven and warp-knitted fabrics) in architecture and building construction. The latest project is funded by the Swiss Commission of Technology and Innovation (CTI) and has started in July 2013. It focuses on the development of multi-layered construction systems with textile materials for renovation and new buildings. The flexible and soft textiles structurally define the construction, and play an important functional, creative and aesthetic role within the
building system. Moreover, there are, for example, a lot of well-engineered high-tech fabrics in the garment industry, or with existing technical applications, which could also play a crucial role in architecture. The project focuses on the possibilities for the increased application of textiles in construction, taking into account current challenges in the building industry. The use of textiles in construction allows for custom-made solutions, by using selective yarn and material combinations, specific construction of the woven fabrics and its assembly. Moreover, by using techniques such as sewing, finishing, embroidering, printing and weaving, it is possible to enrich fabrics with special functions, which can be integrated into the textiles, giving them an added value.

2.2. Textile Insulation in Architecture

In the 1960s and 1970s many industrial buildings without or with insufficient insulation were built. As an alternative to destroying these buildings, sustainable insulation solutions are increasingly being sought after. The project “Stoffwechsel” addresses this problem by developing unique insulation materials: the subproject ‘TexLining’ focuses on insulation for the large inside walls of such buildings while the subproject ‘TexCoat’ creates insulation for the outside façades that are often carried by steal or wooden pillars.

2.2.1 Design vision

The textile insulation needs to fulfil several requirements that are formulated according to the capacity of industry partners within the project, as well as the mechanical properties of the old buildings. However, the biggest challenge of “Stoffwechsel” is to balance the necessary functionality with design and aesthetics of the insulation materials. First, the textile materials need to meet the following functional criteria. They need

- To have a certain flexibility and silkiness and the capacity to be draped and to span a large surface;
- To minimize the working steps from production to assembling;
- To be composed of a minimal (and therefore sustainable) material mix; The aim is to use only one material, for example to conceive cushions with glass fabric and glass-insulation, basalt fabric with rock wool insulation or polyester fabric with polyester-insulation in order to reuse the whole element. It is possible to put it in the furnace or to melt it and get again glass fibres, rock wool or polyester without separating different materials from the cushion.
- To minimize weight and space in transportation.

2.2.1 Procedure

As mentioned earlier, the basic benefits of textiles are their lightweight, flexibility in use, strength on tensile loading and the fact that they can be produced in running meters. These functional characteristics give textiles a great advantage over other materials that are commonly used in architecture and the construction industry. Furthermore, the aesthetic and design potential of textiles for both indoor and outdoor use in buildings is very promising. Several aspects of textiles especially offer design opportunities
• The choice of confection, material and colour.
• The possibility to work with prints, develop woven fabrics and add acoustic features.

The design exploration is deliberately kept low, but on the other hand the design vision and knowledge about textile design possibilities are the benchmark for the decisions and developments. Thereby the design vision navigates through the over all development of this research project. This aspect shall be illustrated by explaining two experimental material-sketches and mounting-trials in a very beginning stage of the project. Through such hands-on trials, presented below, material experience and design inspiration through making is generated.  

2.2.2. Applied experiments

We developed large textile ‘cushions’ that were filled with rock wool granules and could then be connected to girders (large supporting beams used in construction).

• Two different kinds of spacing fabrics are considered: one like a honeycomb structure with “pipe-sequences” which run horizontally or vertically. Each pipe was filled separately with the granules after having been chucked between the girders.
• Another concept to pursue is an interpretation of spacing fabric. Two layers remain open but are jointed together with repetitive placed connection points. These points are crucial because when we try to fill the space between two sown together layers of fabric, the filling material will not divide equally due to gravity. In other words: the fabric will blow up like a big belly. Connection joints prevent this as they will lead the filling material to be divided evenly between the fabric (see figure 5 and 6 on page). In this early stage, the role of the (textile) designer is important, because it has to be taken into consideration, where to put the junction points: are they put in a regular repeat, in a irregular repeat, in which distance are they placed, etc. When the layers have been attached to the girders, the cushions are filled with rock wool granules.

Honeycomb-pipe-fabric and spacer-fabric feature the possibility of being produced as running meters in maximum width (ca. 300cm). Such a panel of spacer fabric can theoretically be mounted in one piece, vertically between girders – from floor to ceiling, or horizontally - panel by panel. In this early stage of the project, in cooperation with the architect researchers and the industry partners, it is important to work along questions among the feasibility of this ‘minimized steps from production to mounting’-concept. Two of such very applied questions are illustrated in the following pictures:
On picture 9 we see a glimpse of the aesthetic capacity of textile insulation. Filling textiles with air would make the cushion stiff, but the rockwool gives it a soft property, like a real cushion as we know it from our sofa. Construction material like rockwool and soft fabric like cotton might be perceived as opposites, but from the tension between these substances new products and applications can be born. Imagine how a room with soft walls like this can serve many different purposes, in for example hospitals, spas and lounges. We argue that it is this aesthetic capability that makes the use of textiles in architecture – in this case specifically in insulation - full of potential.

2.2.3. Considerations I

Considering design, size and feasibility: What will be its form after the filling? Can a cushion made of 100% glass fabric and connecting points set by hand in a 7cm, 9cm and 30cm grid, be filled with rock wool granules? How does the textile material behave when it is filled with the granules? Through this trial it was possible to gain an imagination of the mounting and filling process. Material behaviour, physical aspects and the appearance were proofed during the filling process. Due to understanding processes, physical aspects and possibilities concerning such granule filled cushions, the design vision becomes clearer and offers new inspiration.
Figure 10 / 11: Sketch models for attachment trials. 100% polyester warp-knitted fabric with attached wooden tiling (attachment only in the middle of the tiling), chucked on a girder-model 1:10. Photographs LUASA, 2013

2.2.4. Considerations II

Considering proportions, feasibility and processes: What are possible concepts to merge half-solid tiling with textile? What can be the sizes of the tiles? How can they be in an interesting rhythm to fulfil our vision? How does the material behave when attaching the module overhead as a whole piece by chucking the textile between girders? This trial gave detailed information about the physical behaviour of a stretched fabric with fixation lines and / or points. Furthermore the experiment to fix solid tiling onto a textile gave indications about the process development and logistical issues. By working with this specific semi-transparent fabric, design visions and aesthetic varieties with different tiling sizes and use of colour become nameable.

2.2.5. Further experiments

So far we have experimented with a variety of fabrics and insulation materials, systems of attachment, mounting and confection in order to find meaningful combinations. We are continuing these experiments and will develop a morphological chart of best alternatives.

2.3. Textile pavilion

The starting point for this project was the awareness that modern festival tents are limited concerning interior space and comfort and unsatisfying with regard to their form and external appearance. Our interdisciplinary team consisting of engineers, architects and textile designers has been working in collaboration with textile suppliers, tent manufacturers and event organizers on a concept for a mobile event pavilion, which would fulfil contemporary requirements for aesthetically-extraordinary occasions.
2.3.1. Design Vision

The appearance of the pavilion was defined by the design team, focusing on two crucial aspects:

- First, it was important that the size of the pavilion could be altered. This demand led to the vision of the external appearance of an accordion. In such a way it would be possible to alter the shape of the pavilion according to the number of people using it.
- The second vision was to start with a flat piece of fabric, and then to create the three dimensional form of the pavilion without cutting off, or manufacturing, any material and enabling an easy build-up.

2.3.2. Procedure

Our team worked first with paper, in order to find an adequate form for the future pavilion. As in Origami, it was possible to produce suitable forms, just by folding the paper, without cutting or using glue. Different systems of foldings and repeats have been conceived in order to define the three-dimensional form for the pavilion. The trials are very much influenced by the textile design principles, such as unlimited length of fabric, repeat of foldings and proportion of foldings.

Based on these very first trials, we developed a system using the following principles: the compression elements are manufactured into the fabric, which makes the system melt together. Thereby the bearing structure and the shelter form a unified whole. The system consists of a fabric and compression bars, which do not touch each other. When the whole system is folded, it stiffens and becomes three-dimensional. The LUASA applied for a patent at the Swiss patent office for this “Tex-Fold-System”. Texfold is unique because the textile is connected to the sticks. Figure 15 shows how you start of with a flat surface that has certain openings through which you put the sticks (like with a tent). The sticks are fixed in the textile, but they do not touch each other. When you then fold it, the textile becomes a 3D shape.
However, creating architectural models using textile materials on a small scale is problematic, because these models cannot be easily scaled-up, as would be possible with other materials. For example, a very thin fabric, weighing 30g per square meter in a model 1:100, would weigh 3kg per square meter once scaled-up, which is no longer a textile material in its strictest sense.

During the biennial Swissbau 2012 in Basel, we demonstrated the feasibility of the system by building part of the 1:1 pavilion, which served as our booth.

From May 2013 until January 2014, a further development led to a mock-up of two 1:1 segments of the pavilion, built outside on the university campus (see figure 18). Standing outside being exposed to weather conditions, we realized that the TexFold system cannot be applied on a 1:1 scale for outside events. The structure is not strong enough to resist for example strong winds.
This conclusion has led to the development of two separate research projects. The first is to build a 1:1 pavilion in the shape created by the TexFold system, but constructed in a conventional way: the structure of sticks will be build first after which it is covered by the textile. This project is currently being undertaken by a team of architects and engineers as involves a lot of measurements with regard to weather conditions. The goal is to complete a well-engineered pavilion by summer 2014. The second project is to develop other applications of the TexFold system.

2.3.3. Conclusion

The procedure of the pavilion project shows clearly, that the start with a small model to conceive and clarify the outer form of the future pavilion by the designers, allowed the invention of a totally new system, which would not have been possible without this approach. We believe in the procedure of planning not only theoretically, but also “by hand”. Doing by hand helps us to solve possible problems already in the very beginning of the project.

3. Further research

We perceive the work that we are currently doing with Stoffwechsel as only the beginning of our efforts to explore the aesthetic use of textiles in architecture. The following projects
are examples of how we can further integrate textiles in architecture: three of them are our own projects and two projects were undertaken by colleagues. A big challenge when using textiles in architecture is that new ways need to be found to for example build lighting into walls – as it is not possible to drill a hole as you would in a concrete wall. There are several examples of integrating light like the projects TIF and E-Broidery reveal.

### 3.1. Own research projects

**TexFas**<sup>9</sup>:
The objective of the pre-project<sup>10</sup> “TexFas” was to prove the potential of multi-layered textile constructions. The principle was made out of traditional polyester fabric with polyurethane coating. Hereby the feasibility and the aesthetic potential were clarified.

![Figure 19: textile wall](image)

Photograph LUASA

**Textile Interfaces TIF**<sup>11</sup>:
Woven textiles with conducting light can make the fabrics shine or conduct electricity. Glass fibre-monofilaments are integrated in the fabric. With the aid of mechanical treatment the glass fibres reveal patterns by shining through the treated spots. We think, that textile material offer the possibility to be enriched at the very beginning of its construction with different additional functions. These function can be adapted to the final use in textile insulation or construction.

![Figure 20: Visualisation of TIF-façade](image)

Photograph LUASA
E-Broidery: E-Broidery is the name for innovative textiles with electronic components like LEDs, sensors or solar modules, which are integrated by use of embroidery-technology. Fabrics become more than simple curtains, but create f. e. a warm ambience with dimmable lights when the night falls. When curtains become an new form of lamps, it is imaginable that textiles used for construction could be as well insulating as luminous.

Figure 21: E-Broidery curtains
Photograph Isabel Rosa Mügller

3.2. Outside projects

**LUCEM** - Translucent concrete:
The invention of a translucent concrete, developed in cooperation with Aachen University – Institute for Textile Technologies – is very interesting because the use of textiles has both a stabilizing function (glass fibres and Kevlar fibres) as well as an aesthetic function (light-emitting glass fibres): the fine glass fibres allow light to pass through the concrete panels.

Reinforcement in construction:
Textiles are used in wall construction, for example as plaster reinforcement grids, primarily used to prevent cracks in the plaster. Similarly, textiles – including carbon and glass fibres, and fabrics – can be used to reinforce concrete, whilst also allowing for the production of light and free forms in architecture. However, in this case, fine-grained concrete is required to ensure good bonding between the fabric and the concrete.
4. Conclusion

The challenges of the “Stoffwechsel” project consist of using scientific methods as well as doing 1:1 models to prove that our ideas about textile insulation play the crucial role as aesthetic and functional parts in the construction, which go beyond the solutions we know today. We found that textiles can be applied as insulating “cushions” in old warehouses. The next steps are the experiments with different textile materials both woven and warp knitted, conceived after the first evaluation of the experiments at the mockup-wall. Currently we are working on insulating devices, which contain transparent parts for the use in sky lighted rooms. The outer form of the different fabrics can be beautifully shaped and rhythmical with anchor points to hold the insulating part of the cushion element. The design of such cushions in combination with technically advanced fixture, enables the creation of large surfaces and a variety to make them rhythmic by confection or choice of colours. The use of soft textiles in architecture as visible outer layer, in the inside and on the outside of the building will change the appearance substantially. The development of these new building devices requires a tight collaboration of designers, architects and engineers. If the experiments will be successful, the thinking of architecture in small, heavy and hard pieces must change for the benefit of wide, light and soft textiles in construction.

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