Seamless Architecture

Digital Fabrication Research for Integrated Design Innovation

Eva Sopeoglou
Democritus University of Thrace, Department of Architecture, Greece.
http://www.evasopeoglou.com
esopeogl@arch.duth.gr; sopeoglou@yahoo.com

This paper considers the influence of digital fabrication (CAM) technologies with regards to the creative and creating processes and within the specific parameters of materials. Under the title seamless architecture this paper is seeking to study relationships (on a literal and conceptual level) with the existence or not in architecture of ‘seams’. This study draws inspiration from past and present architecture and also design fields such as textile and sailmaking, by examining types of ‘seamless envelopes’ which were only possible when advances in digital fabrication were met. Metal is currently widely used as cladding material. In antithesis to previous notions of steel being the ‘bones’ of architecture, expressing ‘strength’ and ‘sturdiness’, current use of metal as ‘skin’ material has revealed the ‘softer’, highly sculptural, almost textile quality of metal surfaces. Digital fabrication of sheet metals has contributed towards this shift. However, architectural metal skins presently lack this seamless quality of a ‘differentiated-single’ object. It’s capabilities as cladding material have not been fully utilized, in light of drastic developments in digital manufacturing. Design integration of aesthetic, structural and environmental considerations into the design of metal cladding systems is bound to develop in the future. Considering metals as textiles (in terms of architectural concept and manufacturing) can provide new insights to their utilization in architecture.

Keywords: CAD/CAM: fabrication; textiles; metals.

Introduction

Architecture is an art form which is intimately bound to the act of skillful appropriation of materials for it’s realization. As a technological manifestation architecture relies at any given historical period on the tools available for processing materials and manufacturing of architectural components. Technology itself, defined in the Heideggerian sense, is not an end but a means, a way of revealing the essence of the art in architecture, in other words, the poetics of construction. Emergent technologies subsequently afford different ways of bringing forth a new language of building, in other words, the aesthetics of design (Sopeoglou, 2006).
The introduction of digital Computer-Aided-Design (CAD) technologies as a conceptualization tool initiated new form-finding techniques, has made mapping and data-processing easier and facilitated drawing coordination between disciplines. New complex architectural forms emerged, while design teams and manufacturers were exploring ways of rendering these forms buildable. Since Digital-Aided-Manufacturing (CAM) technology was introduced after the introduction of CAD into design, the possibilities of CAM tools have just become the focus of architectural research. Other design fields, such as aircraft engineering and car manufacturing, have already integrated cutting-edge fabrication technology and design.

A concurrent shift is emerging towards a new materiality and the need for a rediscovery of craft in architecture. Practitioners and architectural researchers are ‘exploring the potential of architectural expression of materials by design’ (Picon, 2004). This attempt on the one hand, entails an understanding of the materials’ basic properties, limitations and capabilities which, in turn, can inform the design process. On the other hand, a creative study of available fabrication techniques is necessary so new or rediscovered materials can be actively incorporated. Therefore, adequate material and fabrication design research is currently being sought, which will allow for a smooth, seamless transition from design to realization. This paper considers current digital architectural fabrication and offers possible future developments by drawing inspiration from related design fields. This evolution in design is viewed through the study of a specific building material, architectural metals as a facade component.

Prefabrication and the architecture of seams
Industrialised building of the last 60 years has been founded on the principles of prefabrication. For building envelopes manufacturers relied on mass production in order to deliver low cost and consistent quality.

Even today, architecture’s mainstream practice is still, in essence, an exercise in the synthesis of off-the-shelf components already cut and shaped from raw material into a particular architectural ‘product’, as it is later on assembled along with an array of many others into a finished building. Joining already pre-dimensioned and pre-detailed components results at the level of a building façade in the appearance of assembly or composition-related seams.

This architecture of the objet-trouvé lead architects in the past to research the possibilities in design expressed by the articulation of prefabricated and mass produced architectural parts. For example, Jean Prouvé aimed to discover a new language of construction through prefabricated metal architecture, while Mies Van Der Rohe explored the poetics of the detail in the act of joining. Orthogonal, grid-ded layouts served as the backbone for an integrated seamless architectural composition, linking the building envelope to a support structure, or otherwise a skin and bones organisation.

Seamless and non-seamless processes in architecture
Joints in architecture also exist, in a literal as well as a conceptual level, in all aspects of design-through-fabrication. Design, manufacture and construction in today’s digital environment are in constant negation of their in-between seams.

A seamless digital environment
A smooth, seamless transition exists from concept to realization within a digital environment, when the same three-dimensional simulation is a study model and finally the fabrication file. This replaces the labour-intensive and non-seamless translation of architectural drawings into detailed shop drawings, to manufactured components. It is obvious that such seamless processes are dependent on the capabilities of the available design and manufacturing tools, however, as these develop it is believed that they will become more transparent and the joints less visible.
Performance characteristics such as structural behaviour and environmental interaction can be studied today in a seamless way, through simulation and representation synchronous to form-finding, architectural aesthetics and design. Previously, they were often addressed in an additive manner, for example by adding back-up structure or shading on a given elevation. This development marks a significant evolution for building envelopes, since facade studies can be enhanced via parametric structural optimization and advanced energy simulation. Such seamless processes were carried out for the Eden project by N.Grimshaw/A.Hunt Associates (Le Cuyer, 2003) and recently for the National Aquatics Center in Beijing by PTW/Arup. For a number of high-profile projects today, a completely digital environment from design to manufacturing is the only way their completion is even possible.

Non-seamless construction technology
The digital design-through-manufacturing system often fails, resulting in unwanted seams that are visible on the exterior envelope. When orthogonal prefabricated components are applied to non-orthogonal shapes of complex geometries, the overall architectural impact of dynamic volumes is weakened; one notices the seams in the metal cladding instead of reading the architecture as a whole. The aim could be a more sinuous, seamless interpretation of architecture, while also solving practical problems, since architectural seams need flashing, expansion joints, often leak and are energy-inefficient (fig. 1&2). This phenomenon is mainly interpreted as an intermediate phase in construction technology, between mass-production and more customized manufacturing that is currently under research.

Finally, addressing the poetics of construction a transparent, seamless relationship is sought between technological means and the end product. Technology itself should mediate in order to reveal the art in architecture. Rendering the technology of fabrication visible, does not render it a transparent medium. As new technologies often require time to allow for a new language of construction to emerge, many current digital fabricated architectures lack this seamless quality.

Mass customisation and the ‘cut and sew’ technique
If referring to a building skin, an analogy can carry with the existence of seams in a piece of clothing and the act of tailoring (LeCuyer and Wernick, 2004). Traditionally, clothesmaking begins with finding the appropriate fabric, a material pre-woven from raw threads into a semi-defined shape, the width determined by the textile weaving-machine dimensions while the length is indetermined. The process then
unfolds to placing the desired developable shapes in the most efficient way on the fabric surface and cutting out the clothing components. Subsequently, the cut pieces are sewn together into the final three-dimensional shape. The seams are visible and cannot be eliminated in this process, posing various problems when they rip apart in high-stress conditions or when weather-proofing is necessary (for example, in sports-specific technical apparel). The latter is overcome by laminating a special water-proofing strip, creating a taped seam. Taped seams are labor-intensive and subject to delamination after long periods of exposure to weather conditions.

The analogy between clothing and creating a building envelope in terms of their manufacturing process, is clearly visible here. Architects are today beginning to study building envelopes the way clothes have been designed since many decades ago. Instead of prefabricating identical building components in mass production, repetitive but non-standardized pieces can be mass customized with essentially the same cost or effort. Construction today involves finding an appropriate fabric, a sheet material, and while adhering to the material’s semi-defined, machine-determined dimensions, the developable outline of architectural units is then plotted on this surface in the most efficient configuration. These components are then sewn together to form the finished building. However, the seams are often so clearly visible that the construction of current complex-shaped architectures resembles an enlarged puzzle. There is often little correspondence between the fluid, free-form digital model and the finished building, with clearly visible unforeseen construction seams. Moreover, there are naturally the same problems occurring with ‘high-stress ripping’ and ‘weather-proofing’ of the seams.

**Seamless fabrication technology**

An insight to possible future developments in architectural fabrication may come from examining types of seamless envelopes in related design fields, which were only possible when advances in digital fabrication were met.

The textile and clothing industries often initiate innovation in advanced manufacturing technologies, that is subsequently incorporated in other fields of industrialized production. Indeed, digital cut-and-sew and the mass-customisation model has been known in these fields since the pret-a-porter. Clothes or membrane structures such as sails have been produced in this manner.

In the case of sailmaking, seams are a major problem affecting performance in a very direct way; they result in more weight for the sail, they deform and tear over time, while aerodynamic performance is disturbed by the ‘broken up’ uneven surface the sewn-together pieces produce.
So what is the cutting-edge in textile, clothing and sailmaking manufacturing up-to-date? These fields are currently experiencing a revolution in the form of **seamless computational manufacturing**.

**Seamless computational textiles**
Instead of beginning with a given fabric, clothes today can be woven directly from yarn into a three-dimensional object. Seamless computational ready-to-wear is only possible within a completely digital environment. Clothing is simulated and designed in the computer and then it is fed to a weaving machine. Weaving instead of cutting and sewing eliminates seams. There is no need for the intermediate step of creating fabrics as designers work from the thread, an un-defined non-directional raw material, directly into a finished product and no waste occurs in the process.

Issey Miyake and Dai Fujiwara (2001) in their A-POC, A Piece Of Cloth, line describe this process as a revolution in clothing ‘free from the limitations of conventional tailoring, which were previously dictated by the properties of fabric’ (fig. 3). A-POC creates a single but highly differentiated envelope, that can fit to any body, shape and size. More importantly, A-POCs need intervention from the wearer, an appropriation process to take place so they can be worn and are completely customisable.

**Seamless sailmaking**
A seamless differentiated structure also is possible for cutting edge yacht-racing sail technology, such as the NorthSails 3DL and 3Dr series (http://na.northsails.com/3dr : May 2007). Moving away from previously sewn together fabrics, sails are woven with the desired size, shape and designated materials for structural reinforcement in large fabricating, weaving and laminating machines. This results in lighter and stronger sails, since less seams equal less tear and weight with increased overall performance (McQuaid, 2005) (fig. 4).

**Architectural textile tectonics**
Metal is inceasingly used as envelope material, visible in the textile wavy steel facades of Frank Gehry (fig. 5&6). In antithesis to previous notions of steel being the bones of architecture, expressing strength and sturdiness, current use of sheet metal as fabric material reveals the softer, highly sculptural, almost textile quality of sheet metal surfaces. Advancements in digital manufacturing and processing of metals have contributed towards this shift.

**Metal textiles**
Digital Computer-Numerical-Control (CNC) has made processing of sheet metal easy and cost-effective. Less tools can perform more operations, like
machines that combine cutting and bending, seamlessly turning a two-dimensional metal sheet into a three-dimensional product (Buchfink, 2006). However, architectural metal skins presently lack this seamless quality of a single differentiated object that incorporates shape, structure and surface like seamless clothing or sails. Instead, sheet metal is processed as orthogonal fabric that is cut and draped over the building like a cloth, in the cutting-and-sewing manner of the pret-a-porter.

Sheet metals’ structural capabilities in cladding configurations have not been fully utilized. Prefabricated or mass-customized components are still hung by a standard steel post-and-beam backing system. A shift is expected in the future towards a more integrated structure, making an analogy between old-fashioned framed curtainwall glazing and the evolution towards the more technologically advanced structural glass facades.

Metal fabrics such as woven stainless steel meshes, that also fall into the metal textiles category are being used in a number of projects, notably the French National Public Library by Dominique Perrault. Stainless steel woven meshes however, do not appear easy to incorporate into design, as they cannot be three-dimensionally formed, nor cut and sewn as traditional fabrics; their manufacturing method dictates only limited versatility. If new technology and tooling would permit these steel textiles to be woven into different shapes, then metal woven facades could become truly three-dimensional seamless objects.

**Seamless architecture**

Seamless architecture in a digital environment means that aesthetic, structural and environmental aspects of building envelopes are considered as a whole and manufacturing is coherent with the principle of eliminating or minimising the impact of construction seams. Current manufacturing technology allows for certain tailoring, so the number and location of seams or other special conditions is better fitted into design. However, a larger potential is considered to exist for seamless design of sheet metal facades, namely by applying techniques such as folding sheet metal cladding for rigidity or perforating for light and wind penetration.

There is some evidence of design research towards seamless sheet metal façades. A number of projects by Herzog & deMeuron (Zahner, 2004) explore the possibilities of perforated or punched metal sheets as skin fabric for a single-volume architecture (fig. 9&10).

More evidence is traced in the small scale of interiors and art installation pieces (fig. 3&4). Considering metal as tectonic textile in terms of architectural design and manufacturing can provide new insights to its utilization in building.
To conclude, it will perhaps be possible in the future to design and fabricate metal facades which will be ‘woven’ on large weaving machines. Processing metal directly from raw material into a finished product, eliminating the intermediate step of creating a metal ‘fabric’ or else, a roll of sheet metal, might also become an option. This development could give enormous capabilities to metal and the process of designing and building will be a truly seamless one, similar to that of seamless textiles.

References


