Fibre_Space

Keywords: architecture / textiles / skin / structure

Abstract

Weaving buildings? Crocheting a room? Is it possible with the technological breakthroughs in hybrid or composite materials that we may be able to reconsider the construction of space and how woven and non-woven techniques could be used to deal with form and function?

In order to innovate with this relationship, links need to be made between the parallel worlds of textile design and architecture. Each discipline looks to the other for conceptual inspiration but until now does not converse in order to pursue large possibilities. If the material breakthroughs allow for textile design to function at the scale of a building then terms such as twill, sateen, and plain weave could be added to beam, column and slab.

Innovations in materials and technology are challenging what a 'textile' is and can do. New functions and aesthetics are able to be engineered, creating new appearance and performance characteristics in fabrics. Textile techniques such as weave, knit, crochet and embroidery are being expanded into broader categories of flexible skeletons, meshes, nets, membranes and skins. These lead to new ways of thinking about form, structure and construction. The inside and outside can blur. Concepts such as transparency can be explored through 'fabrication', opening the possibility for more creative and innovative sustainable design solutions.

The aim of thinking about textile design in a building context is to consider the spatial opportunities that can be revealed. To sit under a woven structure that filters light and breeze relates to the most primitive shelters, built in a craft-like manner. But what if this was the condition in a highrise office space, or art gallery or even mass-produced housing? The potential and opportunities are endless.

Introduction

Architects together with textile designers are looking towards new advanced materials to rethink form and function at the macro and micro level of the built environment. Technological breakthroughs are transforming textile fibres and fabric constructions. These are allowing for the application of textile techniques such as weave, knit, crochet and embroidery, once exclusive to fashion and often considered as decorative to be applied structurally at a vast

scale. This is leading to the re-examination of the connection between a form's surface and structure (skin and bones); be it for a building or a garment.

In order to take advantage of these breakthroughs, links must be made between the parallel design worlds of architecture and textile design. Collaboration and a multi-disciplinary approach become vital, at the concept, design and construction stages. This can be demonstrated with the studio Composite_Space, a collaborative project involving architecture, textile design, business and aerospace engineering students at RMIT University in semester 2, 2007. This studio highlighted the potential for how collaboration of this nature can be used as a springboard to develop further research activity and for disciplines to learn from each other. It is exciting to consider that through these interactions new ways of thinking about space and form could emerge and new design solutions and processes could be realised.

This paper will discuss how the use of textiles is being transformed through material innovation and the importance of the relationship between architecture and textile design. It will show through the use of examples from the studio Composite_Space how a multi-disciplinary approach can develop new ways of thinking about form.

Structural Surfaces

The term *textile* and its plural *textiles* (derived from the Latin *texere*, meaning to weave) can be applied to fibres, filaments and yarns and the products made from them (Anstery & Weston 2003). It is closely associated and often substituted with the term *fabric*; a relatively thin and flexible sheet like structure made of fibres and/or yarns. The structure of the textile fabric can be formed in a variety of ways; intermeshing (weave), interloping (knit), stitching (embroidery,) or entangling, melting or bonding together (in the case of non-wovens), braiding (cords and ropes) or through more complex means of combining numerous techniques.

Essential to understanding textiles and fabric is the complex relationship of the surface and its underlining structure and how this can be applied to create form. A fabric (regardless of how it is formed) has a substantial surface area in relation to its thickness and sufficient structure to give the assembly (of fibres and/or yarns) useful mechanical strength (Denton & Daniels eds. 2002). Indeed textiles can be described as "surfaces and volumes made out of yarns, fibres or filaments" (Tellier-Loumagne 2005).

This relationship has long been explored by fashion and textile designers for clothes. Both disciplines often work together to take into consideration the textile's properties and performance to assess its appropriateness. How a fabric might interact with the body; to cover, shelter, adorn, drape, and feel. Is the fabric to protect, conceal, or expose the body? Does it act as a second skin, allowing for moisture and air to pass through, while protecting against harsh environments? Does the fabric provide the surface skin and the structural bones around which the form can develop or does a separate structural skeleton (such as a corset or hooped-skirt undergarment) need to be developed? Is the fabric entirely functional or is it about the decorative; a means of identity and self expression?

With advances in textile materials and technology this relationship is changing. The transformation of textiles due to new technologies is impacting on virtually every industry and aspect of our lives. Surface, structure and form are becoming more interconnected, interdependent and interactive (Colchester 2007). As well, these textile innovations are changing the scale of how textiles can be used. While textiles has traditionally been applied to the micro level, such as fashion (clothing) and household textiles (soft furnishings, upholstery, and carpets), it is increasingly being applied to the macro level of the built form and architecture. How will designers and architects respond to this? Can a textile be simultaneously structural and decorative, be about surface and volume? And can this be applied to buildings, as it has been traditionally with clothing? And how does this change the way architects approach design? This is leading to a reconsideration of a form's surface and structure.

Under question today, is what exactly constitutes a textile fibre or fabric. If something behaves like a textile, is it a textile? Conversely, if a textile is transformed and engineered to not behave or look like a textile, can it still be classified as one? And what happens when textiles are combined with non-textile and hybrid materials, and new functions such as nanotechnology or electronics are incorporated and engineered into the 'fabric'? In the future fabrics may not be passive, but instead monitor and interact with the body.

Fabrics can now take on a range of properties, specifications and performance characteristics that are transforming and challenging what a textile is and can do. Technical textiles are being designed to be as much about functionality as about having an aesthetic. Textiles are also being engineered to be *smart*; integrating sensors, actuators, processors, and microsystems

into clothing (Jayaraman, Kiekens & Grancaric eds. 2006). Smart textiles may be able to sense its surroundings and respond with an appropriate action (McQuaid 2005).

And interestingly, technical textiles are looking to decorative techniques, such as embroidery to develop integral structural forms (Xiaoming ed. 2000). There is a blurring of the traditional boundaries of the technical / structural and the decorative. Techniques, once associated with being hand crafted are being transformed into high-tech automotive processors using complex technology and machinery. This is allowing for textile techniques that were associated more with fashion to be scaled up and considered by architects.

Fundamental to this re-examination are the advances in fibres. The engineering of fibres has accelerated over the past decade. The twentieth century saw the transformation of fibres from natural fibres (such as cotton and wool) to the early synthetics (nylon and polyester), to the blending of fibres, to the development of advanced second, third and fourth generation fibres such as glass, arimids (Kevlar) and carbon and to hybrid forms of materials.

Of particular interest are the fibres that show the most potential for the built environment and construction industry, such as glass, aramids and carbon, and the use of textile composite structures. Textile composites bring together the best of both textiles and non-textiles materials. They can have the advantage of incredible strength to allow for reinforcement. For example, a carbon composite can produce a material that combines “lightweight, quality of strength, high strength-weight ratio, fatigue resistance, vibration absorption and electrical conductivity. When deprived of oxygen it becomes inorganic insulator which is resistant to high temperatures” (Braddock Clarke & O’Mahony 2005). It’s applications, once exclusive to the aerospace field, include sports equipment and furniture, and are being considered for architecture, such as the thought provoking project ‘the Carbon Tower’ by Testa and Weiser (Garcia ed. 2006) (Hodge 2006). This conceptual project draws on techniques traditionally associated with fashion; the tower is literally woven on site. So the form-work is no longer just the support for the structure but is actually creating the structure. It is because of the unique qualities that carbon fibre offer, that projects of this nature can be considered.

Textiles based hybrids are already being used. “Industries are increasingly replacing heavier materials with part textile (flexible), part non-textile (glass, carbon, metal and ceramic) hybrids. They offer high performance but with reduced weight, an important consideration for the

construction industry" (Braddock Clarke & O'Mahony 2005). These fabrics are developed for their technical performance and functional properties rather than their aesthetic or decorative qualities. Generally they are hidden out of sight as they are purely about being functional and structural with no aesthetic value attached. For example, they are used to reinforce bridges, repair existing structures and in the foundations or slabs of buildings (Horrocks & Anand eds. 2000).

However, what if architects and engineers were to work together with textile designers to create composite structures that were not just about being high performance, but were also designed to be seen and valued for their aesthetics? The use of these materials could impact space in a way that is not readily considered by architects. The common approach of architects is to reduce structure and increase span. Using fibres that have a high strength to weight ratio, as does carbon fibre, creates a new possibility of having extremely fine structure but more frequently placed (Figure 1). This blurs the structure and defines the volume of space differently simply because of the sheer amount of structure, in the same way that we see a head of hair but not the individual strands.

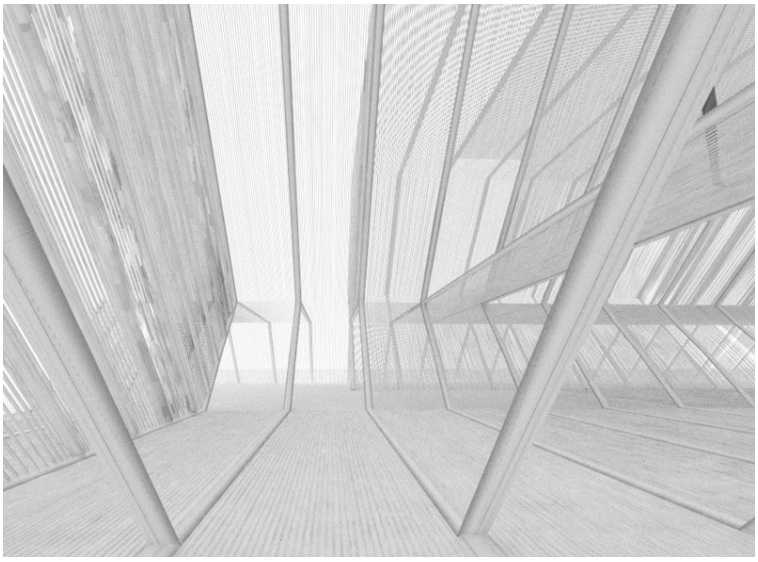

Figure 1. Interior view, by Joey Azman, level 6 architecture student, RMIT University, 2007

Architecture is looking towards textiles to innovate, with fabric to be used as a tool. This leads to changing the way of thinking about form, structure and construction of space. New

possibilities are driven by imagination and creative thinking. This goes far beyond merely looking towards textiles and fashion designers use of textiles for conceptual inspiration. From an architectural point of view, textile composites offer a variety of appearances: translucency, colour, surface texture, finish quality, etc (Long ed. 2005). For example, a textile technique such as a pleating may not only inspire a design, but in fact be used as the structural concept to form the building. With new materials it is possible to use a textile (as a soft membrane skin or as a composite) to achieve a structural function as well as aesthetic quality.

There are practical advantages and also spatial advantages in shifting focus from traditional building materials. Some of the advantages and design opportunities textiles offer architects are the reduction of weight in construction, the (mass) production of complex form components, reduction in construction time, and production of multifunctional components (Long ed. 2005). Using composites, instead of steel could reduce overall weight, which in turn reduces the cost of manufacture of components, transportation costs of materials and the actual cost of construction and operation of the building.

Composite_Space

In order to develop these innovations, links need to be made between disciplines. The studio Composite_Space run in semester 2, 2007 at RMIT University highlights the potential of taking advantage of this.

This was a collaborative project involving architecture, textile design, business and aerospace engineering students. The project started with architecture and textile design students developing textile fabric ideas and concepts. Textile design students were asked to generate conceptual fabrics suitable to be developed into composite structures for use in an architectural form. Working in small groups, students from all disciplines explored and innovated with textile materials, techniques and processes.

As these ideas began to develop, business students assisted with identifying potential markets and product directions/applications, and aerospace students provided technical assistance on the suitability of ideas to become composites. From this initial exploration of textile materials, the architecture students went on to design a building, and business students assessed the feasibility of the outcome.

The beauty of the collaboration was that each discipline needed to refer to another in order to fill in the gaps in knowledge. There was a feverish exchange of information at different periods in the semester where the initial pressure was on textile design and aerospace students who needed to disseminate the techniques, technologies and structural possibilities that lie in the textile world. Then architecture students took this information on board and reprogrammed themselves to deal with the 'floppy' in order to consider space. At this point aerospace and textile students provided feedback to push the concepts further. Architecture students developed physical and computer generated models which were made in collaboration with the textile students. The business students then went ahead and found out the possibility of producing such ideas and who the major manufacturers were, as well as the sustainability of such material.

A particularly strong example of the value of this exchange was a collaborative effort by two students Vanja Joffer (student in architecture) and Jessica Henderson (student in textile design) with the assistance of Caleb White (PhD candidate in aerospace). A starting point was a simple croqui of knitting that dropped off a knitting machine and was placed in the hands of the architect who explored scale, shape and form. What was a piece of knitting at a small personal scale slowly began to be transformed into the possibility of a building, exploring the concept of structural skins. Ideas were discussed, scale was increased, and materials were considered. The textile designer re-knitted the croqui, at a larger scale and with more thought for the purpose (Figure 2). And back and forth it went. Once a spatial intent was found the aerospace engineer, who understood the potential, commented on the structural weakness and how this could be resolved. The tension for the knitted pieces needed to be much tighter if it was to support the weight of the building. The slabs needed more support or to become smaller. What emerges, through this involved process was a building that was both innovative in form and function and used textiles and its inherent efficiencies (Figure 3).

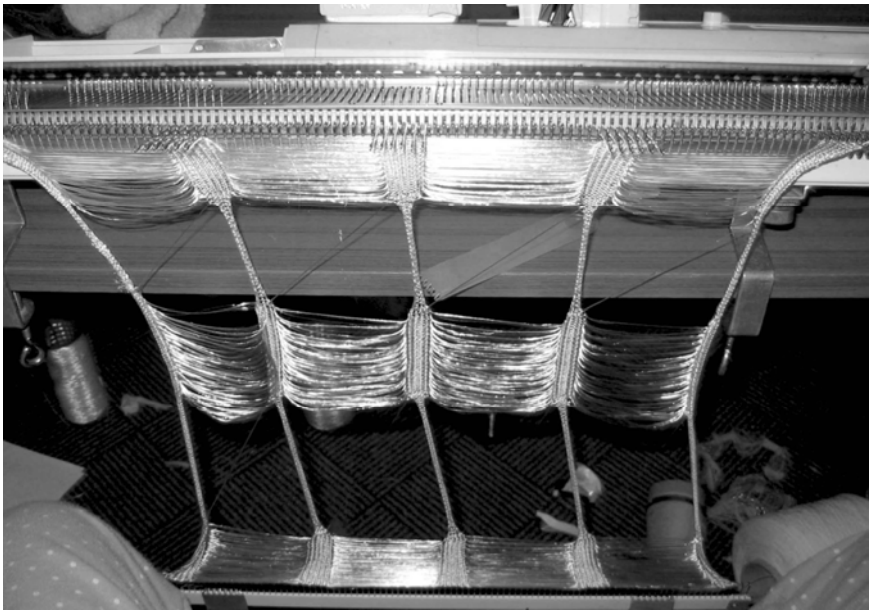

Figure 2. Knitted fabric in progress, by Jessica Henderson, 3rd year Textile Design student, RMIT University, 2007

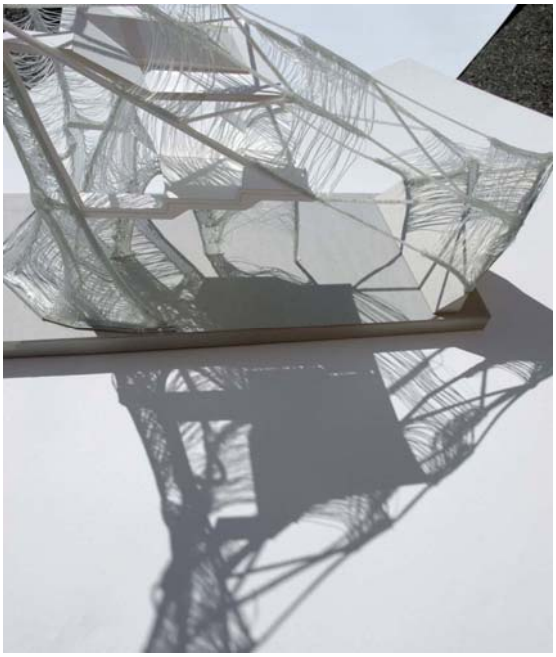

Figure 3. Architectural model in knitted composite fabrics, by Vanja Joffer, level 8 Architecture student, RMIT University, 2007

This exchange of ideas and knowledge highlighted the potential for future innovative design solutions to be achieved. The collaboration process was non-linear, with each discipline informing the other disciplines.

This studio showed that Architecture has much to learn from the structural qualities in textiles. For example, a knit or weave is a repetition of a stitch or structure so its ability to withstand impact is very high. This can be illustrated by putting a hole through a fabric. While the impact area and a certain distance around it might fail, this doesn't mean that the whole piece fails, in fact patching can easily be done (just like a garment can be darned and repaired) and the piece can continue to be used. In conventional construction, as with the World Trade Center in New York, impact often leads to complete failure of the structure. Therefore many of the proposals for the World Trade Center developed a network of structure where local impact could be managed in the overall structure without imminent collapse.

While material innovation has opened up a dialogue with architecture there is now an even richer dialogue looking at the micro structure of textiles to inform structural ideas and ways of thinking about construction. The aerospace industry, which has long been dealing with composites and therefore fabrics, operates at a maximum structural efficiency. It does not have the luxury to think about space because of the extreme environmental pressures it needs to consider. However, when architects look at the principles embedded within this high-tech industry there is the opportunity to change the way structural integrity is understood.

The lessons learnt from textiles could have a dramatic effect on all aspects of architecture. The non-conventional nature of combining the lessons from textiles with the practice of architecture allows for a range of scales to be reconsidered. The City scale of buildings has the potential to hold different forms and different spatial arrangements because structure and skin can truly be a fusion and not just a set of components grouped together. The interior scale can engage with the tactile qualities that textiles innately have, shaping light and form in a unique way.

A more sympathetic response to the building environment could be achieved, both internally and externally, such as how to respond to changes in temperature or prevailing winds. Much like a fashion designer selects a fabric with particular characteristics (such as breathability) to sit against the body, architecture may need to think about a more intimate response to a fabric. In a sense fashion and architecture are only really separated by their scale of production (Hodge 2006). How we respond to a building and its surrounding environment is immediate and personal.

The potential is for both the inside and outside, the structural and decorative to blur. Concepts such as transparency can be explored, particularly through membrane structures, and flexible skeletons, meshes and nets. This opens up the possibility for more creative and innovative sustainable design solutions.

The term 'transparency' is attracting a lot of interest from both architects and textile designers. Transparency can be addressed through use of materials such as transparent concrete, and technical textile fabrics and composites. For example a woven fabric (Figure 4) made with a double warp of ballistic nylon (a high strength yet flexible yarn) and a strong transparent nylon (more commonly used as fishing line). The weft yarns are wire, nylon and carbon and are woven in a structure to mimic a rib like surface. The weave is densely packed, providing the foundation and structure within the skin. The resulting fabric is strong, lightweight and has semi-transparent qualities, with the fabric capturing and reflecting the natural light.

Figure 4. Woven fabric, by Merri Cranswick, 3rd year Textile Design student, RMIT University, 2007

The fabric could be made as a continuous length by a fully automotive loom. The weaving loom warp could be over 500 metres in length. The weave structure could change along its length, to allow for areas that need greater strength or more open mesh-like qualities. It could be made off-site or on-site. It could be produced, rolled up and transported. On-site it could then be stabilized with resin and made rigid.

This leads to thinking about how it could be used to define a form. What sort of building could be developed? A fabric that is both the skin and bones of the building. What would come first the fabric or the form? The architect, structural engineer, textile designer and textile technician would need to work together. As ideas are suggested, prototypes can be explored and tested. And as the project's complexity increases more experts are called upon.

Another example of architecture using textiles both structurally and decoratively is the bringing together a number of textile techniques, such as weave and print to develop a textile composite. This could lead to the possibility of developing a more responsive building. For example a simple open plain weave structure in a yarn that is strong with transparent qualities (Figure 5). The structure consists of the weft passing over one warp, under one warp, over one and so on. On its return, the sequence is reversed. The structure is repeated and the weave created is a strong, balanced, interlaced texture. This becomes the structural framework for say a wall. Over this a pattern is developed and printed onto the substrate and then a resin applied to stiffen and further strengthen the piece.

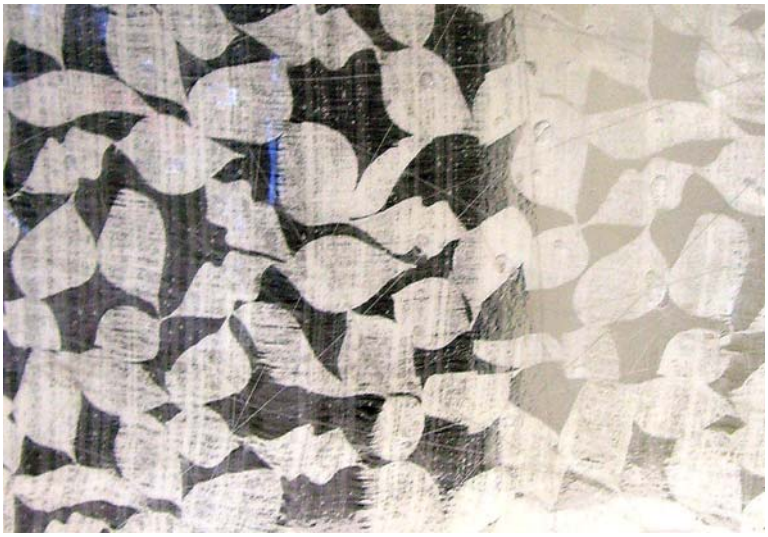

Figure 5. Printed composite by Linda Marek, 3rd year Textile Design student, RMIT University, 2007

Integral to the wall is the pattern. The pattern could be designed to give added strength and reinforce particular parts of the wall. It could be both decorative and structural, with the pattern

being repeated across the building to any scale. The wall could still maintain a transparent quality. Have it respond and change to different light conditions. The print base could be made of a material that incorporates nanotechnology and/or electronics, to absorb light (during the day) and emit light at night; think of an office tower and the amount of energy used to keep a building lit up at night. The pattern is structural as well as decorative. The pattern could be also a means of personalising the space, of giving identity to the building and the individual. The wall could also be transformed with the use of nanotechnology from being transparent to translucent to opaque to respond to the individual. It could change a space from being public to private.

Additional applications and coating could be applied, such as a very fine layer of dirt-repelling chemicals, or for the wall to respond 'intelligently' to temperature and climatic conditions. Many of these ideas already exist, such as nanotechnolgy for self cleaning textiles and glass (Braddock Clarke & O'Mahony 2005). The potential of these ideas to be applied to the built environment and transform how we live and interact is huge.

It would mean having to change the way we think about space, structure and the approach to design. There is the need for a multi-disciplinary approach. To work closely from the start of the process. Because of the innovations of fibres and technology, a knitted or woven building is possible. Scale is opening up opportunities and challenges for the textile industry and for designers. The possibility exists to move beyond using each discipline as inspiration but to converse in order to pursue large possibilities.

Conclusion

Advanced materials have become a new tool for designers and architects. Because textiles handle and behave in very different ways to traditional architectural materials like wood, steel or metal, they need to be treated differently. This opens up new opportunities for architects to explore the relationship of surface, structure and form. Because of the complexities of this relationship and the new materials, a multi-disciplinary approach is vital from the beginning of the design process. It is through this collaboration and interaction that new innovative design solutions may emerge. The impact and possibilities are proving to be very exciting indeed.

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