Timber Fabric:
Applying Textile Principles on a Building Scale

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Abstract

Textiles are interesting from both a structural and an architectural point of view. Their patterns and textures, created by the interworking of yarn elements, are not only highly appealing on an aesthetical level, they also possess load bearing qualities. The research project “Structural Timber Fabric: Applying Textile Principles on Building Scale” sets out to investigate this potential and proposes to develop a new family of timber constructions based on the logic and principles of textile techniques. In this context, and within the scope of several case studies, one of the core objectives is to create an innovative structural system with concise aesthetic, spatial and structural qualities. Thus, the proposal addresses important challenges at the frontiers of the fields of architecture and civil engineering. The here presented paper outlines selected parts of this research.

Keywords: Timber construction, Textile techniques
Building with Textiles

Textile Structures. Textiles are omnipresent in our everyday life. They surround us in the form of carpets and curtains. We wear them on our bodies as apparel, in the most extreme cases as diving or space suits. As towels they are essential for our daily personal hygiene, textile bandages and bioimplantable textile devices are indispensable for medical treatments (McQuaid 2005). Recently, textiles were even proposed as external cover of a concept car developed by a renowned German car manufacturer.

Despite of that, the fact that textiles have been used for architectural and structural applications since their invention is little-known. The work of Gottfried Semper plays an important role in this context. The theories presented in his writings declare textile craft as the most important one. He also points out the relevance of knots as early means of joining separate elements of a construction as well as the importance of textile mats and carpets as spatial separators in early buildings (Semper 1851, 1860-63). This had a large impact on modernist architecture and the development of curtain wall facades.

Actual textile structures then entered the domains of contemporary architecture and civil-engineering in the nineteen fifties. Large parts of the pioneering work that preceded the numerous realizations of such structures can be ascribed to the research and prototypes executed by Frei Otto at the Institut für leichte Flächentragwerke at the Technische Hochschule in Stuttgart (Nerdinger 2005). Since then, the term textile architecture is commonly linked with those often tent-like membrane structures. Although dealing with textiles as well, it is important to clarify that the approach inherent to the here presented research is quite different. Instead of literally working with textile fabrics, it is focusing on the textile principles that are applied on the level of the interaction of the yarn elements. Textile techniques are applied on a larger scale and with materials different to textile production. A whole set of questions is linked to this aim of applying textile principles on building scale, some of which shall be mentioned in the following.

Changing the Scale. In fabrics, as well as in basketry, the coherence of the interlaced yarn elements is governed by friction. This radically changes on building scale. Although there might be a possibility of building structures that are partially relying on friction, it’s very unlikely that they will be manageable without additional fasteners such as nails, screws and bolts. But fasteners as additional elements are not alien to textile fabrics either. Textiles such as beadwork are a good example of that. In this group of textiles, the beads not only act as ornamental elements but actively contribute to the coherence of the fabric (Seiler-Baldinger 1994). Beadwork therefore could help finding solutions on large scale.

Additionally to this, the yarn elements used in textile fabrics are, in principle, available with infinite length. On building scale, the length of elements is limited. Those limitations, due to the different scale, are multiple. They are material related. Trees for example only grow to a certain height, and timber production facilities introduce additional limitations as the machines can only produce panels up to a certain size. The required transport of the elements to the building site in-
roduces yet another constraint. Leonardo da Vinci’s studies on reciprocal structures indicate how one could react to that problem (Fig. 1).

**Figure 1:** The upper images show an exterior and interior view of a vault structure made of interwoven timber elements. The images below show studies of structures based on two- and three-directional weaving and similar to Leonardo da Vinci’s studies on reciprocal structures.

**Textile Qualities.** It’s a matter of course that a profound knowledge of textiles is essential for the successful execution of the beforehand described research. In this context, the system effect innate to textiles is of special interest. Textile cohesion is, as mentioned above, based on friction between the individual interworked elements. During the procedure of fabrication, a multitude of separate yarn elements is processed into one coherent entity. The failure of one or several of the yarn elements therefore doesn’t lead to the failure of the whole structure.

Despite this advantage, textile cloths can typically only be charged on tension and not on compression. Unless they are tensioned and brought into shape, as it is done with membrane structures, they are formless, flat surfaces. Still there are textile-like fabrics that are actually capable of bearing compression. Those can be found in basket structures: basketry employs textile techniques, but with materials that dispose over bending stiffness, such as osier or bamboo.
The idea of using large basket structures as shelter is obvious. Some peoples, amongst others Ethiopian tribes, are still building dome-like huts by plaiting strips of split bamboo today (Dethier et al. 2000). However, in our industrialized civilisation, the idea of applying textile principles on building scale goes way beyond those basic methods of shelter construction. On the one hand there are rigorous building regulations that have to be met. On the other hand there are new and exciting technologies and materials that can be employed.

The Textile Module

Evaluation of Techniques. Different ways of classifying textiles exist. In the course of this research two taxonomies were compared: The Primary Structures of Fabrics by Irene Emery (Emery 1966) and Textiles: A Classification of Techniques by Annemarie Seiler-Baldinger (Seiler-Baldinger 1994), to which it has already been referred to above. Emery’s work focuses on the different structures that can be found in the different types of textiles. Seiler-Baldinger, by contrast, emphasizes on the importance of the process of production, as different techniques can lead to a similar result in the textile structure.

During the process of analyzing those techniques regarding their suitability for large scale application, it became clear that, apart from the commonly known techniques such as felting, knitting, braiding and weaving (Fig. 2), an immense amount of variants exists. This insight triggered an adjustment in the direction of investigation. Instead of aiming at a comprehensive overview of existing techniques, the quest for a least common denominator of textiles was launched. This quest resulted in the finding that practically all textile structures can be reduced to one in principle identical unit cell. This unit cell acts as a kind of basic module and consists of two intercrossing threads.

Figure 2: The yarn structures of felt, knitted and woven fabric.

Generation of the ‘Textile Module’. In a following step, the principle of this unit cell was brought to large scale by interbraiding two strands of glue laminated timber. By doing so, the research’s first promising outcome, the so-called ‘Textile Module’, was produced (Fig. 3).
It shows how the use of a particular textile technique of assembly, together with the properties of a specific material, can lead towards a particular and structurally efficient construct, whose geometry is automatically generated by the process of assembly. Additionally, it commands of exceptional behaviour when put under pressure: the structure becomes longer and flatter but in the same time, the sectional triangle in the middle of the module narrows, becomes higher and therefore stiffens the structure.

Figure 3: Generation of the ‘Textile Module’.

Developing Structural Fabric

Structural Advantages of Textiles. One of the structural advantages of textiles is the already described system effect: they are made up of many basic elements that are interconnected and work together as a whole. Therefore the failure of one or several of the basic elements doesn’t lead to the failure of the whole structure. In order to achieve a similar effect on building scale, it is likewise necessary to create a structure that is composed of a multitude of elements. At present, the research work focuses on how this can be accomplished by using the ‘Textile Module’ as a basic element, or, in other words, as unit cell of such a structure.
Modular Fabric. The most obvious method of doing so is to combine several modules in a linear way, which creates an arch like structure. A sequence of several of those arches can then be combined again to form a structure similar to a vault. The disadvantage of this approach is that the arch elements stay independent from each other. There’s no continuity in the cross direction. A possible reaction to that is the addition of elements perpendicular to the arches which also improve the overall structural capacities by large amounts (Figs. 4 and 5). A second possibility is to create a fabric that is continuous in both directions. This becomes possible by shifting the basic modules and increasing the distance between them. However, this can also lead to geometrical complications in the total of the structure. All the same this is a promising direction for future examinations and further development.

Figure 4: Single basic module and different variations of fabric based on that module.
**Figure 5:** The upper row shows a perspective and a top view of the ‘Textile Module’. The intermediate row shows three modules as arch structure in a top view and a perspective side view. The bottom row shows a model of structural timber fabric with support elements in perpendicular direction.
Modelling and Calculation

Physical Models. The “Textile Module” is a good example for how a specific technique of production, in connection with a specific material, can serve as a form generating tool. Handmade physical models played and will play a crucial role for its development. This is for several reasons. First of all, physical modeling offers direct feedback. The material behavior, such as elastic deformation and its limits are experienced directly with the real material at hand. Another reason is the possibility of producing smaller models in rather short time and, by doing so, creating whole series of study models.

Despite of the importance of the physical model, the use of digital tools will be indispensable for exploring the potential of the discovered phenomena. Furthermore, the aim of developing a marketable product demands the incorporation of digital planning and production tools.

Digital Tools and Active Materiality. Although contemporary CAD software is in a continuous state of evolution, it still has its limitations. Until now, a tool capable of digitally simulating the deformations as they can be identified in the Textile Module hasn’t been found. In order to be capable to execute first analysis with FEM software, the physical model was scanned by a 3D scanning device. An alternative approach would be the simulation of the process of assembly, again with FEM software. Both directions are potentially promising. However, a lot of research still needs to be done in this direction.

Conclusions

Summary. Textiles and textile techniques possess properties that are of interest for both architects and engineers and demand for an interdisciplinary approach. The results of the first studies, especially the ‘Textile Module’, are encouraging and promising at the same time. The insights obtained with the finalized research will be able to contribute to buildings with a higher disaster resistance. Also, it will generate timber buildings with appealing designs which will promote the renewable building material wood.

Outlook. Considering the first results, this research promises to prepare the ground for a new family of timber constructions. However, several questions will have to be addressed in order to achieve that. In the near future, the development and testing of further prototypes is planned. With the help of those prototypes, the assembly of modules on large scale will be optimized. Alternative options of textile patterns using the textile module will be verified.

In the same time, steps are undertaken in order to approach the beforehand described problem of digital simulation. It will be important to work on a mathematical, respectively a mechanical description. And another essential question will have to be addressed: how can waterproofing and thermal insulation become integral elements of the here proposed structures?
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