Eco-envelopes: An Environmental Approach to Parametric Design

Aaron Paul Brakke
Universidad Piloto de Colombia
WHITEKNEE - www.whiteknee.com
aaron.brakke@gmail.com

Rodrigo Velasco
Universidad Piloto de Colombia
FRONTIS 3D
velasco.rodrigo@gmail.com

ABSTRACT
The development of the digital discourse in the field of architecture has been a principle concern at the beginning of the 21st century. Attempts at developing methodologies for the utilization of digital tools in the design process have been present for decades. In the past decade that interest has been augmented by a stance that aims to emphasize the use of generative tools that can facilitate an iterative systems approach to design. This article illustrates how a parametric modeling process has been applied in the design and dimensioning of brise soleil double facade systems.

KEYWORDS: Digital Discourse; Parametric Modeling; Design Process; Environmental; Brise Soleil

Introduction

The development of the digital discourse in the field of architecture has been a principle concern at the beginning of the 21st century. Attempts at defining the juncture of analogue and digital in architecture have been present for decades, during which, the digital paradigm has shifted. At the outset, the focus was on harnessing technology to aid design and expedite standard processes (a representational utilization of digital tools), but in the past decade that interest has been augmented by a stance that aims to emphasize the use of generative tools that can facilitate an iterative systems approach to design. (Bermudez and Klinger, 2003)

One such area of the discourse is known as parametric modeling. As programming has become more intuitive (Grasshopper and Generative Components), a proliferation of 'parametric design' with an organic aesthetic has emerged. (Woodbury, 2010) Intending to solidify and increase coherence for this new movement, Patrik Schumacher states, "*Contemporary avant-garde architecture is addressing the demand for an increased level of articulated complexity by means of retooling its methods on the basis of parametric design systems*." (Schumacher, 2008, 1.) He goes on to say that a style is evolving which he calls *Parametricism*. Yet despite these efforts in the aesthetic articulation of a new style, critics of this movement can easily argue that the wastefulness in virtuous form making has no place amidst the environmental crisis now being actively confronted. Jones states, "The new terminologies and procedures of designing and planning lose both their realism and their validity as soon as they cease to reflect the personal issues which matter most to the people who take decisions or are affected by them." (Jones, 1992, 73.)

However, this field in the architectural discourse has the potential to become of greater value if it is able expand upon the current focus of design theory and aesthetics to an agenda which includes other narratives that incorporate criteria of use and performance. "Constructing narratives of utility provides an escape from tautological parametric solipsism without forsaking formalism by providing an instrumentality of form, which could include pragmatic performance, the visceral, as well as the intellectual, discursive, or meaningful."(Meredith, 2008, 8.) Keeping in mind that those 'affected' by architectural constructions include

83% of North Americans who are pro-environment (more than 250,000,000 people in half of one continent), approaching environmental design through parametric modeling could be meaningful on many levels. Considering these circumstances, we ask, "How might digital aptitude aid architects in the quest to develop solutions that mitigate negative environmental impact and strive to achieve maximum performance through the agency of parametric modeling?"

It should be clear that the culmination of research to date will not provide a defined equation which explicitly states the manner to which an ecologically oriented digital design process should be approached. Rather what will be illustrated is how we have gone about using parametric modeling in our exploration of designing and developing brise soleil facade systems which seek a level of high performance. We will illustrate our work through; a research project called Eco-envelopes, through student workshops and through the projects developed at Frontis3D, a Colombian facade design firm led by Velasco. Being that space does not allow for us to delve into detail in each of the areas of exploration listed above, we will try to explain the methodology of the research project. Parts of this methodology are being replicated in the other contexts (not to the level of detail as in the Eco-envelope project), so a brief overview of the other studies will be presented to illustrate a broader range of results. The aim is to present the development to date and offer helpful insight to other designers and educators with agendas that look to create environmentally sensitive structures through the use of digital tools with a parametric sensibility.

Eco-Envelopes

The first project to be explained is an ongoing research project which follows an integrated and iterative approach that defines, analyzes and considers a set of parameters which guide the development of a high performance building skin. The structure of this paper is outlined in three steps of development. The phases consist of; 1) Formulation of the problem, 2) Development of a parametric model, and 3) The application of this model.

Three main areas of determining factors: functional, technological and environmental were decided upon in the organization of the design problem. These were chosen to comply with the general approach of the research project which aims for performance with low environmental impact.

Functional Factors: These factors are associated with the manner in which the building envelope functions as a protective barrier and as a mechanism to gain internal comfort. The *functional factors* delineate the degree of comfort that the system regulates in the covered spaces. We have focused on four main aspects for this factor: thermal control, light transmission, ventilation and soundproofing.

Technological Factors: These factors have to do with the structural system and building technologies used to realize the proposed building envelope, that is, what, and how it is built. We defined four aspects, which include; structural capacity, construction efficiency, safety and durability, and costs and maintenance. These factors determine the degree of articulation of the proposal in terms of technology and construction and define how the performance of the proposed design might be assessed.

Environmental Factors: These variables are related to the global physical environment where the envelope will be located. This includes factors such as sun, wind, energy issues and biodiversity (native plants and/or other living species). These variables provide a structure to measure the system's impact on the surrounding natural environment, which may point toward the resolution of other items, such as; embedded energy, absorbed-emitted thermal energy, local biodiversity and O2 production.

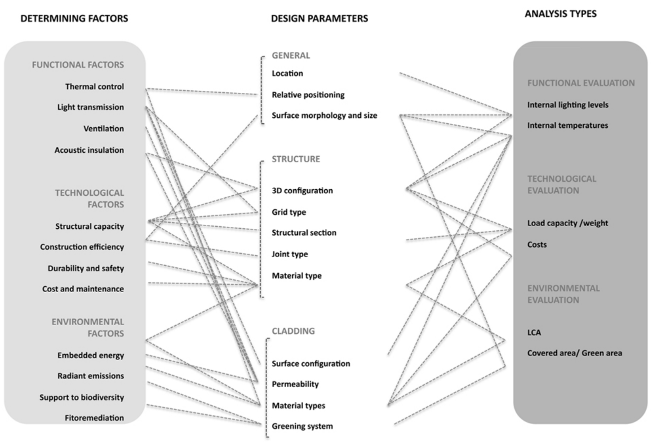

Fig. 1. Definition and relationships among factors, design parameters and types of analysis.

According to the universal configuration rules established above, the parameters for design are divided into three groups: the first relates to the general definition of the envelope, the second group corresponds to the structure, and the third relates to the cladding. Thirteen (13) parameters have been identified to define the design and character of architectural envelopes for tropical climates. These parameters include; location, relative position, surface morphology, scale, structural configuration, grid type, sections of structural work, joints and anchors, structural material, type of closure, permeability, and materials for closure and plant support. The illustration above shows the relationships between the determinants and the proposed design parameters.

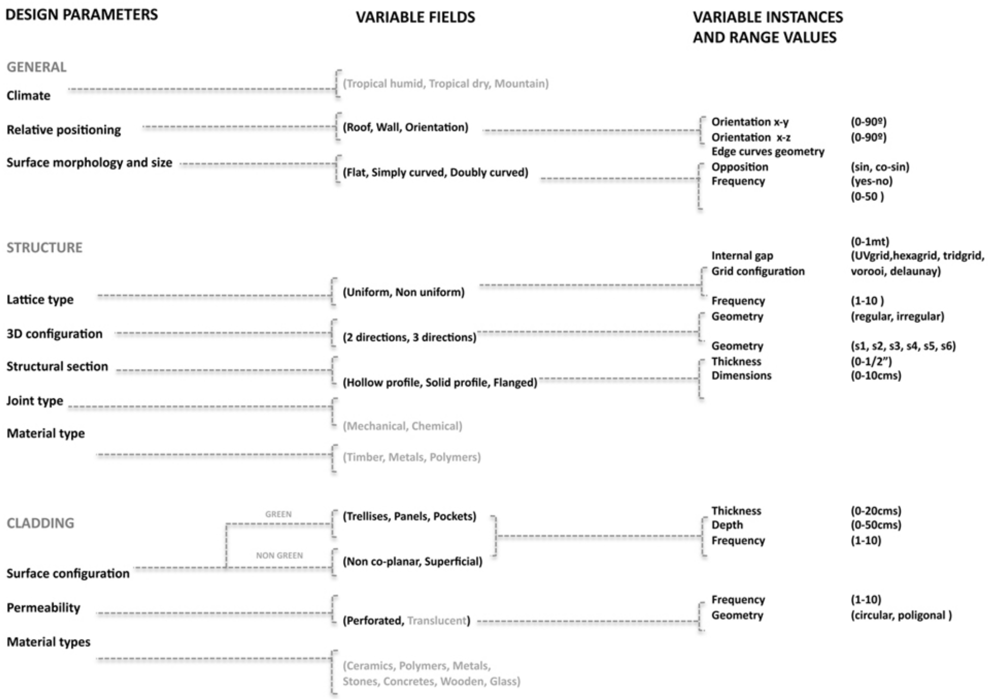

Fig. 2. This diagram shows a definition of structure and design parameters. The names in black indicate a direct relationship to geometrical configurations, which are included in the 3D parametric model definition.

Development of the Parametric Model

The next step was to further define the variable fields of eight design parameters in which functional and technological behavior could be significantly influenced by their geometrical configurations following the above mentioned organizational structure in which the technological, environmental and functional factors that delineate our particular space for physical configurations were integrated. As previously explained, the design parameters were restricted to three groups, the first corresponding to general conditions, the second to the structure, and the third to the definition of the cladding which was subdivided into internal and external.

The diagram below in Figure 2 shows a further depiction of the design parameters proposed for this research,. The design parameters related to geometry (in black) can be directly controlled from three-dimensional parametric definitions built into Grasshopper within Rhinoceros which produce specific digital models to be evaluated using structural and environmental software packages. Both functional and material variables are defined using a spreadsheet in Excel, where options are linked to specific pre-determined values and computed with the incoming data gathered from evaluations of the 3D model.

Application

The above-mentioned generic parametric formulation had to be used under the specific conditions of a particular building envelope. In this case, we chose the west façade of an existing building in Girardot, Colombia. This is a building that hosts the headquarters of the Universidad Piloto de Colombia in that region.

Following the selection of site, functional, technological and environmental factors took particular definitions that in turn fine-tuned the formulation and gave further viability to its application: In terms of functional performance, the climatic conditions of Girardot were studied, and the geometric possibilities of the general formulation applied to that particular façade were evaluated in terms of solar protection and thus avoidance of solar gains. The results were crossed checked with previous FEA analyses for geometric configurations that would be structurally sufficient, and further material characterizations (after LCA analyses for the site) were definitively assigned to the cladding and structural models. As a result, double skin solutions with limited cladding and structural possibilities were evaluated using temperature and CFD simulations. The software utilized was that of the Energy Plus engine via Design Builder as interface. The results of those simulations were compared to simulations of standard solutions used in the region, and the proposed design showed a significantly higher efficiency, noted by approximately 5 degrees Celcius lower in the internal temperature compared to simulations of standard solutions used in the region. (Velasco and Robles, 2011, 539-548.)

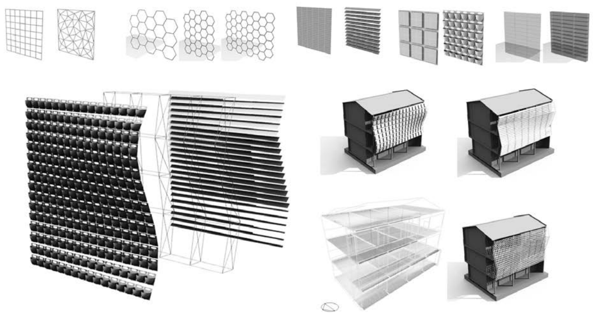

Fig. 3. The process of analyzing the selected parameters and designing to generate high performing solutions.

Modular Geometric Façade Design Workshop

The courses in which we are working with students to encourage the use of digital tools to deepen their understanding of building performance include TecV which focuses on the building envelope and through several electives that deal with geometry and digital fabrication.

Being that advances in construction technologies and materials are directly linked and enable the creation of new architectures and that the physical envelope divides a building from its exterior environment (building generally implies that a boundary is constructed, i.e. skin), we have decided to focus our attention on the building envelope so that the students begin to understand the dynamic relationship between technology, aesthetic communication, and performance.

The students are asked to do case study research in which they can clearly see that advances in the field of sustainable architecture lead to functional refinement, increased performance and typological specialization. Literature often references techniques that use biological metaphors of complexity and that are articulated as the architectural envelopes. After collecting information and writing about their case studies, the students are then asked to draw and model the selected projects. Generally the students gain an insight into the process that the designers followed which allows the students to develop a deeper understanding of how the projects evolve and are articulated in order to best meet aesthetic and performance criteria.(Fig 4)

After conducting this analysis we ask them to apply their knowledge in a design problem of developing a brise soleil to be used in our local context. The challenge is to limit direct penetration of the sun's rays but allow the best possible apertures so that vision to the exterior is not inhibited. We use sun path diagrams as a first step to analyze the sun's movements and the proportions that we will need to use as parameters in the design of the shading devices (depending on the height and angle of the sun). Then the project is imbued with a geometric definition which aims to create a dynamic modular system. The designs are analyzed with simulations from a variety of software, from 3-d modeling in Google Sketch-up and 3ds Max to programs like Eco-tect and Design Builder. Though time does not allow students to take full advantage of tools like thermal analysis and CFD that these programs offer, they are introduced to the digital tools available and we have seen these same students implement more complex analysis in other projects. Often we have the students develop a 1:1 scale mock-up which further enriches the students understanding of design performance in the brise soleil.

Frontis3D

The projects developed at Frontis also follow a similar design process. The differentiating factor is that the form of the geometry is developed at a more advanced level and this allows for a more rigorous aesthetic, daylight performance and economic understanding of the projects. As the projects are developed, both computer and physical models are created through the use of digital tools (primary software includes Rhino and the plug-in Grasshopper). Knowledge about fabrication tools and processes and the development of good working relations with fabricators is extremely important so that projects not only meet the design specifications, but come in on time and on budget. (Fig. 5)

Conclusions

This paper presented several cases where parametric design definitions and the use of digital tools assist the development of research and design projects that look for appropriate solutions for building envelopes in hot and humid climates. The process involves the selection of geometrically dependent parameters and their

Fig. 4. Physical models are constructed in tandem with digital models so that students understand various scales.

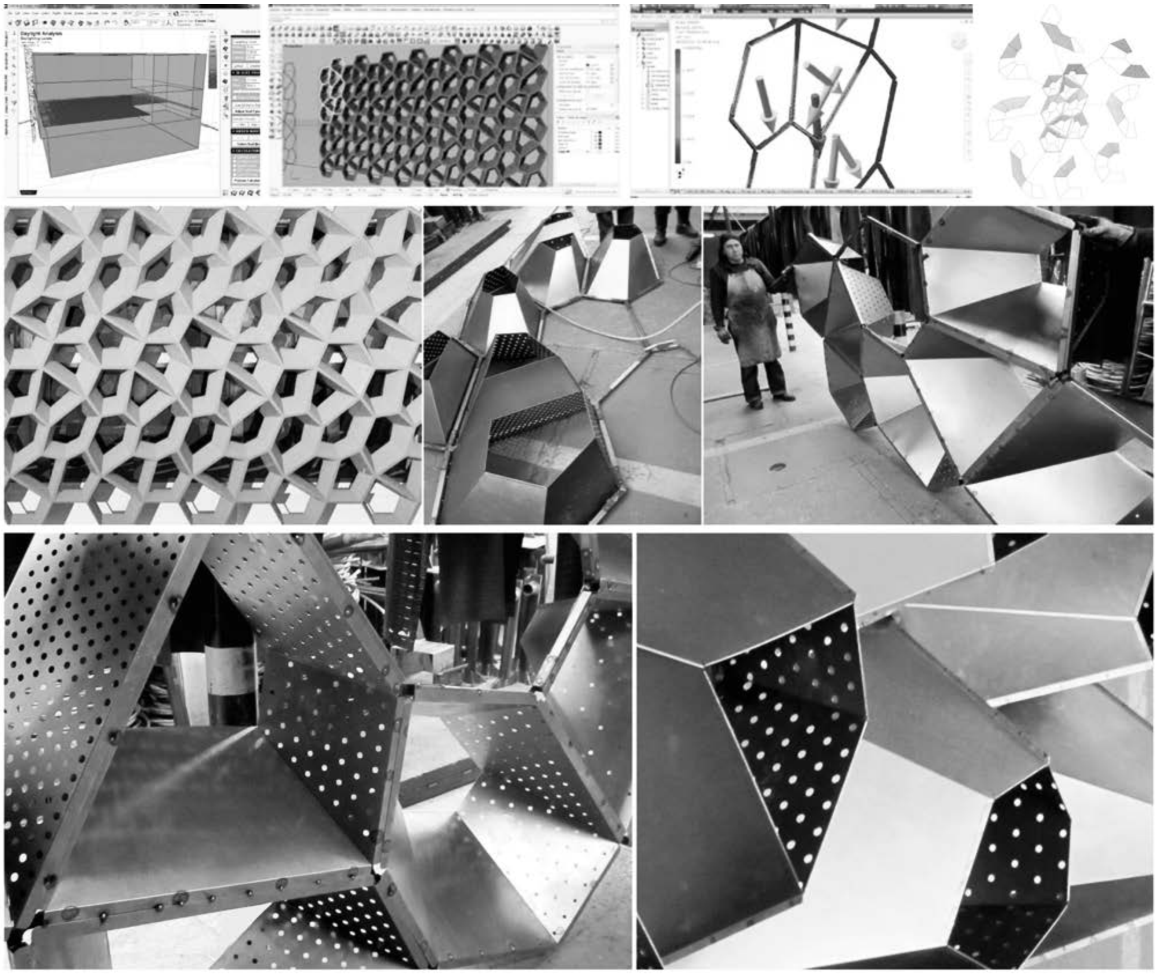

Fig. 5. This shows the process of modeling, conducting simulations and fabricating a facade system.

translation into variable fields, variable instances and range values. The parameters and the possible values were formed based on information found in literature reviews and digital simulations (pre-evaluations) of different types, but categorized as functional, technological and environmental. Architectural design is discursive and even though our work is in-progress and lacks articulation, there are already results that can guide designers towards informed solutions for projects of similar characteristics. More importantly, the study presents a methodology that, understood as part of so many other similar proposals, can assist in the construction of new and more efficient digitally driven and environmentally sensitive design processes.

Acknowledgements

The research project Eco-envelopes is being led by Dr. Claudio Varini and the CFD simulation in Figure 3 was created by Sara Luciani. The methodology of Eco-envelopes was presented by Rodrigo Velasco in 2011 at ECAADE 29 in Slovenia.

Bibliography

Bermudez, J. and Klinger,K. (ed.) 2003. *Digital Technology & Architecture* – White Paper submitted to NAAB by ACADIA. Retrieved September 2012, from http://www.archvoices.org/downloads/acadia.pdf

Jones, J.C., 1992. *Design Methods*. New York: Wiley.

Meredith, M., 2008. "Never Enough", *From Control To Design*, Barcelona, Spain: Actar-D.

Robles, D. and Velasco, R. 2011. "Eco-envolventes: A parametric design approach to generate and evaluate facade configurations for hot and humid climates" in: ECAADE 29 Proceedings of The 29th Education and Research in Computer Aided Design in Europe.

Schumacher,P. 2008. *Parametricism as Style - Parametricist Manifesto*. Retrieved in August 2011 from http://www.patrikschumacher.com/Texts/Parametricism%20as%20Style.htm.

Woodbury, R. 2010. *Elements of Parametric Design*. London and New York: Routledge.