The Most Important Airplane In The History Of Architecture

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Composite Structures consist of high strength carbon threads held together in a matrix of epoxy resin or thermoplastics. Surfaces made from these materials are typically 10 times lighter and 1.5 times stronger than aluminum. Both simple and highly contoured shapes possessing extreme strength can be produced using a computer controlled fiber placement machine (FPM). These incredibly thin, corrosion resistant membranes require little or no supplemental support to manage loads and enclose space. The computer’s ability to determine the precise location of each fiber strand in a fiber placed part also facilitates unprecedented control of its aesthetic and functional properties. Fiber placement technology integrates building components that would normally be separated into clearly distinct systems. Here ornament, structure and cladding are collapsed into one material process. This paper explores the architectural potential of a technology normally reserved for aerospace applications through research conducted in close collaboration with fiber placement engineers at Automated Dynamics in Schenectady, New York (ADC).
The frame has been the catalyst of architecture: but one might notice that the frame has also become architecture...Thus one recalls innumerable buildings where the frame puts in an appearance even when not structurally necessary. Colin Rowe

For its size, the Premier 1 is very light and features a composite fuselage for superior strength...The fuselage is built without an internal frame...

Hawker Beechcraft Premier 1 Light Business Jet, USA 2

Fiber-reinforced composites have been around since the late 50’s and their potential use as a building material has been widely theorized. While the dream of constructing incredibly thin, multi-functional load-bearing membranes continues to dominate the architectural imagination very little research has been directed toward their actual production. What is sadly missing from contemporary research is a serious understanding of the tectonic possibilities offered by real fabrication technologies and their modes of operation. By failing to examine specific systems, designers run the risk of either proposing unrealistic applications or worse missing their radical potential.

Computer Automated Fiber Placement Technology is a relatively new fabrication processes that is necessitating fundamental changes in the way we think about materials, space, structure and program. The system deploys carbon fiber, Kevlar or translucent glass threads in a composite matrix held together by high strength plastic or epoxy resin. (Special taping geometries and hybrid fiber combinations provide for shelter against the elements, while controlling daylight and thermal conductivity.) Using a computer to lay down strands of material on a metal mold or “mandrel”, non-standard forms can be produced with a high degree of precision. What’s more these tapped surfaces are incredibly strong, lightweight and corrosion resistant. (Steel has a tensile strength of 50 ksi. S-glass is 10

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1. Colin Rowe
2. Hawker Beechcraft Premier 1 Light Business Jet, USA

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times lighter with a tensile strength of 175 ksi.) Through the fiber placement process different aesthetic effects can be produced by simply varying the pattern of the taping process. The resulting structural membranes are also able to handle dynamic mechanical loads without the need for an independent structural frame. The entire fuselage of the Premier 1 business jet is a taped composite shell that has no internal frame.

1 Anisotropy

Despite differences in style and function most buildings today share two basic characteristics: 1. they organize space using an interlocking system of non-load bearing panels attached to a lightweight structural frame, and 2. they are constructed of some combination of reinforced concrete, masonry, steel and glass. These are fairly universal constraints found in both low-rise and high-rise structures where significant typological deviations are limited by economic considerations, building codes and established construction practices. Even from a modernist perspective where technology is used to both inspire and actualize new forms these constraints seem almost inescapable. But if one looks more closely at the materials and processing technologies that are changing the way airplanes are made it becomes clear that the rules governing basic frame and panel construction are more or less irrelevant.

Using unconventional manufacturing techniques composites are being used to create ultra-thin, “frameless” assemblies that are entirely self-supporting. Through the fiber placement process structural surfaces can be optimized without resorting to minimalist strategies of formal abstraction. Rather than pursuing designs that tend toward excess i.e. solutions that create more problems than they solve, composites facilitate an organic complexity with integrated designs that achieve more with less but without reduction. In other words diversity is produced through the conservation of mass and energy. Decadent architectures generate waste and are less appropriate in a global economy dependent on limited natural resources. In this context the anisotropic properties of reinforced thermo plastic composites are significant. By avoiding an iconographic brand of intricacy where
ornament evolves from the unrestrained, over-development of surface and structure, fiber reinforced composites become strong, visually dynamic and responsive by efficiently incorporating multiple functions in a single production process. By comparison even a stripped down frame and panel building is over-designed!

2 Sustainable Applications for Advanced Composites

Unlike steel reinforced concrete shells and heavy walls made of stone or brick, fiber reinforced composite membranes are not limited to a fixed set of structurally optimized shapes. (arches, hyperbolic parabolds, etc.) With advanced composites architecture can be transformed when the frame is eliminated and the skin assumes the task of managing loads without itself gaining weight. (Because lighter materials and sub assemblies require less energy to transport and install they are far more economical. (A building that weights less costs less.)

Instead of retrofitting an established design style with sustainable technologies a new and ecologically responsible architecture can be engineered from the ground-up. This is possible because the fibers in a fiber-reinforced composite can be precisely controlled on a local scale. Rather than producing structural components that are homogeneous and over designed (I-beams, T-sections, etc.) these structures achieve their efficiency by increasing material density where stresses are high and decreasing them where they are low. Non-standard taping patterns can also be produced without a subsequent increase in cost. The complexity of the final component is produced for free by simply modulating the data fed to a composite taping robot.

Composites also have the potential to reduce the energy and natural resources needed to form complete building envelopes by incorporating multiple functions (walls, floors, structure, fenestration, etc.) into one system. The computer-automated production of composite structures in the factory drastically cuts down on the waste normally associated with in situ construction while simultaneously effecting clear improvements in component quality. Time saved by the elimination of multiple trades and the subsequent decrease in materials shipped to the job site also helps reduce costs. Unlike most robotic fabrication techniques computer automated fiber placement is a material specific technology that generates forms possessing unprecedented lightness and strength. Where a mill or a laser cutter produces variable components using conventional materials like wood, metal or foam, fiber placement technology builds innovative assemblies while conserving material resources through an additive, rather than a subtractive, process of lamination. (CNC mills and laser cutters are notorious for generating large amounts of waste during the produc-
With fiber placed composites architecture can become ‘green’ while transcending both the limits of current digital construction technologies and the tectonic restrictions that have determined architectural forms since the advent of the Chicago Frame. (3)

3 MP Sports Center: Mike Silver Architects

The MP Sports Center (Unbuilt 2008) was designed for a large, recreational park in Vittorio Veneto, Italy. Located on the southern corner of the site, the proposed center will house two Futsal courts, a fitness area, locker rooms and an outdoor swimming pool. The main indoor spaces are sheltered under a 100’ long span canopy made of fiber placed trusses. (The ceilings, facades and traffic areas are also produced using the same materials and fabrication techniques.) The trusses are fabricated using Lexan impregnated s-glass tape laid down on clear Lexan sheets. In this way the surfaces that keep out the weather and the materials that manage structural loads are produced using the same plastic matrix.

The taping geometry of the truss consists of an expanding spiral that minimizes build time while responding to localized stresses flowing along the length of the structure. Denser zones of fiber in plan alleviate mid-span buckling and have a thinner cross-section. The less closely packed fibers are much deeper in section and help transmit natural light. In a traditional frame and panel building there is no structural synergy between infill walls,
transparent openings and load bearing supports. The composite system of the MP Sports Center on the other hand uses its binding matrix to form both a window with minimal reinforcements and a reinforced structural skin without windows. This duel purpose system eliminates the mechanical discontinuity between envelope and frame while creating a “complexity without excess” through the precise deposition of materials on a local scale.

4 Notes


3. Increasingly, plastics made from petroleum are being replaced with soy protein resins. Carbon fibers can be up-cycled from discarded automobile tires in a process known as pyrolisis. Sustainable alternatives to oil based fibers have also been developed.