Computational and Algorithmic Design for Design Innovation in Architecture

PERFORMATIVE FACADE VOL.01

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PERFORMATIVE FACADE VOL. 01

H Architecture

This research paper was written and edited by Dongil Kim
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H Architecture

Contents

Introduction

Computational design in building practice

This design research is a part of 'Computation design in practice' developed at H Architecture in New York, which aims to identify different approaches on how physical and digital information are implemented into innovative architectural practices and fabrication processes. The research defines information as Architecture is used as design parameters to achieve not only building performance and an efficienct design process, but also design innovation in an architectural practice.

This first volume of design research,"Performative facade", represents integrative design process which incorporates environmental data, contextual data and digital fabrication methods for an integrative building design.

Performative Facade

Computational and Algorithmic Design for Design Innovation in Architecture

Design process in general, and particularly in architecture, is a complex process that involves a combination of knowledge, skills, experiences, practices, etc. In recent decades, digital design emerges as unstoppable trend, which adds to all the aforementioned factors the use of digital tools. The techniques cover this issue with computational and algorithmic design system, the so called parametric design. It already vividly present in the first half of the twentieth century in the automotive sector (geometric design), and finally impact on architectural design which represents a new step that has led to a new type of Architecture.

This research aims to prepare architects and designers for the continuing advancement of computational processes in architecture in their practice. The topics is exposed as both a technical and intellectual venture of formal, spatial, construction and ecological potentials. The research is to establish a practical foundation in the fundamentals of parametric and algorithmic design strategies. This research provides a platform for further exploration into the efficient use of computational process in architectural design, with particular focus on information-based and performance oriented models. There are great potential of combinations of current design software: Grasshopper, Rhinoceros, Revit, Dynamo, etc, which allow to change design process, transforming architects from builder of model to builders of system.

The primary research fields in this proposal is the theoretical and practical development of generative computational design process for performative facade system on both conceptual design and construction phase, allowing for the integral use of computer-controlled manufacturing process in this design system. The later of this research will reach to critically review computational design towards a more challenging and self-demanding commitment to physical and environmental constraints as fabrication stage.

A History of Environmental Parametric Computational design

Computational design is a design methodology in which the output is generated by a set of rules or algorithms, normally implemented on the computer. In the early 1970s, Prof. Ralph L. Knowles at the University of Southern California implemented an external factor, a solar vector data, as the main principle for the design rule set in The Solar Envelope project where all adjacent neighbors are capable of solar access. While the early project was operated manually, generative design process using a computational method has been triggered to mediate a rule set between humans and the environment factors in this fast changing and unpredictable contemporary period.

The Article by Mimi Zeiger at METROPOLIS magazine (January 2017) is perfectly demonstrate environmental design impact in contemporary society.

Game Changers 2017: Ralph Knowles
"Daylight isn't the first urban-planning consideration, but it is among the most important. This pioneer in solar design has worked for half a century to spread the message."

Throughout the bruising 2016 election, climate change and the ecological impact of our insatiable demand for energy were the policy questions that were always on the sidelines and never explicitly addressed. Similarly, architects have often evaded these issues—embracing sustainability and LEED requirements as necessary, but rarely tackling them head-on. This uneasy relationship between energy and architecture dates back decades. Knowles published his first book in 1974, just when the global economy was in the throes of an energy crisis. Petroleum and heating oil were in short supply, leading to not only the famous gas lines but also the political tensions between the United States and Middle Eastern nations that we still see today.

The text of Energy and Form: An Ecological Approach to Urban Growth was part energy conservation treatise and part call to action. Drawing on studies of pueblo architecture and analysis of California's Owens Valley watershed, Knowles proposed a systematic method of shaping architecture and urban development in response to seasonal and climatic rhythms. In the book's introduction, he writes that "its method is deduction and rests on the premise that human survival depends on our willingness to consciously direct *urban growth."*

Read today, Energy and Form is a remarkably prescient predecessor to parametric analysis, which can approximate environmental impacts on building form in response to solar gain, shadow, or wind. Knowles, however, traces the inspiration for his solar envelope research back to when he was a student at North Carolina State University in the 1950s. (He was a pupil of the Argentine architect Eduardo Catalano.)
And in the preface, he credits Buckminster Fuller, who taught in the college of design, as the first issuer of a prophetic warning about the impact of urban expansion and industrialization on the earth's resources. "At the time, we heard him only faintly," writes Knowles. Like Fuller, Knowles was dedicated to research that would tackle the big energy issues, even if an audience wasn't ready to hear his message.

Knowles's research into environmental conditions and theories about solar envelope zoning prefigured the parametric tools architects and planners use today. This scheme for an LA. row-housing project demonstrates how dense developments—both low- and high-rise—could still provide equity in terms of natural sunlight.

Courtesy Ralph Knowles

Images courtesy Ralph Knowles

Lately, people have been listening. This past September the Harvard Graduate School of Design (GSD) convened a two-day conference titled "Heliomorphism." The esoteric-sounding term taken up by the GSD broadly describes the use of solar responsive design approaches in shaping cities and buildings. The inaugural event of the school's Office for Urbanization, founded by architect and urbanist Charles Waldheim, used Knowles's research into solar envelope zoning—a legal designation that if adopted as policy would guarantee solar access in urban areas—as a jumping-off point. "Architecture that conforms to solar envelope allows us to look at the whole city," Knowles explains.

Waldheim sees equal access to light and air as part of the social contract of cities and a topic that deserves renewed attention. "What appeals to me about the topic is that it is both archaic and undercultivated in the last 25 years, which makes it ripe for appropriation," Waldheim says. Knowles's research, he adds, suggested (and still suggests) the possibility of understanding the making of individual energy-conscious buildings and sustainable city planning as a synthetic process. "Right now we have a condition that when talking about the city, we end up in one of two places—either we talk about policies and politics, or every project is a singularity," Waldheim says. "[Heliomorphism] allows us to deal with questions of collective urban form in a directly ecological way."

Over the years, Knowles's research received funding from the National Endowment for the Arts and the Solar Energy Research Institute (launched in 1974 and now the National Renewable Energy Laboratory), but he found that moneys to support his efforts vanished under Ronald Reagan's presidency. Mainstream interest in environmentalism ushered in during the '60s and '70s, a time of activism and policy change, faded in the '80s as the energy crisis abated. Now the issue is back in play. The GSD conference was timed to coincide with the anniversary of New York City's 1916 Zoning Resolution, which was the city's first regulation of development in relationship to access to sunlight and air. A hundred years later, Waldheim's Office for Urbanization hopes to augment Knowles's research with public and private partnerships that propose zero-carbon approaches on a global scale capable of countering what it describes as "neoliberal corporate and governmental urbanizations." The Office for Urbanization at Harvard GSD produced a zoning exercise along the lines of Knowles's research and applied it to Manhattan.

A study for a mixed-use development illustrates how the solar envelope (above) determines both the form of the development and its articulation (below). The configuration ensures that every unit has at least four hours of direct sun exposure, as well as cross ventilation. Courtesy Ralph Knowles

Courtesy Charles Waldheim

Although Knowles didn't attend the conference, it featured keynote lectures by architects Thom Mayne and Jeanne Gang, who both credit him as an influence. In particular, Gang's design for the Solar Carve Tower along Manhattan's High Line used his solar envelope theories to shape the building. The architecture is "carved away" to maximize daylight within the office building and to maintain sunlight access and view corridors along the park. Gang first read about Knowles's work in 2000 while prepping for a passive and low-energy architecture conference, and then visited him at the University of Southern California in Los Angeles the following year. "He generously received me and told me about the program, even though I was there simply to ask him questions and learn more about the solar envelope studies," Gang recalls.

Now a professor emeritus at USC, Knowles taught in the school of architecture for more than 40 years and even served as interim dean from 1973 to 1975. Mayne was one of his students. "[Knowles] embedded in me an openness—an inquisitiveness for exploring the limitless potential of architecture, giving me the confidence in our discipline's capacity to form and give life to the complex, interrelated, highly differentiated, and enduring phenomena that form it," says the Pritzker laureate.

At USC, Knowles pioneered a new kind of design studio within the school of architecture. His studios were designed as testing laboratories and, in a pre-CAD era, focused on hands-on research. He and the students built equipment to simulate the movement of the sun across a structure and designed experiments to model wind and water-flow dynamics. Energy and Form is full of photographs of student projects made out of wood sticks and blocks that were generated through testing. Knowles's methodology won him the 1974 AIA Medal for Research and lives on with USC's master of building science graduate program. Like Bucky Fuller, Knowles was dedicated to research that would tackle the big energy issues, even if an audience wasn't ready to hear his message.

Applied on an urban scale, the work makes a case for access and equity that can directly affect policy. He flips through a copy of a later book, Sun Rhythm Form (1981), and points to a diagram that shows the arrangement of multifamily units on a site. "We were pushing for the highest density and a range of housing types," he recalls, and acknowledges the continued need for a diversity of housing types. "Form has its own social implications." The point is especially relevant in tight housing markets like Los Angeles or San Francisco, where an increase in developer-driven urban infill may threaten access to sunlight and rising apartment towers cast long shadows.

It is this social impact of his research that resonates the most with contemporary practitioners. "It struck me that while so many at the time were preoccupied with the technology of harvesting solar power, here was someone who was considering the societal impact and how sunlight could be considered a key driver for urban form and zoning," Gang says.

Knowles seems genuinely surprised and touched by the new interest in his work. As we thumb through his books together around the balcony table, I can see clippings of articles—some yellowed, some fresh—tucked into the pages. "It indicates that they have faith in solar energy," he says of Waldheim and others who are reviving interest in his work, but also cautions, "We still have a long way to go." His lengthy career working on designing with nature has taught him perspective. As we wrap up our conversation, he quotes his wife, Mer: "The seeds that you plant in the ground take a long time to grow."

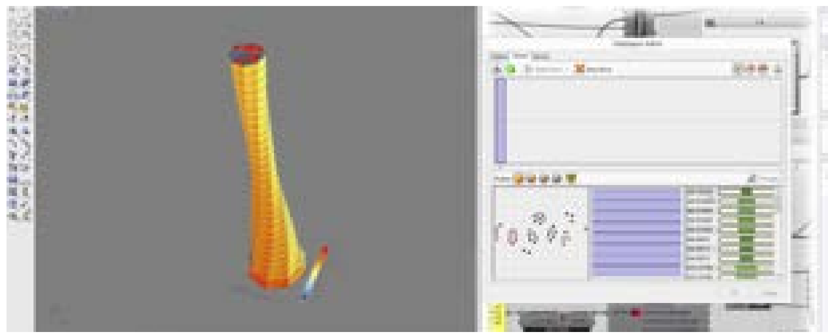
Based on Ralph's countless contribution of theory, development of parametric and computational analysis in architecture practice trigger intense application on the architecture practice. The Performative Facade Volume 1 is currently limited to prototyping of specific region such as enclosure of a building and not precisely engineered, but it will be developed more active and comprehensive way through following research. In addition to current body of environmental data driven design research, this research will also investigate the methodology of fabrication from very earlier stage in design process which allows the innovative design thinking strategy.

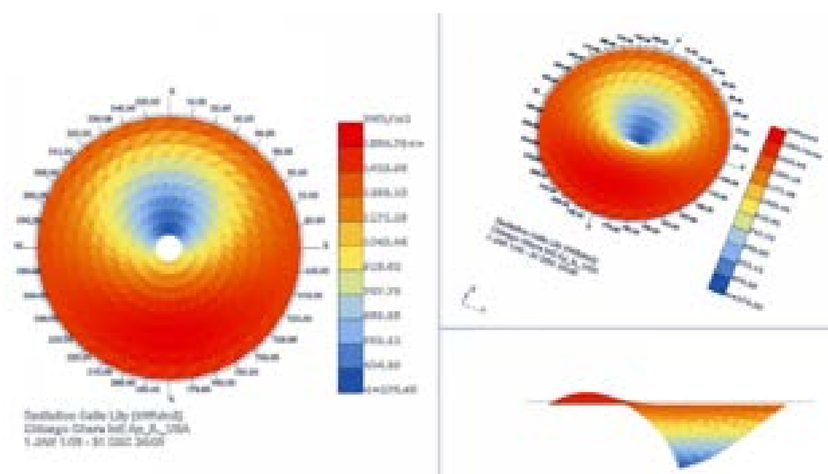
The research introduce contemporary application of computational and algorithmic design in architecture practice. For instance, 3XN's research ground GXN(GreenXN) is leading architecture office in environmental parametric and system making. By 3XN serves as triple function including reducing thermal effect, optimizing of view, and securing daylight in creative ways. Another practice is Morphisis, lead by Thom mayne in California as well as New York. They always bring up sustainability issue on the table and provide solution in computational design challenge. Phare Tower, winning proposal, but canceled, represents systemized panelization within undulating morphology of tower shape in earlier computational design era. Big and UNStudio, recently, involve computation design process with environmental data into their practice. Someone considers it as a short trend of architecture practice. However, it has been believe that the data driven design is not only a design process with fficiency, but also reflection of social and political impact of architecture.

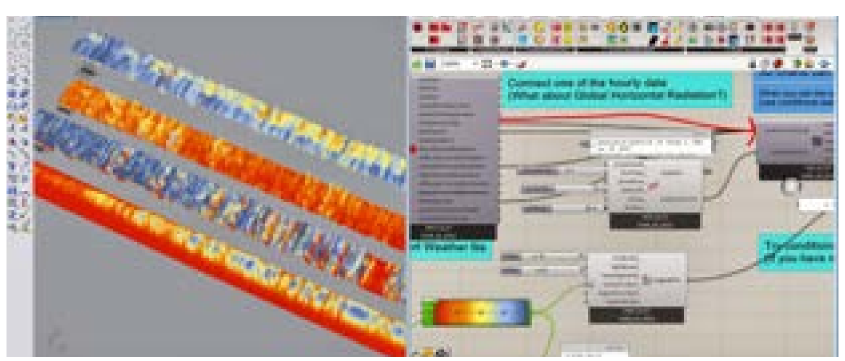
Research Objective

Toward Performative Facade

Top left: Formal optimization test optimization based on thermal effect through Galapagos and Honeybee plug-in
Top right: Ladybug thermal simulation
Bottom: Thermal simulation for urban form through Honeybee and Ladybug





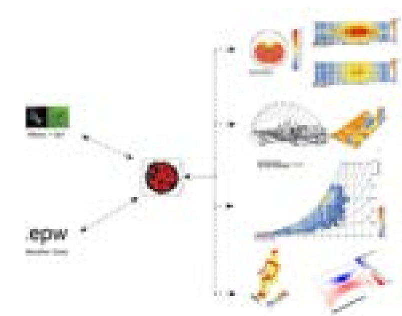


Top: Software interdependency of Honeybee plug-in
Bottom: Software interdependency of Ladybug plug-in

Toward Performative Architecture

The research aims to constitute a platform for dialogue on experimental practice and research within the field of computationally informed architectural design. This allows architects and designers to prepare for the continuing advancement of computational processes in architecture in their practice. The topics is exposed as both a technical and intellectual venture of formal, spatial, construction and ecological potentials. The research is to establish a practical foundation in the fundamentals of parametric and algorithmic design strategies. It provides a platform for further exploration into an efficient use of computational process in architectural design, with particular focus on information-based and performance oriented models. There are great potential in combining of current software tools: Grasshopper, Rhinoceros, Revit, Dynamo, etc; which allow to change design process, transforming architects from builder of models to builders of systems.

Based on the fundamental knowledge of computational modeling, this research will focus on an advanced computational design strategy through information based modeling plug-ins;



1. Environmental information based design – Honeybee + Ladybug
2. Force information based design – Kangaroo
3. Urban and geographic information Based Design – GIS, Local Code, Elk
4. Advanced Geometry Analysis in Design – Lunchbox

Especially, this research utilizes intense environmental data. Therefore, Honeybee and Ladybug, parametric environmental simulation plug-in play a central role in this research. In addition to the environmental softwares, the later part of the research will explore the fabrication and build system through computer-controlled manufacturing process such as robotic fabrication, flat sheet based cutting and assembly and rapid additive manufacturing.

Precedents

1. Roof Structure of Middelfart Saving Bank / 3XN
2. The Horten Headquarters / 3XN&GXN
3. Phare Tower / Morphosis
4. Raffles City / UN Studio
5. Astana National Library / BIG

Exterior image of Middelfart Saving Bank

Top Left : Outside View of Roof Structure
Bottom right: Cross section of building
Bottom left: Interior View of Roof Structure

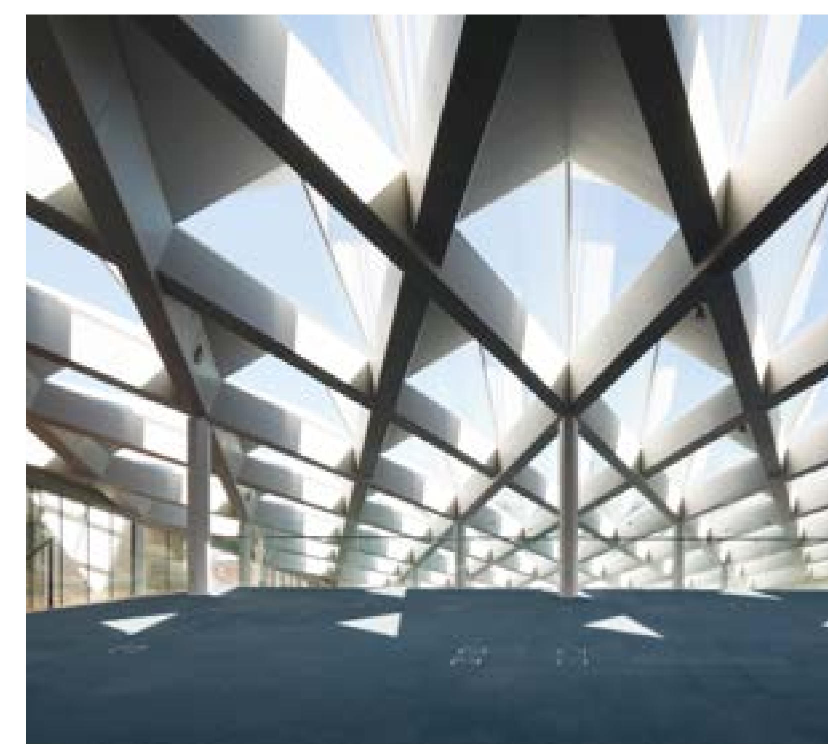
1. Roof Structure of Middelfart Saving Bank

Iconic Headquarters for Key Institution

Middelfart Savings Bank is a key institution in the town of Middelfart on the island of Funen, Denmark. Thus the Savings Bank wanted their new Head Office to provide a new public space for the local citizens as well as an architectural icon for the town and the Savings Bank.

Dramatic Roof and Sustainable Features

The building is characterized by a dramatic roofscape accommodating multiple functions. 83 prism-like skylights compose the spectacular roof surface defining the geometry of the building – in reference to the maritime environment as well as the surrounding buildings. The roof is specially designed to frame a perfect view towards the water while at the same time shading from direct sunlight. The working environment is further improved by sustainable features such as natural ventilation and the latest technologies in energy efficient heating and cooling, facilitate energy savings of 30-50 percent.



Exterior image of the Horten Headquarters

2. The Horten Headquarters

3XNs design for Danish Law Firm Horten's new head office reflects the duality between the classic and the modern. The building combines solidity with an advanced choice of materials expressing Horten's solid integrity as well as the firm's visions for new, future forms of collaboration.

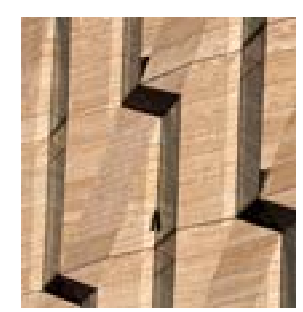
The volume's travertine-clad facade reinterprets the classic concept of a corporate head office. Depending on the angle, Horten's facade gives the impression of being a craggy cliff face, an ocean blue glass facade or an intricate geometrical pattern of chunky diagonal, vertical and horizontal friezes. The facade elements were developed especially for this building's complex geometry while taking on board the requirements for sustainability. The elements were designed to ensure a pleasant working climate with beautiful bay window views towards the water while avoiding direct sunlight. Sustainability, in other words, is integrated in the architectural design itself: The building units are consciously designed to ensure that the building's energy consumption is 10 per cent less than required by the energy guidelines in the Danish building code.

Top Left : Office Facade open view toward North Canal
Top Bottom : Office Facade blocking direct sunlight from south
Right: Installation Process of Facade

Large Energy Savings

With these thermo-active concrete elements it is possible to reduce the energy consumption for heating by 30 percent and the energy consumption for cooling and mechanical ventilation by up to 85 percent; in total, an energy saving of 30-50 percent. This is due to the fact that the system allows for better use of alternative supply sources, i.e. the plant can operate as a low- temperature floor heating system during winter, based upon heat-driven heat pumps, and during summer, the cool night air, soil tubes, ground water or sea water can be used for cooling.

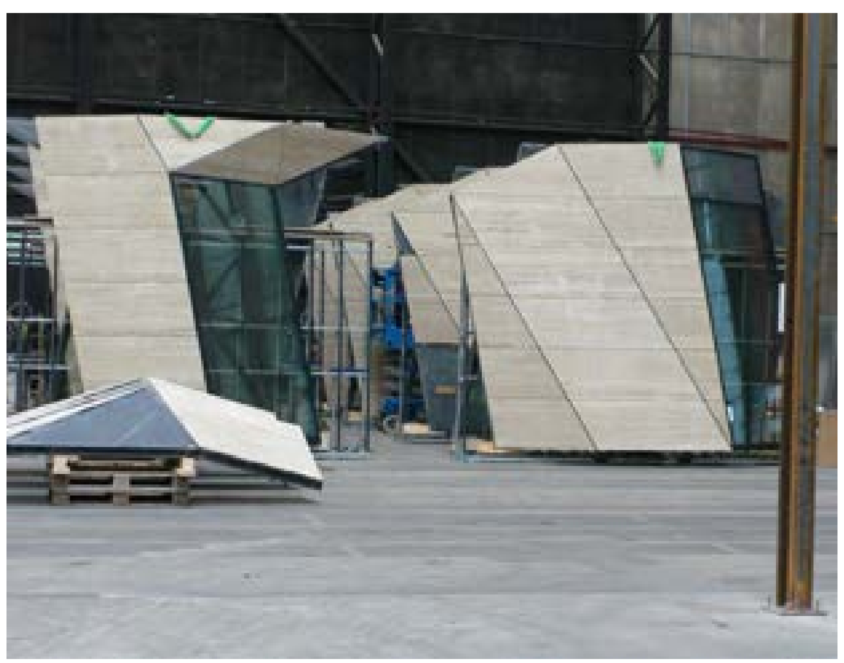
The system is partly self-regulating as water for heating and/or cooling is circulated with a temperature only a few degrees from the desired room temperature, and this is the key to the large energy savings. In addition to energy savings the capital costs were lower due to the reduced needs for cooling and heating.



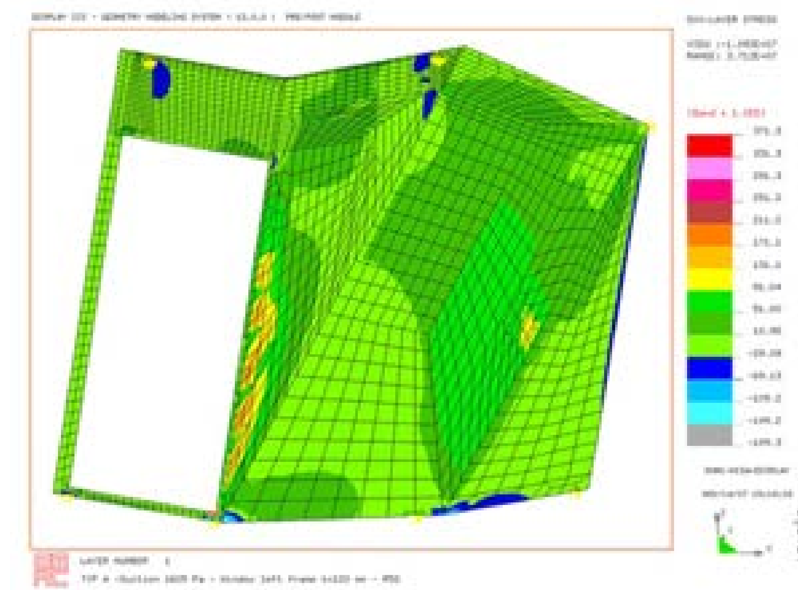
Pre-fabrication of facade

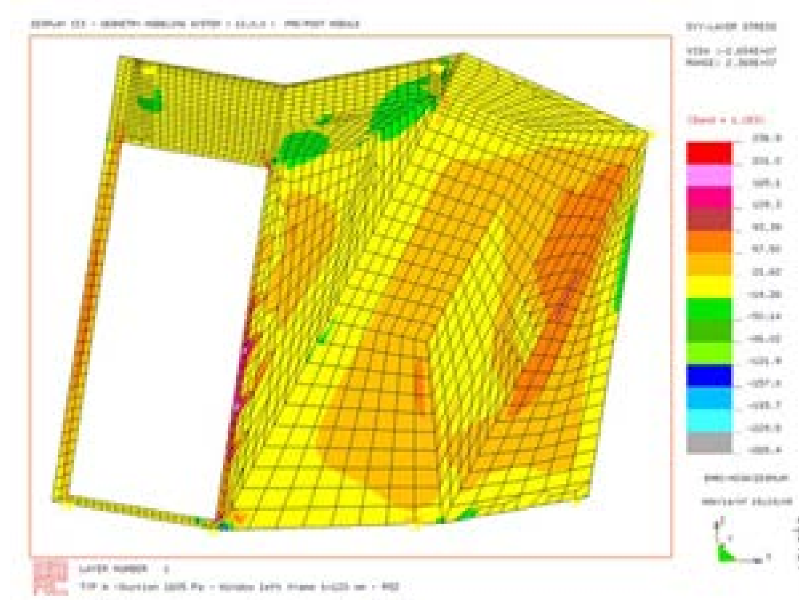
The emphasis is placed on a spatial experience with optimum daylight conditions in the individual offices as well as in communal areas. The main layout places the offices in two angled building volumes with open atria between them, creating visual contact between the two. Between the atria, distinctive sets of stairs criss cross up through the circular stairwell, the spine of the building, creating interaction and contact between floors.

One large roof covers all functions in the building. The roof is a large elegant wooden structure with numerous openings. The openings bring in abundant amounts of day-light and allow for direct view of the sea from all places in the building, up and down. In this way, the light and friendly atmosphere sought for by the bank is achieved.



Top left: Structural simulation of Lamination of composite backup structure 1 direction
Bottom Left: Structural simulation of Lamination of composite backup structure 2 direction
Right: Digital model to demonstrate various angle of Facade types





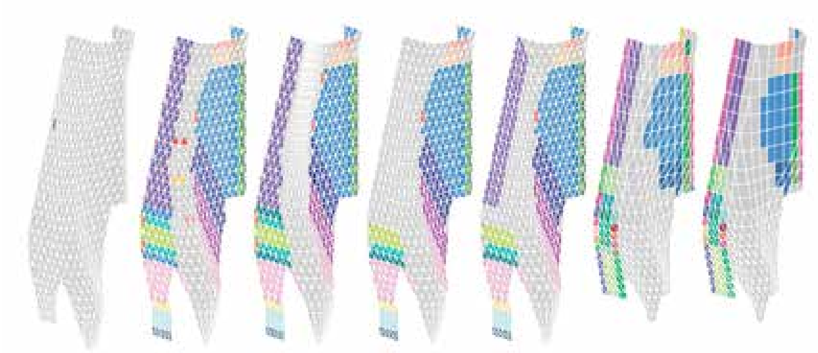
Evolution of diagrid structure

3. Phare Tower

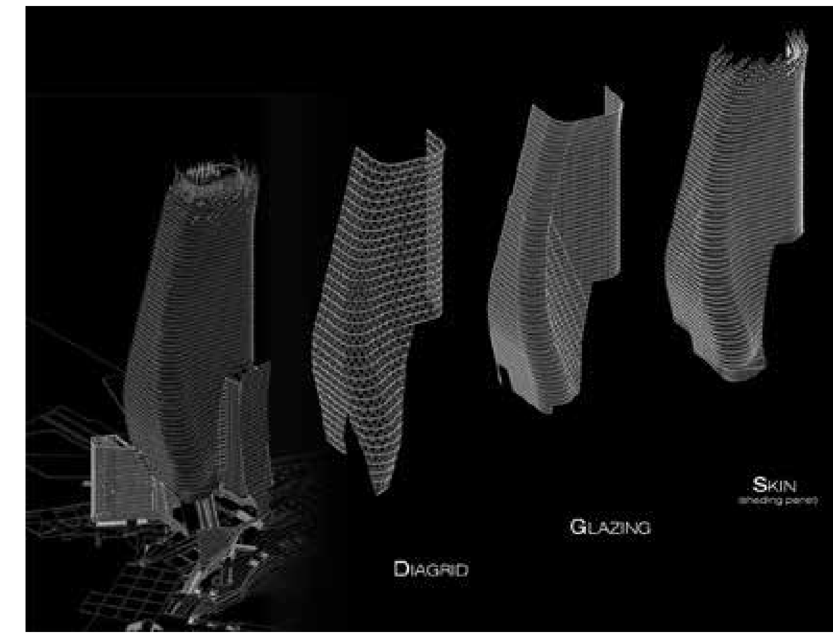
Drawing on the power of parametric scripting, the design of the Phare Tower gathers disparate programmatic, physical, and infrastructural elements from the requirements of the building and synthesizes these into a form that seamlessly integrates the building into the idiosyncrasies of its site while expressing multiple flows of movement. In the spirit of the Paris Exposition competition proposals, the tower embodies state-of-the-art technological advances to become a cultural landmark.

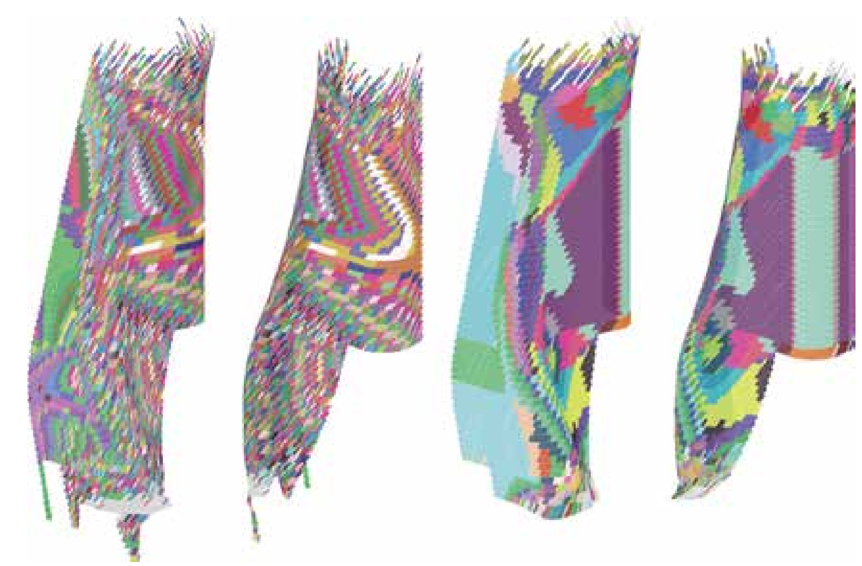
The complex structure and skin adapt to the tower's nonstandard form while simultaneously responding to a range of complex, and often competing, physical and environmental considerations. Technologies integrated into the Phare Tower capture the sun and wind for the production of energy and selectively minimize solar gain while maximizing glare-free daylight. Its high-performance skin transforms with changes in light, becoming opaque, translucent, or transparent from different angles and vantage points. At night, ribbons of light garland the building to animate the building's shifting form.

Technologies integrated into the Phare Tower harness the wind for the production of energy and selectively minimize solar gain while maximizing glare-free daylight. The tower is crowned with a cluster of antennas and a wind farm of turbines that harvest energy-a metaphorical garden in the sky. Both the form and the orientation of the building respond to the path of the sun. The planar, clear-glazed north façade maximizes interior exposure to year-round natural daylight. A curvilinear second skin of diagonal stainless steel mesh panels wraps the tower's continuous south, east, and west glazed façade to minimize heat gain and glare and maximize energy efficiency.

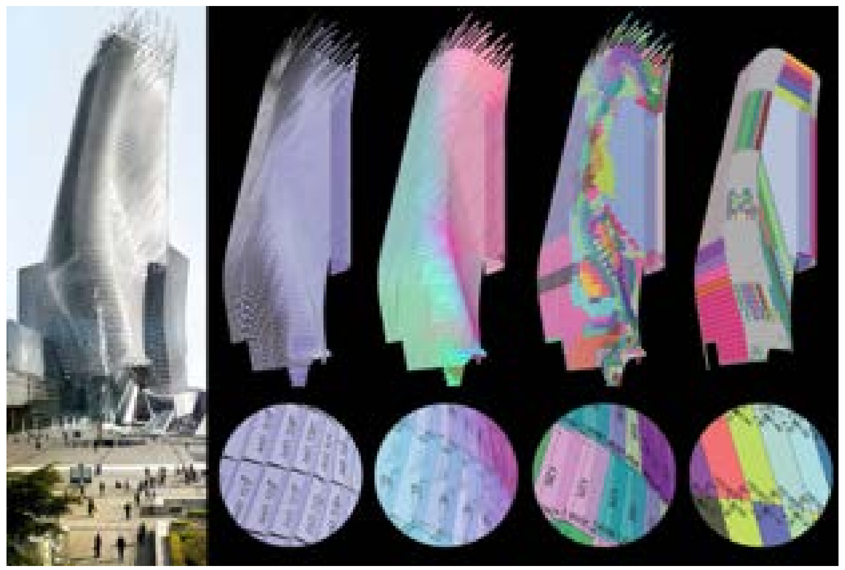


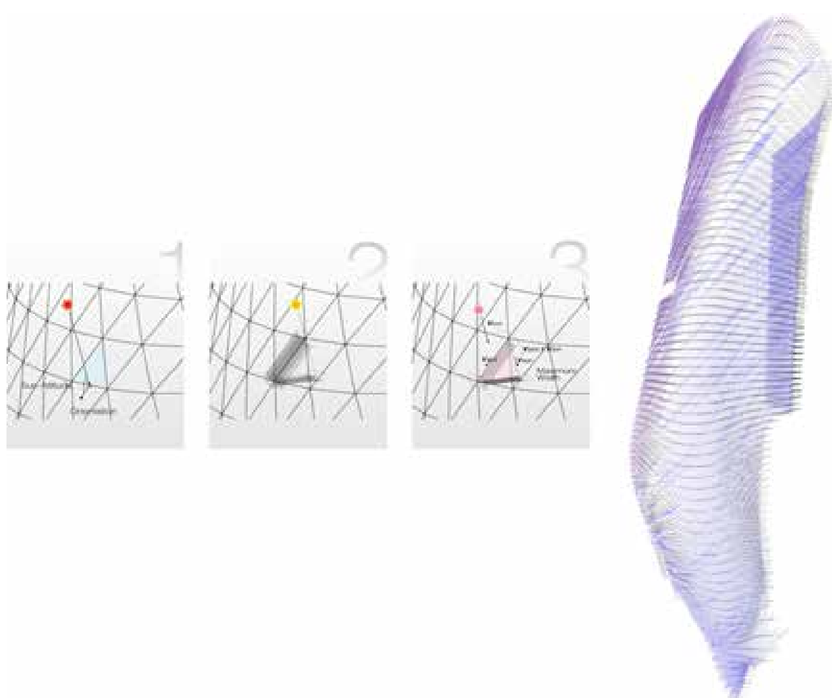
Computationally generated components in Phare tower project
Solar shading skin unitization



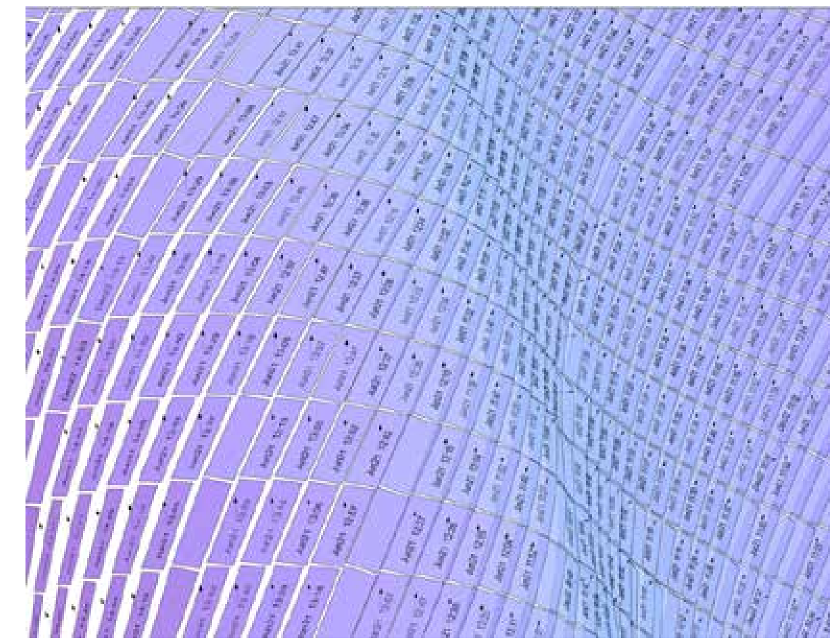


Top: Phare tower, solar optimization diagram, skin joint analysis, skin panel unitization, glazing panel rationalization
Bottom: Solar optimization algorithm for Phare tower skin. Each panel seeks the highest solar angle at each building orientation and determine the panel angle around the diagonal fixture.





Top: Enlarged solar optimization diagram. As a result of the optimization algorithm, each panel is optimized for different time in the summer solstice day. Some areas are optimized for the winter solstice day for differentiated patterning.
Bottom: Unfolded color-coded skin panels with panel counts



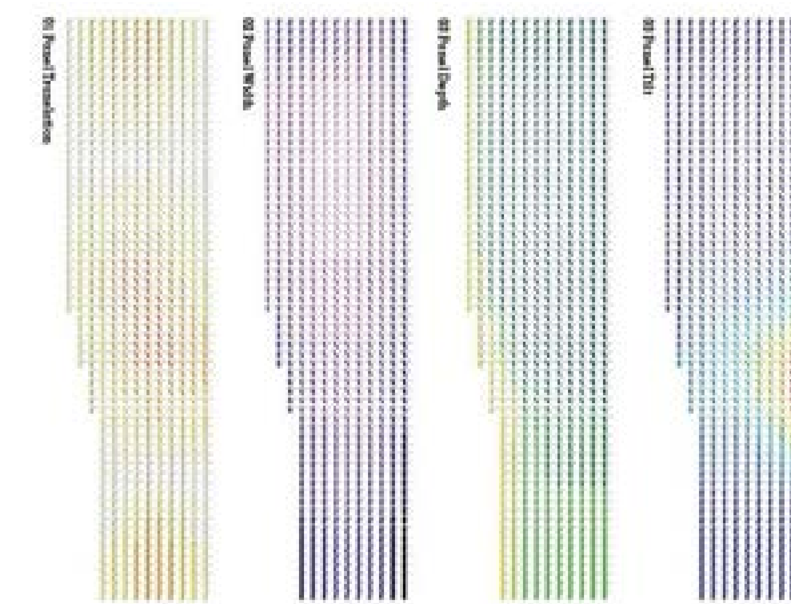
Top: Phare tower, solar optimization diagram, skin joint analysis, skin panel unitization, glazing panel rationalization
Bottom: Solar optimization algorithm for Phare tower skin. Each panel seeks the highest solar angle at each building orientation and determine the panel angle around the diagonal fixture.

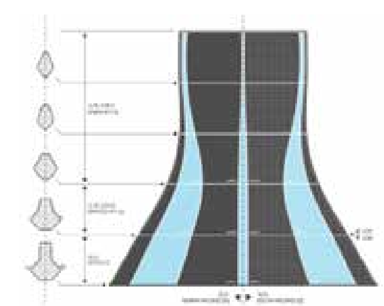
4. Raffles City

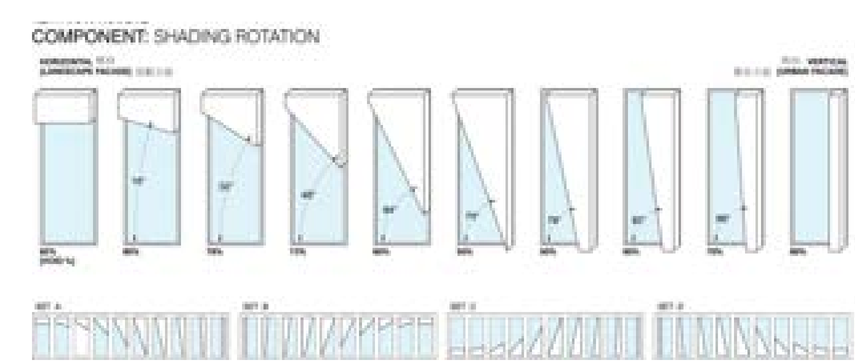
UNStudio's mixed-use Raffles City development is located near the Qiantang River in Hangzhou, the capital of Zhejiang province, located 180 kilometers southwest of Shanghai. Raffles City Hangzhou will be Capita-Land's sixth Raffles City, following those in Singapore, Shanghai, Beijing, Chengdu and Bahrain. The project incorporates retail, offices, housing and hotel facilities and marks the site of a cultural landscape within the Quianjiang New Town Area.

Raffles City Hangzhou will reach a height of 60 stories, presenting views both to and from the Qiantang River and West Lake areas, with a total floor area of almost 400,000 square meters.

Top left: Solar optimized fin installation
Top right: Identification of parameters
Bottom: shading component variation based on geometry



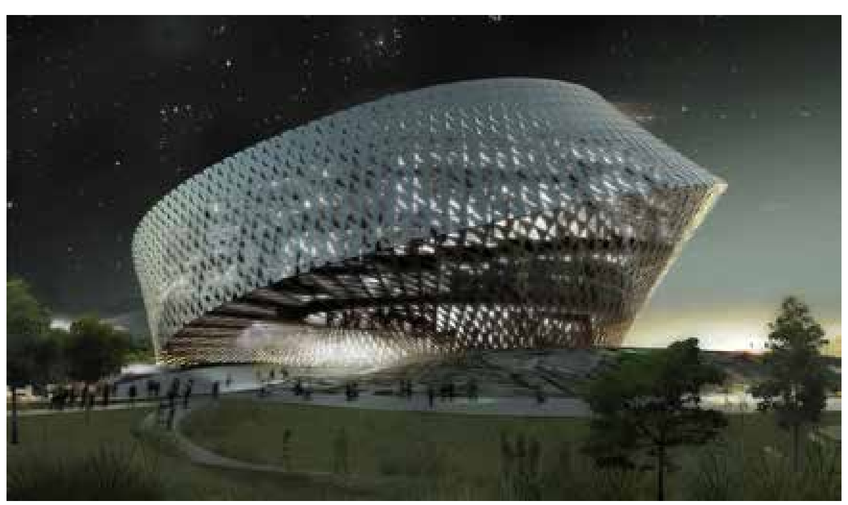


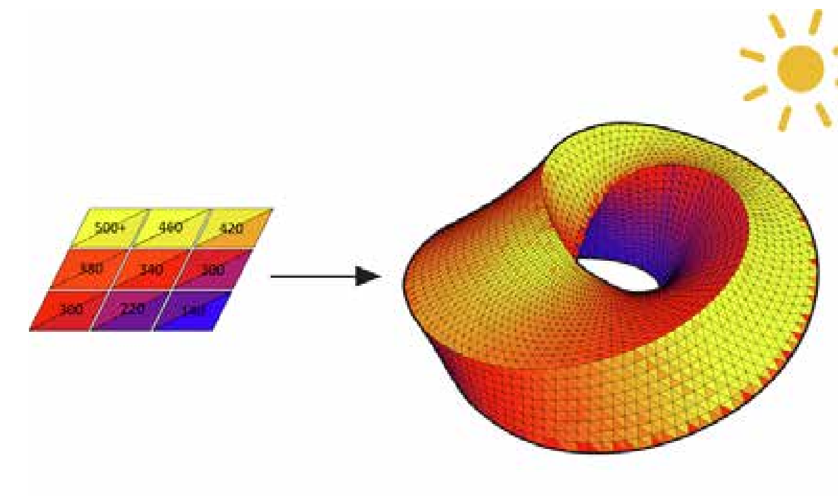


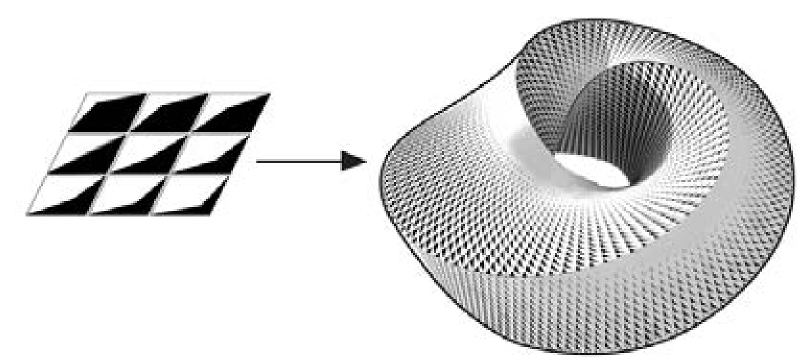
5. Astana National Library

The national library is conceived as the integration of four organizational strategies into one new national institution, the perfect circle of the national archives; the orbiting spiral of the public spaces; the complex of geometry of mobius envelope; the radically distributed section of the kazakh landscape.

By Using state of the art technology and simulation capacity such as lady bug and honey bee which introduced early in this paper, BIG team have calculated the thermal exposure on the building envelope. Due to the wrapping and twisting geometry the thermal imprint on the facade is continually varying in intensity. The thermal map ranging from blue to red reveals which zones do and do not need shading. Translation of the climatic information into a facade pattern of varying openness creates a from of ecological ornament that regulates the solar impact according to thermal requirements. The result is a contemporary interpretation of the traditional patterns and fabrics from yurt on both sustainable and aesthetic way.







CASE STUDIES

Computing the Performative

Case Studies 1. Yuido Post Office Facade System

Case Studies 2. Hyundai Department Store Headquarter

Case Studies 3. Lamborghini Road Monument

Case Studies 4. NEXEN R&D Center

Computing the performative

The research has been conducted through a series of architecture projects. The project are mostly collaborated with Haeahn Architecture in Seoul, and the development of computational system has been set up at H Architecture. A series of experimental projects are crucial demonstration by research on environmental and contextual data driven design.

The case studies has been focused on work space, while optimizing diverse parameters such as thermal effect, daylight, and view. The morphologies of facade reflect each program and brand identity, but the goal of design assimilates as improving work environment through environmental parameter within different context of projects.

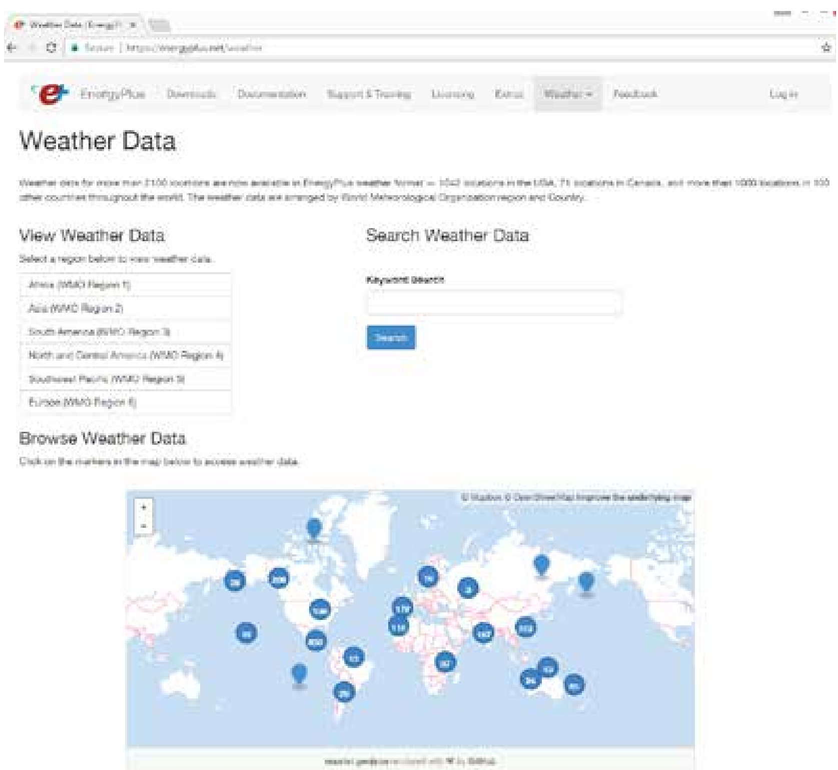
Each project demonstrates methodology of computational development of parameter and system development in both physical and digital way. Especially, Ideal process of research is NEXEN R&D Center regarding further development to integrate material and fabrication system.

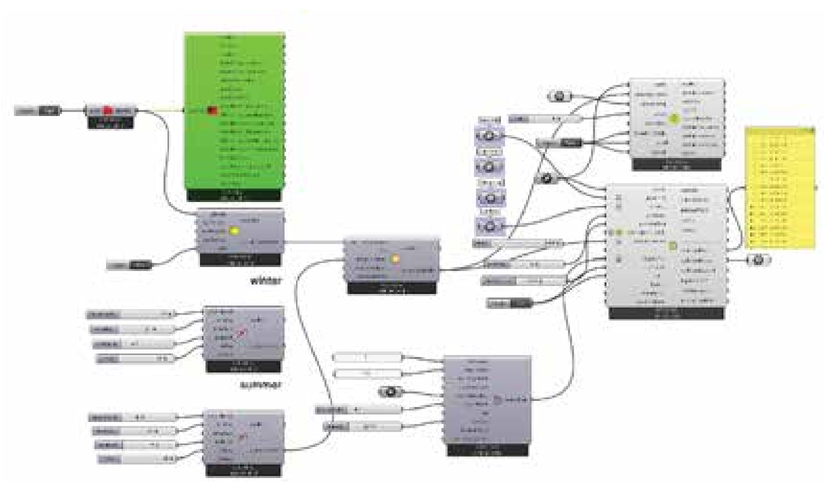
CASE STUDY 1

Yuido Post Office Facade System Debelopment

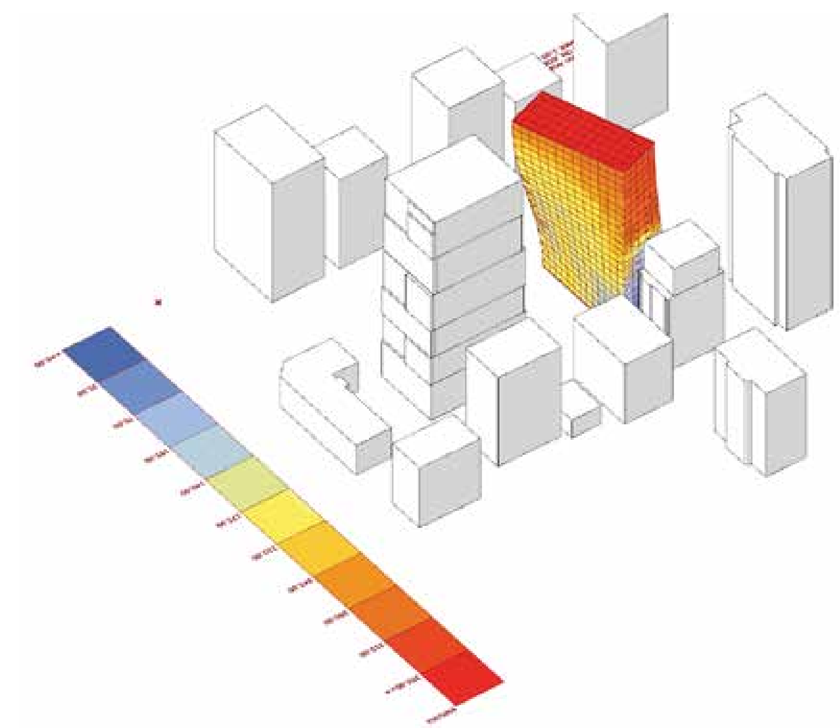
Top: Introduction of "EPW Weather Data base system Website"
Bottom: Preset of Thermal simulation through Ladybug & Honeybee

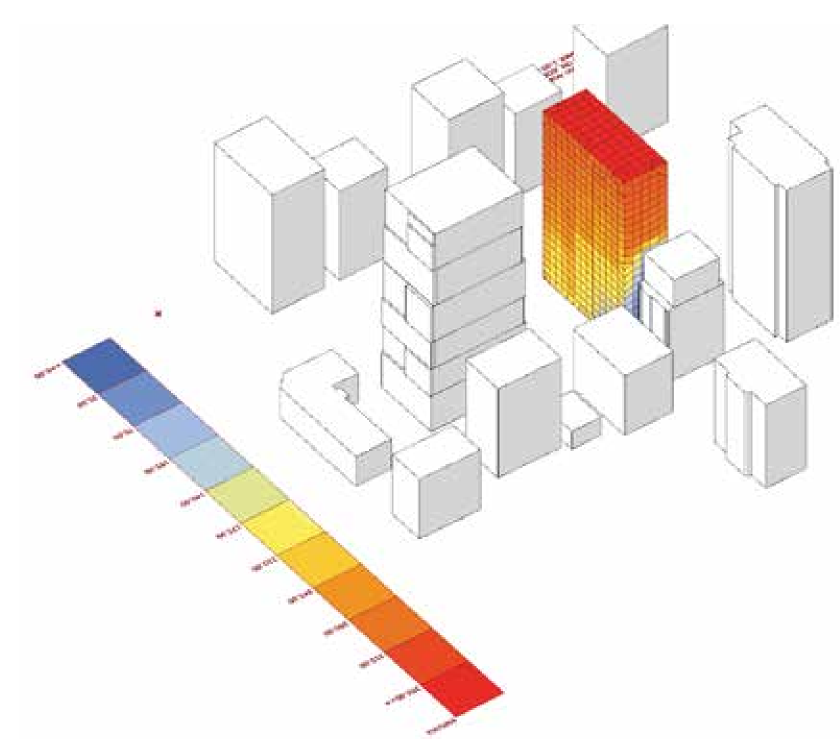
Case Study 1. Yuido Post Office Facade System Development



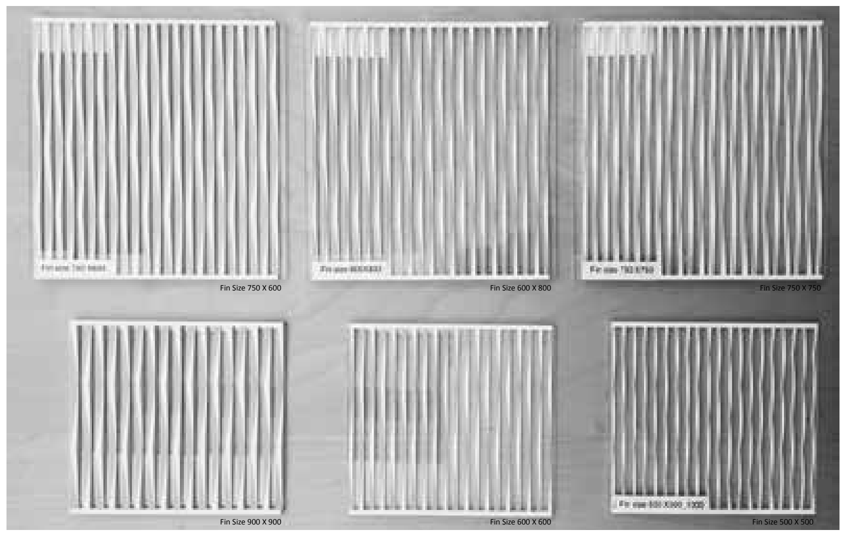


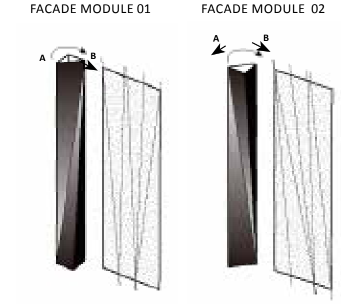
Top, Bottom: Comparison of Thermal data based on adjacent context and building form



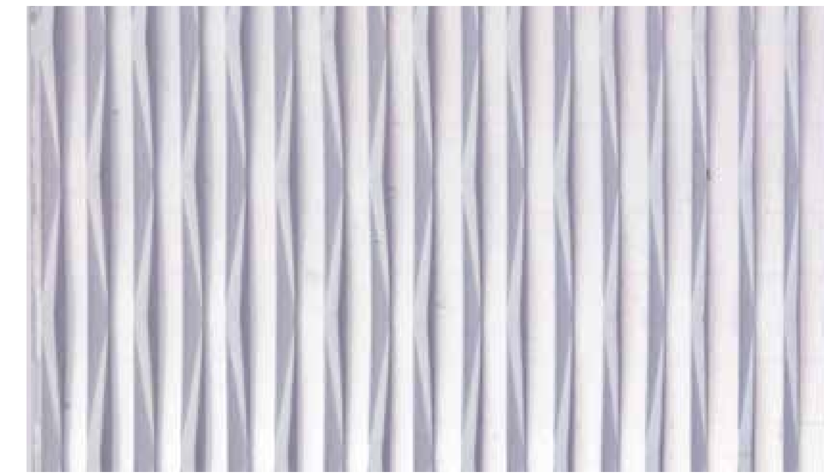


Top Left: Prototyping based on depth and width ratio
Top Right: Exploded Plan of facade module 01, 02
Bottom: Facade Application Model



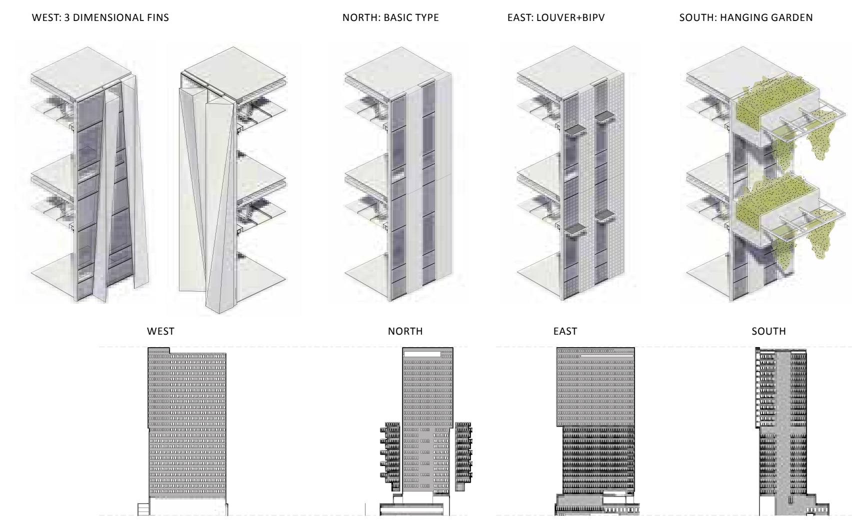


Interior view test based on fin size
Top: Depth 750, Width 600, Spacing 1500
Middle: Depth 600, Width 800, Spacing 1500
Bottom: Depth 750, Width 750, Spacing 1500



Top: Open and closed view based on orientation
Bottom: Enclosure Type West

Top: Enclosure Typologies
Bottom: Enclosure Type East



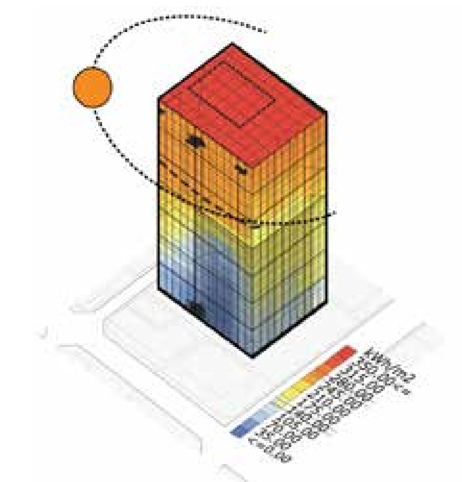
CASE STUDY 2

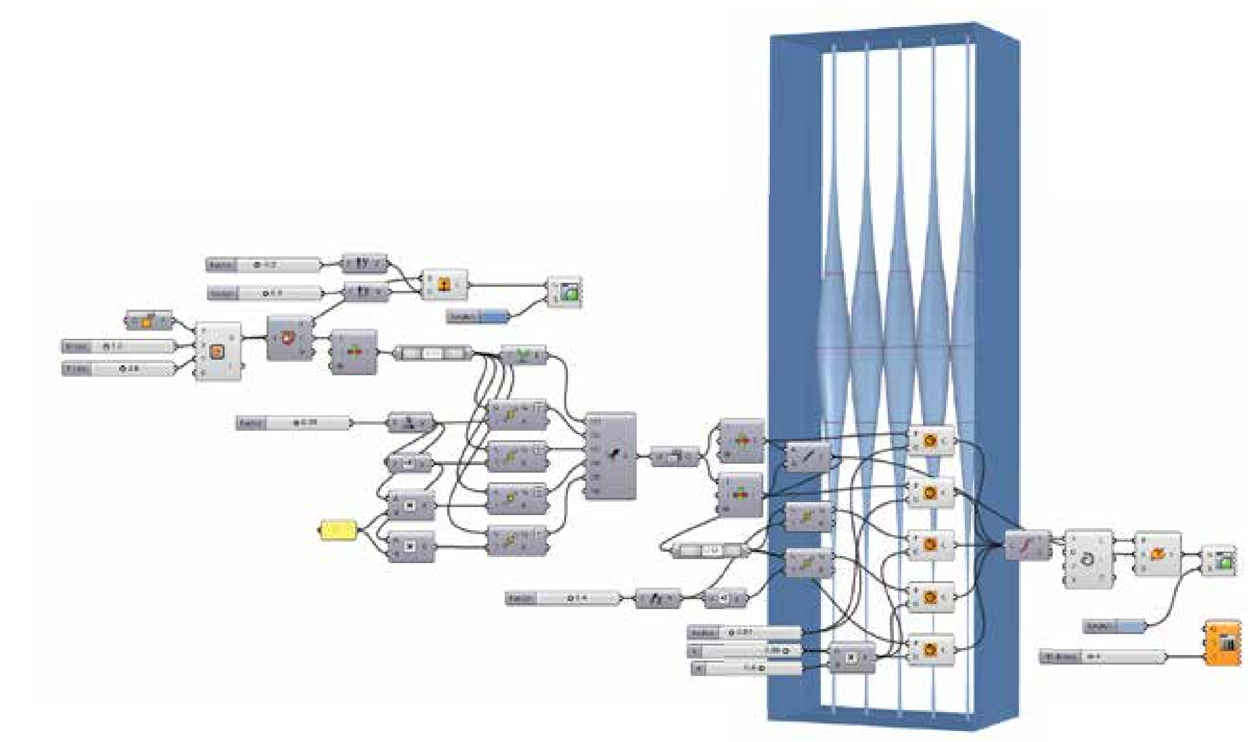
Hyundai Department Store HQ Facade System

Bird-eye view of the project

Case Study 2. Hyundai Department Store HQ Facade System

Top: Solar radiation simulation of basic volume
Bottom: Facade prototype script

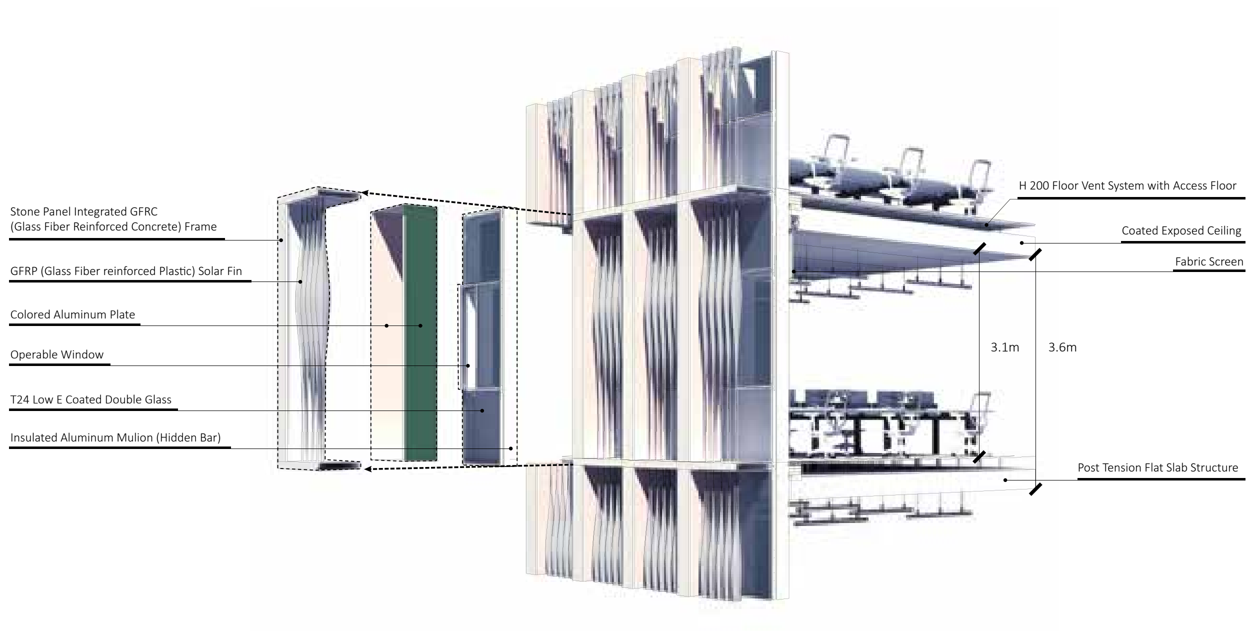


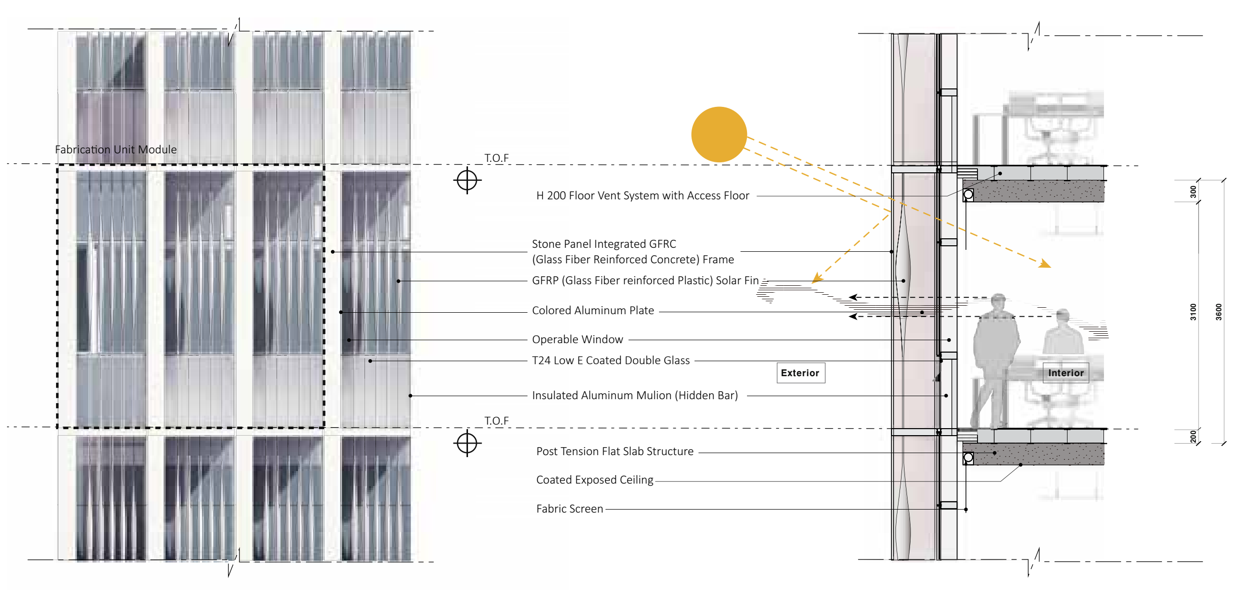


1:300 Scale model

1:20 Facade detail model

Top: Facade exploded detail axon
Bottom: Partial Elevation and Section





Rendering from North-West view

CASE STUDY 3

Lamborghini Road Monument: Fibrous Tectonic

Top: Rendering of Prototype 01

Case Study 3. Lamborghini Road Monument: Fibrous Tectonic

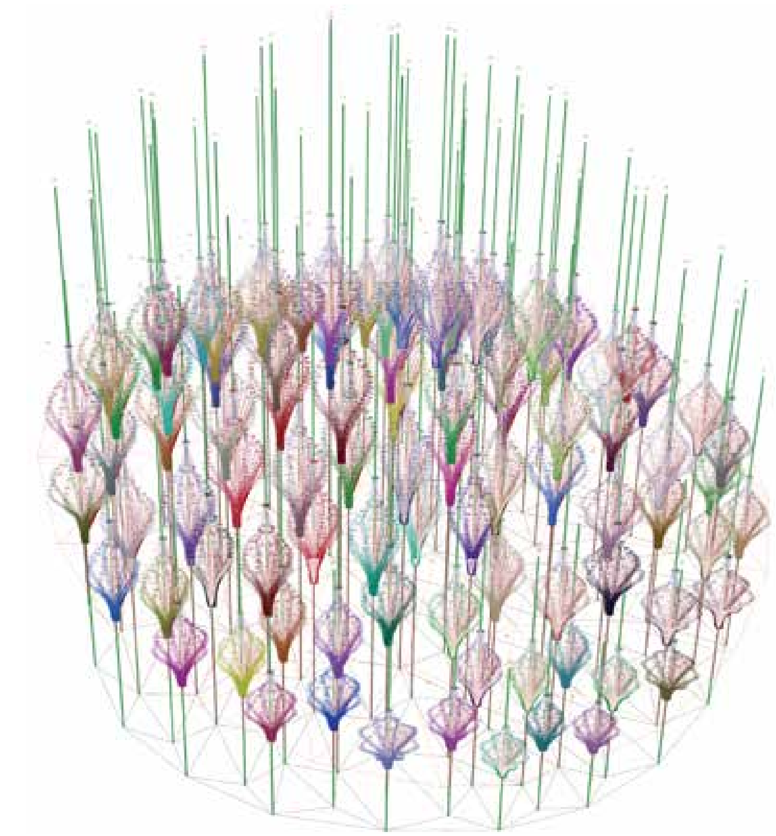
Designed by digital computation techniques, the pod assemblies are fabricated by weaving carbon and glass fiber threads around a reusable form-work made of bending-active carbon-fiber rods. The form-work can be adjusted into an unlimited variety of shapes and lengths providing for an extremely simple and efficient fabrication process. Construction is also optimized as the prefabricated assemblies can be brought to site as groups and quickly installed into the pre-constructed foundation with minimal labor.

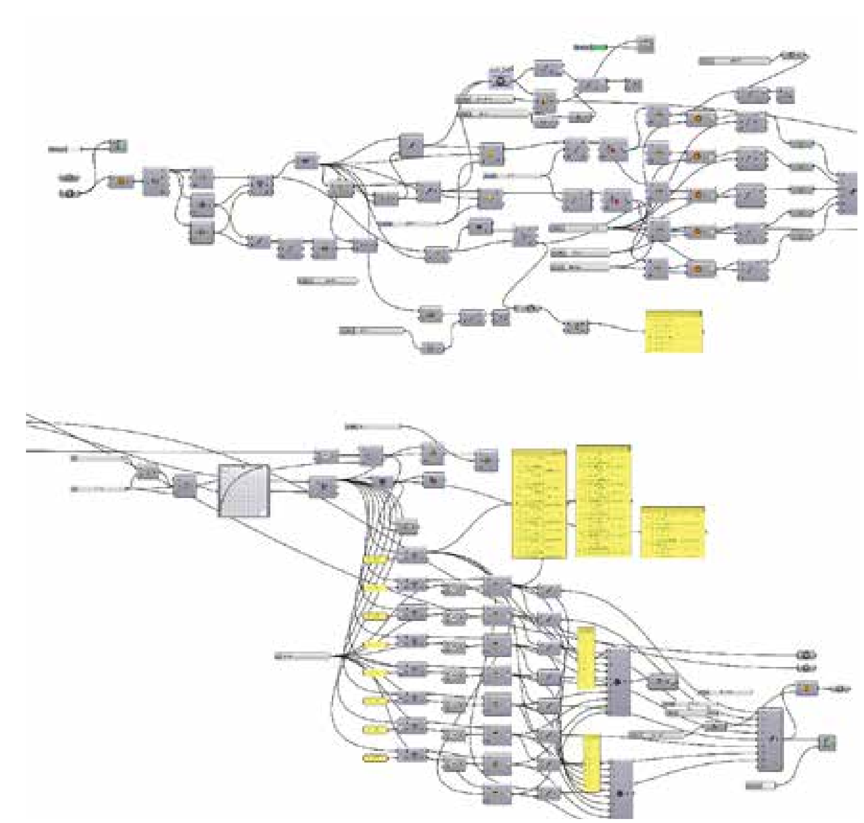
All values from physic simulation based computational modeling allow not only complex formal logic, but also give a full access of all different individual pieces for the making process through the automatically generated syntax.

As a preliminary study of digital crafting, The bending active carbon-fiber rods as a form-work are engineered to accommodate various heights and widths through the material property. Even though proposal consists of many different size and shape of pods, the system of elastic form work will adopts the variations of proposal.

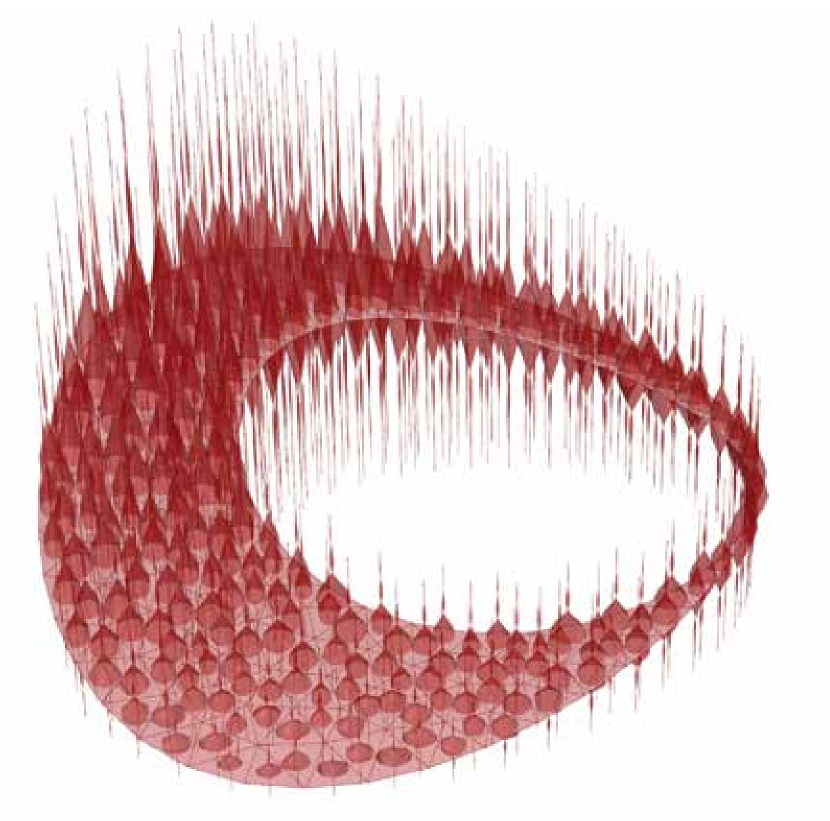
The charts fully demonstrate the lengths for the center rod and elastic form-work for pods. The combination of linear dimension based fabrication and computation modeling set is the innovation in design and construction of the proposal as Lamborghini's challenge for the endless advancement.

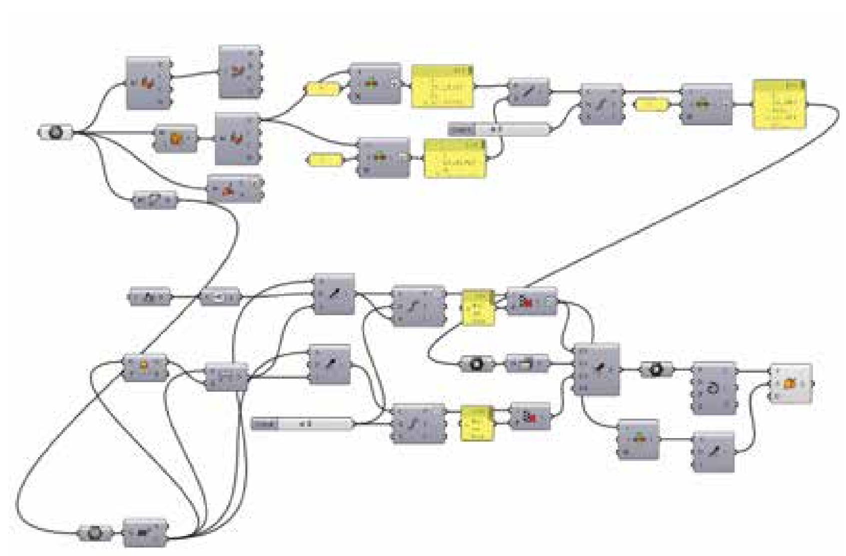
Top: 3D model represented all information
Bottom: Code for form generation of winding syntax



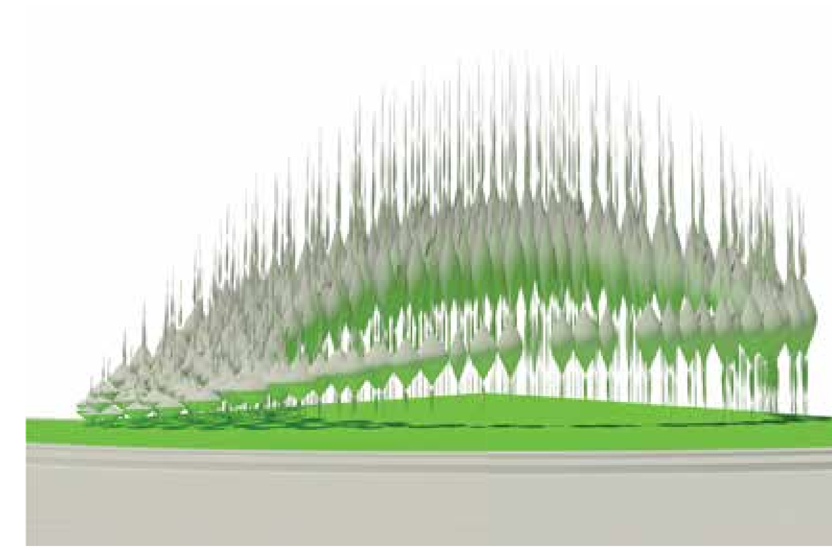


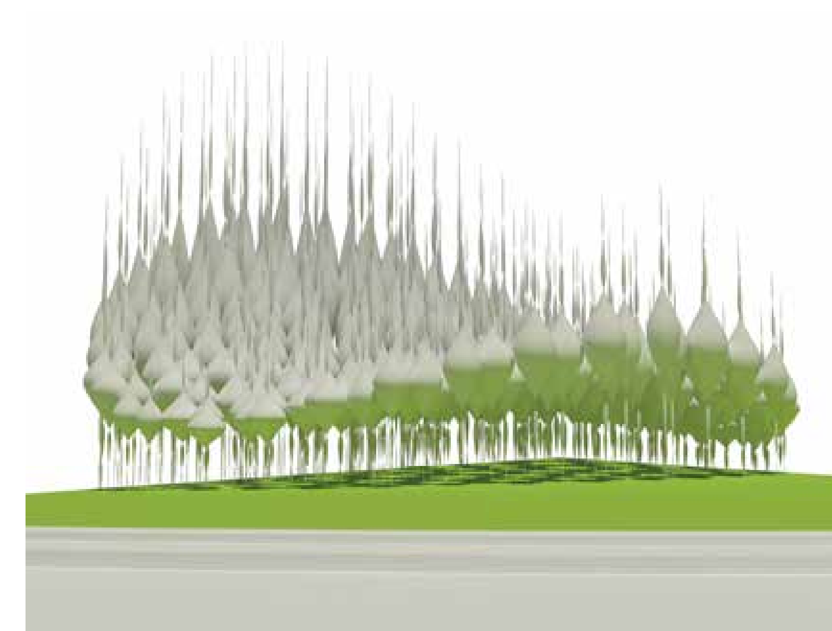
Top: Visualization of preliminary geometry
Bottom: Syntax of initial morphology



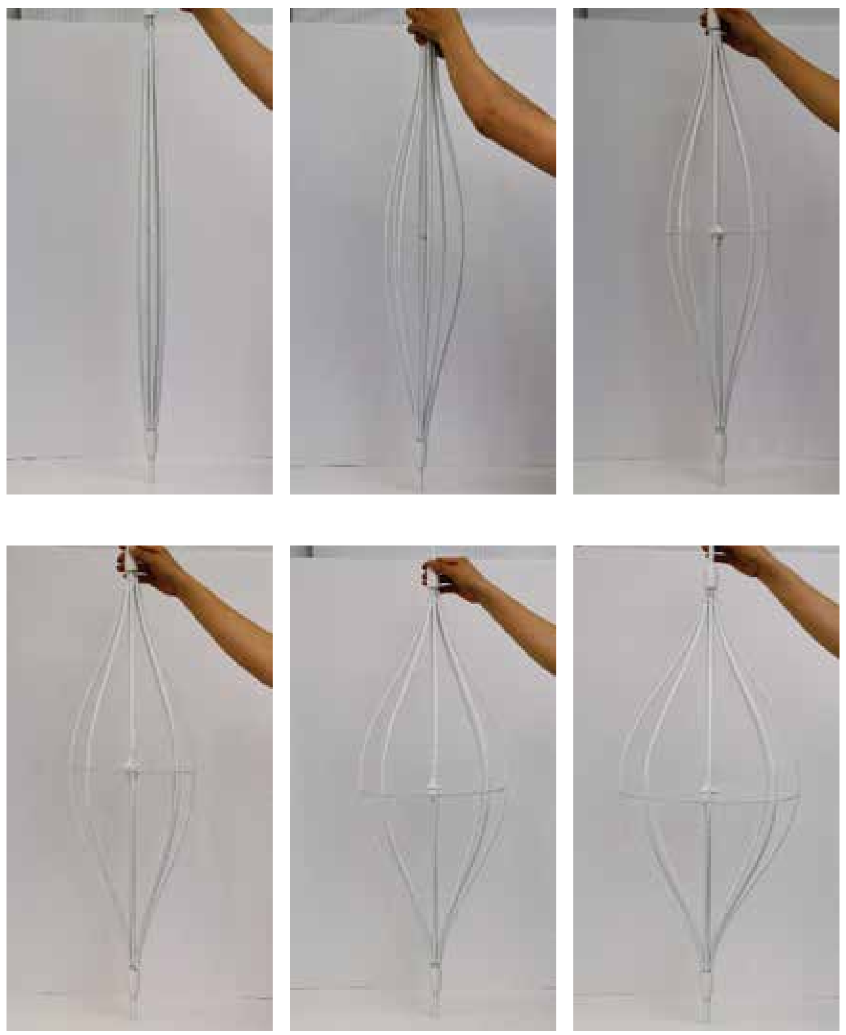


Top: Rendering of prototype 01 (Donut)
Bottom: Rendering of prototype 02 (Disk)

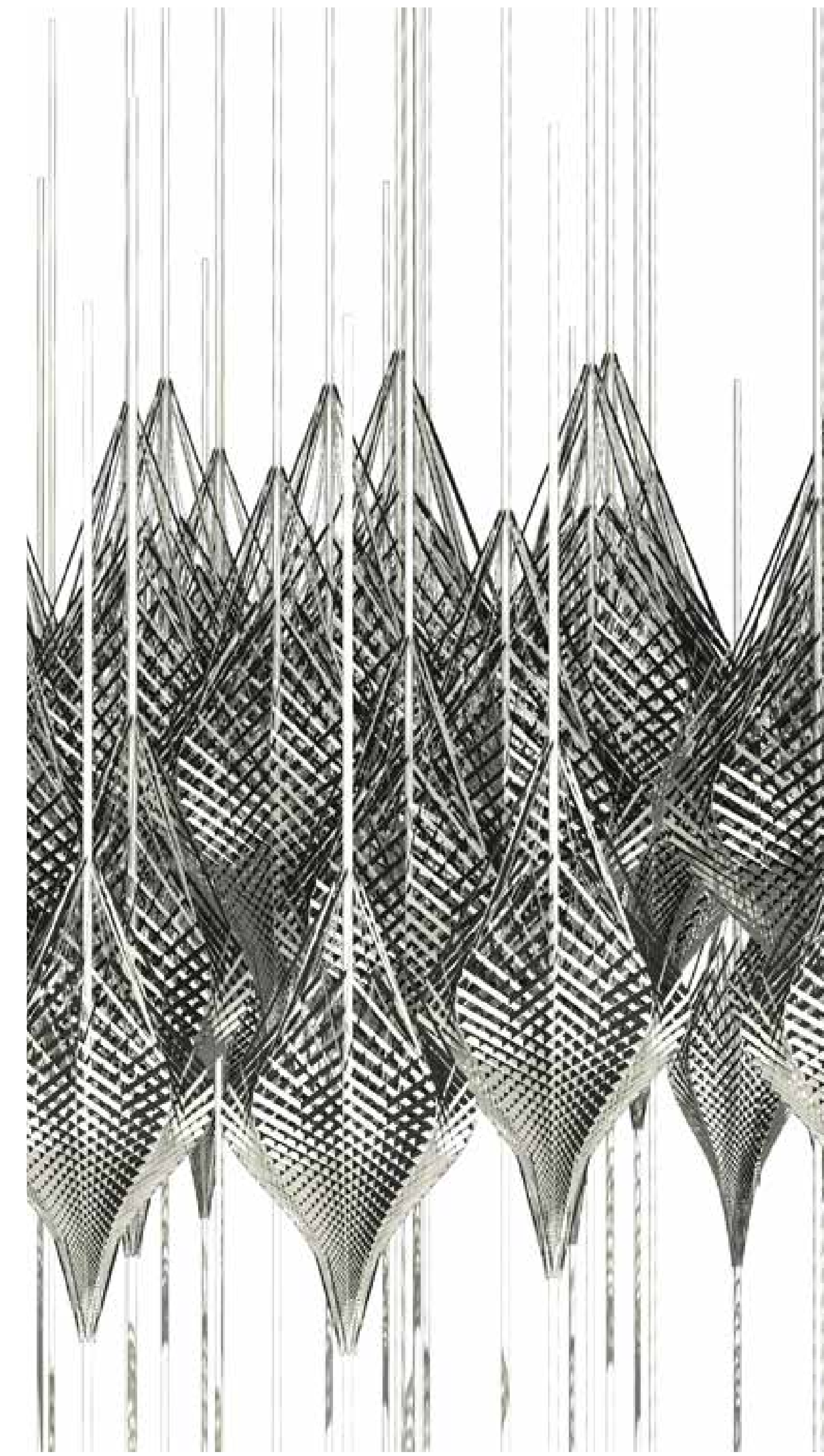




Material computation of elastic form-work : Glass-Fiber rods and plastic pellet holders

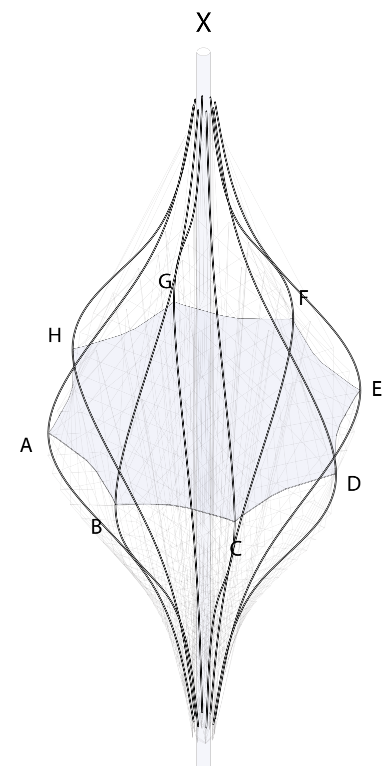


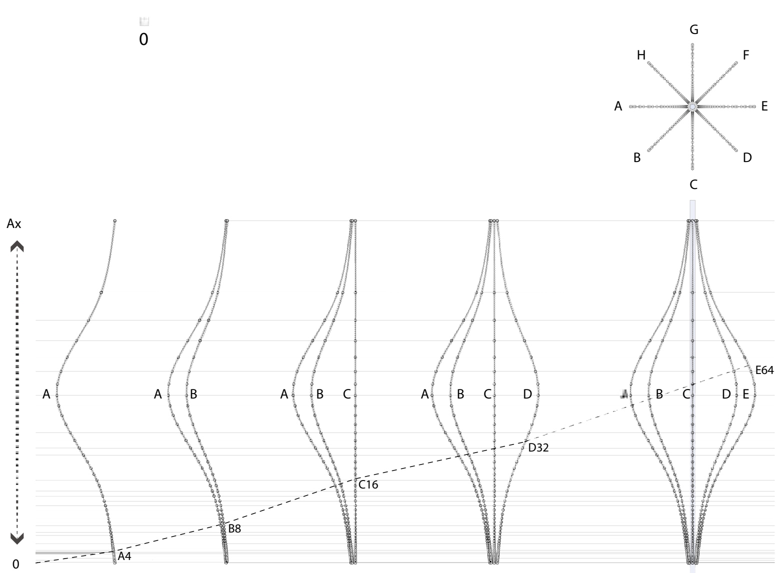
Detail of computation winding Model



Top left: Elastic form-work with pellet holder
Top right: Winding syntax form-work
Bottom: Sequence of Syntax

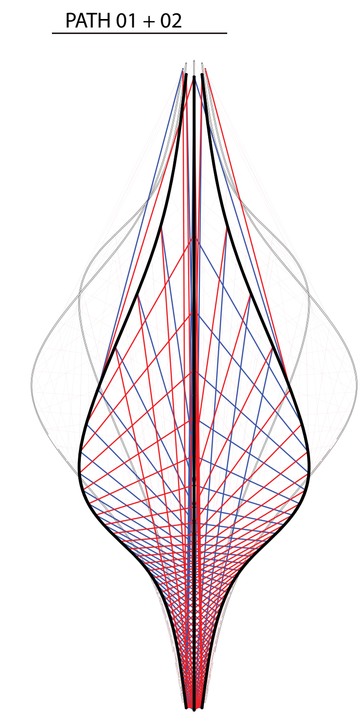
The winding syntax in physical state requires incremental holders for the each carbon-fiber and glass-fiber to be captured. The series of beads on the elastic rods allow to hold each filaments following syntax.

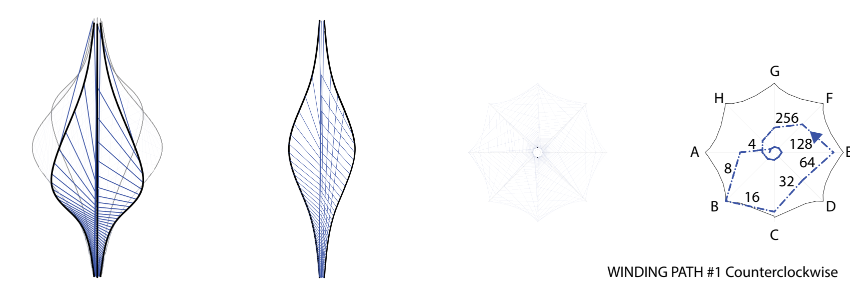


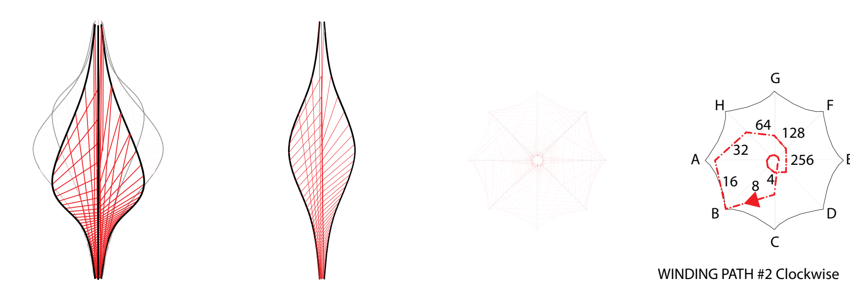


Top left: Combination of two winding path visualization
Top right: fiber arrangement detail
Bottom: winding path visualization

Resin applied fiber displacement strategy is two winding syntax cross each other and create intersecting paraboloid surfaces. The overlay of the simple layout of syntax generate the complex volumetric geometry.

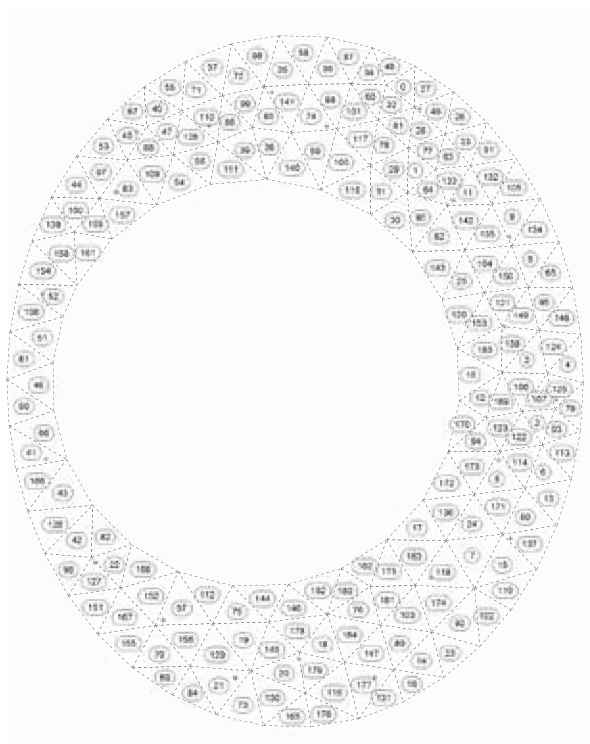


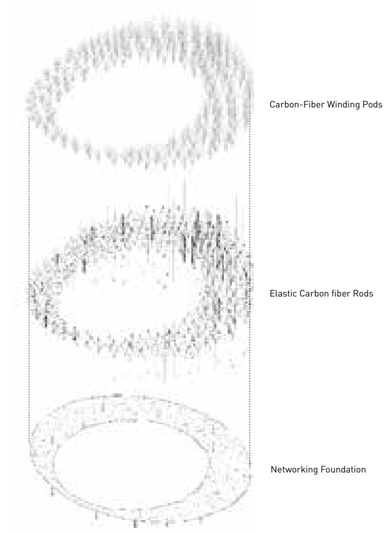




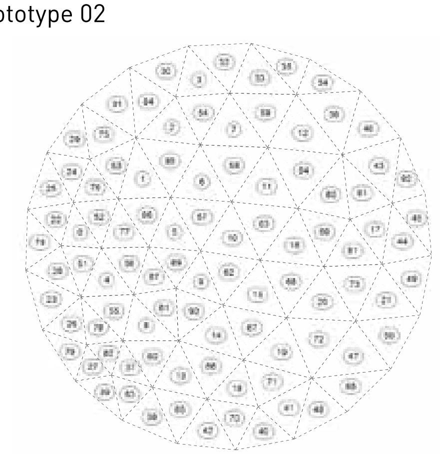
Left: Elastic form-work through material computation computing material
Right: Exploded axonometic view

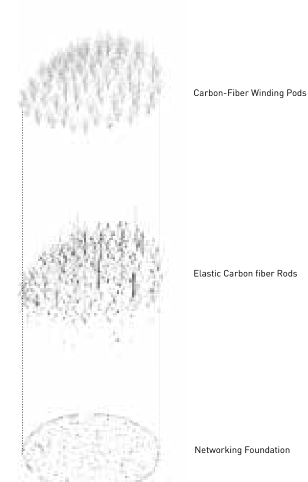
Prototype 01



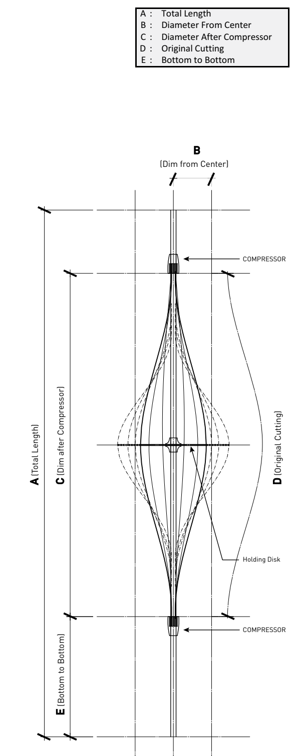


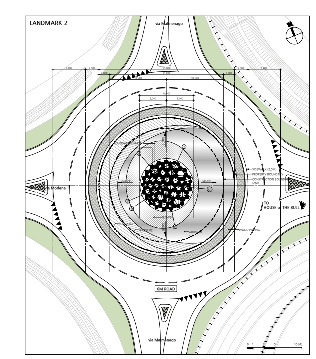
Prototype 02

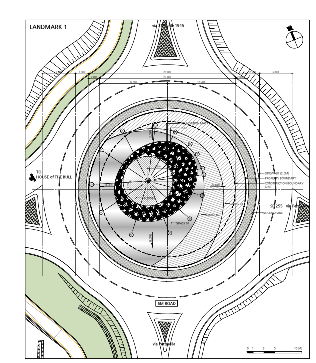




Top left: Dimension Reference of elastic formwork
Bottom left: Site plans for prototype 01, 02
Right: Dimention charts for prototype 01, 02





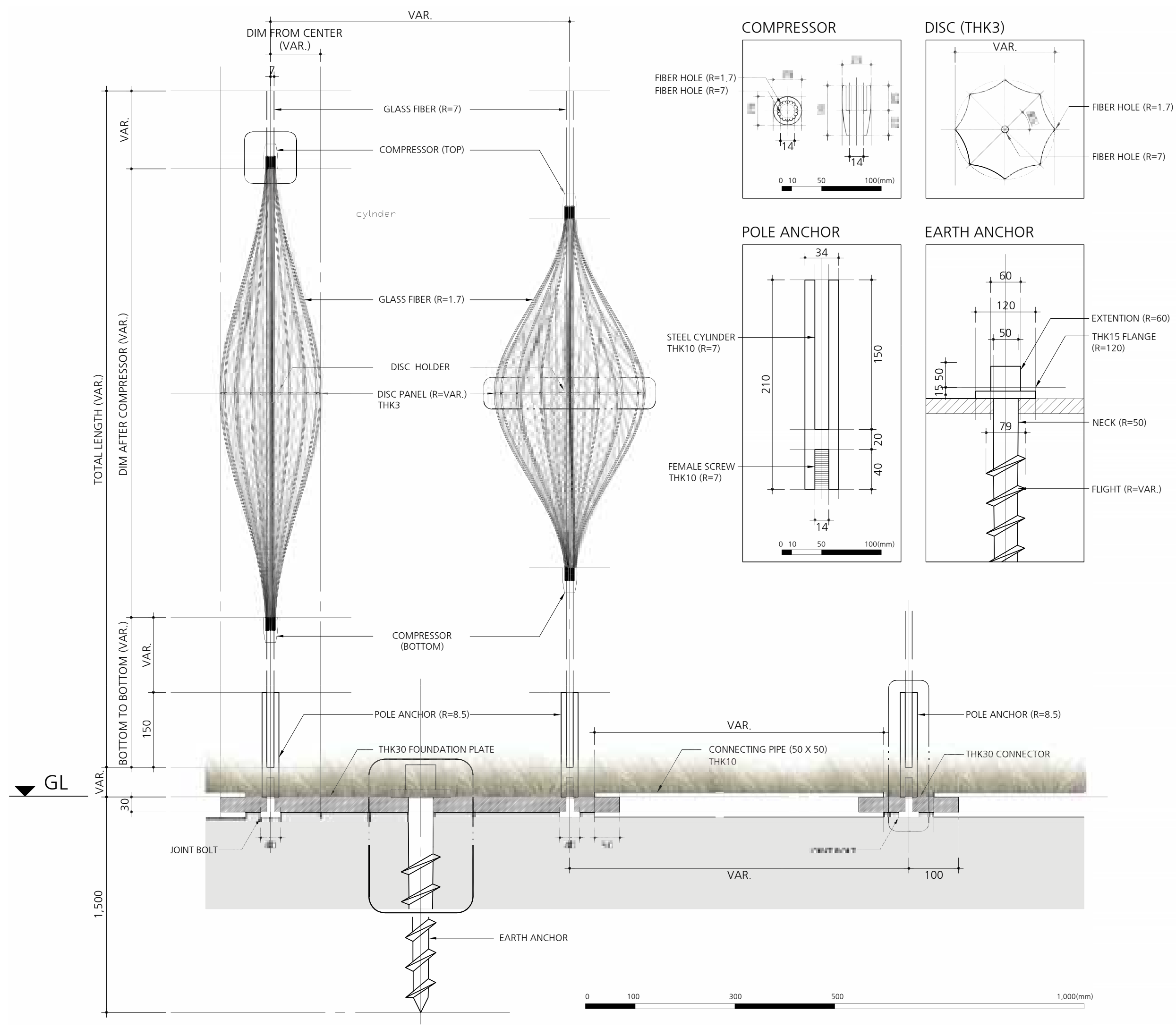


	A	B	C	D	E
95	7.272	0.288	2.181	2.263	2.545
96	7.546	0.306	2.264	2.356	2.641
97	4.644	0.314	1.393	1.543	1.625
98	2.469	0.324	0.741	0.993	0.864
99	2.256	0.342	0.677	0.971	0.790
100	2.640	0.286	0.792	0.979	0.924
101	4.081	0.359	1.224	1.448	1.428
102	3.757	0.295	1.127	1.281	1.315
103	7.665	0.312	2.299	2.395	2.683
104	6.739	0.342	2.022	2.156	2.359
105	6.500	0.324	1.950	2.071	2.275
106	6.399	0.321	1.920	2.040	2.240
107	7.625	0.297	2.287	2.371	2.669
108	7.945	0.238	2.383	2.429	2.781
109	3.397	0.352	1.019	1.261	1.189
110	2.697	0.338	0.809	1.069	0.944
111	2.494	0.304	0.748	0.969	0.873
112	3.143	0.336	0.943	1.175	1.100
113	5.181	0.338	1.554	1.717	1.813
114	8.430	0.292	2.529	2.602	2.951
115	7.860	0.297	2.358	2.440	2.751
116	6.034	0.370	1.810	1.988	2.112
117	4.436	0.350	1.331	1.529	1.552
118	4.054	0.300	1.216	1.366	1.419
119	7.109	0.376	2.133	2.294	2.488
120	7.875	0.301	2.362	2.447	2.756
121	6.450	0.321	1.935	2.054	2.257
122	6.974	0.279	2.092	2.170	2.441
123	7.792	0.280	2.338	2.408	2.727
124	7.486	0.252	2.246	2.301	2.620
125	7.899	0.295	2.370	2.450	2.765
126	8.185	0.246	2.456	2.503	2.865
127	4.501	0.373	1.350	1.577	1.575
128	4.708	0.305	1.412	1.550	1.648
129	2.591	0.306	0.777	0.995	0.907
130	5.230	0.370	1.569	1.768	1.830
131	5.567	0.372	1.670	1.862	1.948
132	6.521	0.263	1.956	2.027	2.282
133	5.980	0.310	1.794	1.911	2.093
134	5.458	0.252	1.638	1.713	1.910
135	7.004	0.324	2.101	2.215	2.451
136	6.359	0.320	1.908	2.027	2.226
137	7.030	0.332	2.109	2.229	2.461
138	8.174	0.334	2.452	2.559	2.861
139	7.295	0.282	2.188	2.265	2.553
140	2.784	0.294	0.835	1.026	0.975
141	3.638	0.371	1.091	1.351	1.273

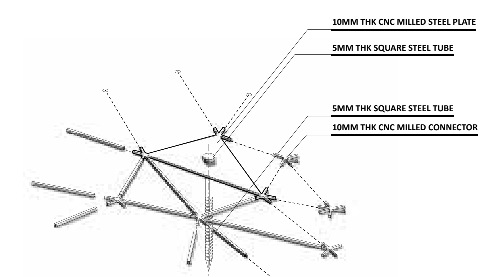
	A	B	C	D	E
142	2.976	0.322	0.893	1.113	1.042
143	5.962	0.317	1.789	1.912	2.087
144	5.943	0.360	1.783	1.952	2.080
145	5.506	0.323	1.652	1.791	1.927
146	5.576	0.324	1.673	1.811	1.951
147	5.711	0.316	1.713	1.841	1.999
148	6.401	0.330	1.920	2.049	2.240
149	7.929	0.308	2.379	2.468	2.775
150	7.302	0.276	2.191	2.263	2.556
151	6.893	0.307	2.068	2.168	2.412
152	4.757	0.342	1.427	1.606	1.665
153	4.906	0.376	1.472	1.688	1.717
154	6.815	0.294	2.044	2.135	2.385
155	3.116	0.353	0.935	1.193	1.091
156	4.896	0.339	1.469	1.640	1.714
157	5.095	0.353	1.529	1.711	1.783
158	2.925	0.333	0.878	1.116	1.024
159	3.013	0.332	0.904	1.136	1.054
160	2.905	0.272	0.871	1.026	1.017
161	2.725	0.291	0.817	1.007	0.954
162	3.082	0.307	0.925	1.119	1.079
163	6.269	0.278	1.881	1.966	2.194
164	6.764	0.370	2.029	2.192	2.367
165	6.193	0.349	1.858	2.009	2.168
166	5.723	0.280	1.717	1.811	2.003
167	4.318	0.328	1.295	1.470	1.511
168	4.843	0.357	1.453	1.647	1.695
169	4.824	0.344	1.447	1.626	1.688
170	7.427	0.274	2.228	2.298	2.599
171	7.021	0.267	2.106	2.175	2.457
172	7.679	0.334	2.304	2.416	2.688
173	6.994	0.343	2.098	2.229	2.448
174	7.257	0.334	2.177	2.296	2.540
175	7.046	0.369	2.114	2.269	2.466
176	6.523	0.325	1.957	2.079	2.283
177	5.901	0.271	1.770	1.854	2.065
178	6.311	0.371	1.893	2.066	2.209
179	5.753	0.314	1.726	1.851	2.014
180	5.875	0.299	1.762	1.871	2.056
181	6.150	0.275	1.845	1.929	2.152
182	6.511	0.293	1.953	2.047	2.279
183	5.914	0.338	1.774	1.920	2.070
184	6.992	0.324	2.098	2.211	2.447

	A	B	C	D	E
1	4.558	0.277	1.367	1.479	1.595
2	6.539	0.386	1.962	2.145	2.288
3	6.952	0.374	2.086	2.248	2.433
4	6.731	0.361	2.019	2.173	2.356
5	4.755	0.332	1.427	1.594	1.664
6	6.909	0.357	2.073	2.218	2.418
7	7.589	0.410	2.277	2.464	2.656
8	7.564	0.426	2.269	2.474	2.647
9	4.891	0.336	1.467	1.635	1.712
10	6.783	0.317	2.035	2.146	2.374
11	7.685	0.405	2.306	2.485	2.690
12	7.975	0.450	2.393	2.615	2.791
13	7.213	0.446	2.164	2.400	2.524
14	4.463	0.353	1.339	1.540	1.562
15	6.035	0.379	1.811	1.998	2.112
16	7.172	0.406	2.152	2.343	2.510
17	7.695	0.428	2.309	2.514	2.693
18	6.437	0.325	1.931	2.055	2.253
19	4.994	0.319	1.498	1.644	1.748
20	6.114	0.416	1.834	2.064	2.140
21	6.836	0.422	2.051	2.269	2.393
22	5.712	0.394	1.714	1.928	1.999
23	3.984	0.285	1.195	1.330	1.394
24	2.801	0.347	0.840	1.108	0.980
25	4.751	0.293	1.425	1.549	1.663
26	4.033	0.327	1.210	1.393	1.412
27	2.966	0.290	0.890	1.066	1.038
28	2.692	0.231	0.808	0.922	0.942
29	3.463	0.309	1.039	1.220	1.212
30	4.807	0.318	1.442	1.592	1.682
31	6.260	0.360	1.878	2.040	2.191
32	5.679	0.409	1.704	1.937	1.988
33	6.473	0.381	1.942	2.122	2.266
34	6.689	0.399	2.007	2.201	2.341
35	5.784	0.284	1.735	1.832	2.025
36	6.093	0.300	1.828	1.934	2.132
37	6.204	0.411	1.861	2.082	2.171
38	3.589	0.252	1.077	1.186	1.256
39	2.913	0.327	0.874	1.105	1.019
40	2.464	0.258	0.739	0.896	0.863
41	4.137	0.319	1.241	1.411	1.448
42	4.745	0.350	1.424	1.612	1.661
43	3.559	0.353	1.068	1.305	1.246
44	5.790	0.390	1.737	1.944	2.026
45	5.599	0.354	1.680	1.850	1.960
46	5.036	0.278	1.511	1.614	1.762
47	5.360	0.367	1.608	1.799	1.876

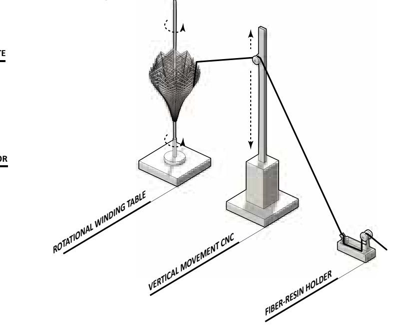
	A	B	C	D	E
48	5.444	0.428	1.633	1.899	1.905
49	4.651	0.345	1.395	1.582	1.628
50	5.090	0.344	1.527	1.699	1.782
51	5.020	0.380	1.506	1.723	1.757
52	4.300	0.291	1.290	1.422	1.505
53	5.275	0.311	1.582	1.713	1.846
54	5.899	0.333	1.770	1.910	2.065
55	7.190	0.367	2.157	2.308	2.517
56	4.431	0.321	1.329	1.493	1.551
57	5.582	0.318	1.675	1.806	1.954
58	7.496	0.396	2.249	2.423	2.624
59	7.855	0.443	2.356	2.574	2.749
60	7.312	0.418	2.194	2.395	2.559
61	4.376	0.336	1.313	1.496	1.532
62	5.698	0.311	1.709	1.832	1.994
63	7.290	0.390	2.187	2.359	2.552
64	7.918	0.440	2.375	2.588	2.771
65	7.615	0.462	2.284	2.529	2.665
66	3.683	0.351	1.105	1.333	1.289
67	5.197	0.384	1.559	1.776	1.819
68	6.518	0.395	1.955	2.149	2.281
69	7.341	0.421	2.202	2.407	2.570
70	7.459	0.369	2.238	2.386	2.610
71	4.263	0.328	1.279	1.456	1.492
72	5.358	0.366	1.607	1.797	1.875
73	6.227	0.445	1.868	2.130	2.179
74	6.582	0.394	1.975	2.166	2.304
75	3.297	0.297	0.989	1.161	1.154
76	5.571	0.344	1.671	1.831	1.950
77	5.343	0.292	1.603	1.714	1.870
78	5.805	0.326	1.741	1.877	2.032
79	3.597	0.265	1.079	1.202	1.259
80	2.404	0.268	0.721	0.894	0.842
81	7.332	0.397	2.200	2.378	2.566
82	6.926	0.360	2.078	2.226	2.424
83	3.366	0.224	1.010	1.097	1.178
84	3.024	0.269	0.907	1.054	1.059
85	6.373	0.379	1.912	2.092	2.231
86	7.109	0.420	2.133	2.341	2.488
87	6.500	0.349	1.950	2.095	2.275
88	5.977	0.296	1.793	1.897	2.092
89	4.760	0.348	1.428	1.614	1.666
90	6.623	0.308	1.987	2.092	2.318
91	6.202	0.329	1.861	1.992	2.171
92	6.635	0.349	1.990	2.134	2.322
93	5.035	0.277	1.511	1.613	1.762



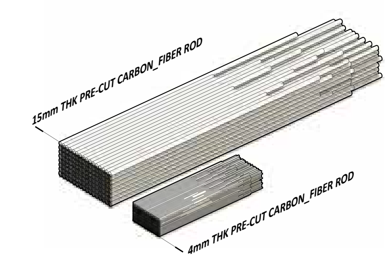
Anchor Mechanism of Foundation Mat



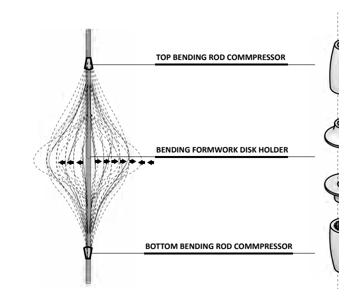
Winding Mechanism



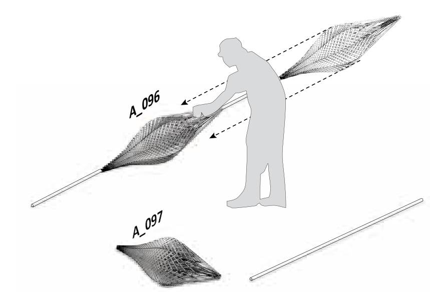
Pre-Cut center-pole & Elastic Form-work



Elastic Form-work



Assembly of Pods on the center poles



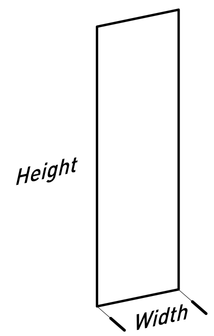
Installation on Site

CASE STUDY 4

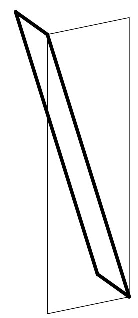
NEXEN R&D Center Bespoke Fiber Structure

Geometry Definition based on Solar Radiation and View

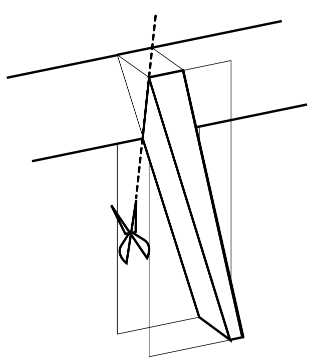
Case Studies 4. NEXEN R&D Center Bespoke Fiber Structure



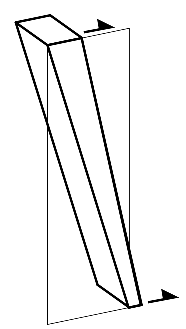
Identify Curtain wall module



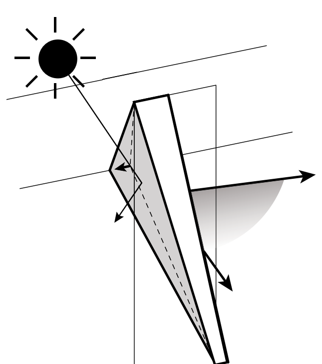
Identify window module



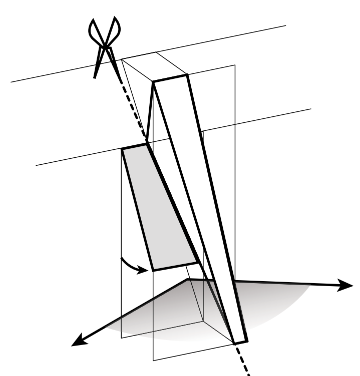
Optimization of Geometry vs Function



Volumetric Extrusion

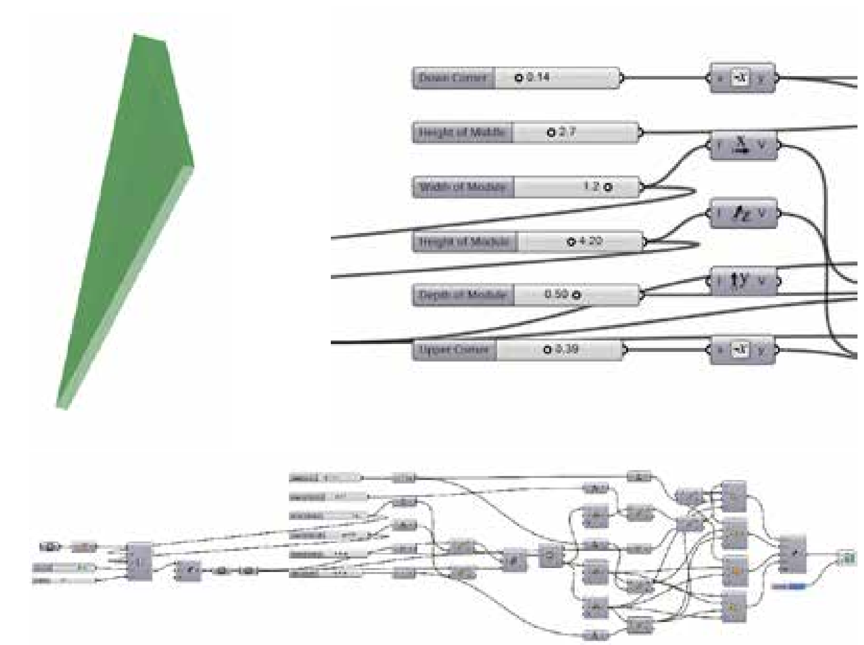


Optimize Shading Performance + Views



Optimization of Geometry vs Code

Top: Fin geometry Parametric Setting
Bottom: Development of geometry of fin



Result & Limitation

/ Conclusion

Result / Limitation

1. Environmental form finding

H Architecture has developed case studies which allow designers to estimate energy consumption in early design phases. Today 80% of the energy savings in a building is dictated by the first 20% of the office work, which means in the sketching phase. There were no tools that provide quick feedback on the energy consequences, which means it is taken into account much later in the design stage where it is often too late or very costly to change. However, the development of environmental analysis tools such as Diva, Ladybug, and Honeybee, allows the case studies to examine could be used to estimate environmental aspects in the early design phase.

2. Energy simulation today

Today energy simulation is done by using external programs (such as BSIM, Be06, Ecotect and Energy Plus). These programs are complex and data intensive, and require the exchange of detailed 3D models. This makes them hard to use in the early design phase which consists of many open questions and quick process of design change during design development. Therefore, the use of energy simulations is mostly used in later phase where the building design is more or less confirmative. This usually means that the design cannot benefit from possible energy - form optimizations.

3. A green game for architects

The project investigates how parametric tools would be used to work with environmental aspects in the earlier design phase. Through the development process, the projects ahve been developed with with aspects from the gaming industry, resulting in an interactive three-dimensional game that gives designers immediate energy feedback. The goal for the case studies has been set to create a sketching tool suiting in the architectural workflow and integrated into the existing drawing applications. The CAD drawing applications are currently used through all the design phases (from competition to the design stage) and therefore it is important to develop the tools on that platform. The tool has been used by the competition team where it has been used to optimize the overall building design or facade system in relation to the solar radiation and direction of view.

4. Method

The tool is developed in a parametric free-ware plug-in (Grasshopper) in the 3D drawing application Rhino. Rhino is an integrated tool in most offices, and a recognized tool in the architectural industry. The parametric tool makes it possible (through code) to relate the specific energy data to the subscribed geometry in a 3D program. Hereby it gives a quick feedback (in terms of colors / numbers / values) where the geometry can be altered until the desired outcome is achieved. It means that simulation and modification of the basic building geometry could be done simultaneously and not through file exchange between multiple applications. However, the limitation of time frame in competition phase and less support from environmental analysis team have tackled further development of the theory. The broaden perspective on environmental parametric of entire teams between H Architecture and Haeahn architecture is necessary for a lager goal in performative building and system in advance.

Conclusion

The computation design in environmental parametric plays a significant role in design process. The vision of H Architecture is the informative architecture for design innovation. The list below is key ideas for potential contribution to the field reflection on future development. The first volume represents the focus on environmental section. The following research will incorporate more advanced computational analysis and application with design process. For the further development of this design method, the list below are the key aspects for next steps.

1. Strategize
We will develop strategic initiatives focused on implementing a computational design within the central region. The research will reach new and emerging technologies related to data and computation to inform future initiatives. It will represent H Architecture in the global digital design community including research venues, marketing events, and conferences.

2. Create
We will work with H Architecture's design team needs to to identify project opportunities for implementing new work-flows. H Architecture will create new computational design tools and work-flows for use of project teams and collaborate with spatial analysis team for the competition phase to integrate data-driven planning concepts into the design work flow.

3. Educate
The following research will define knowledge expectations for current and future design team members. H Architecture will deliver project-focused workshops and brainstorming sessions for implementing computational design concepts.

Computational design tools provide an easier way to harness the power of computation in a design process without having to learn how to write code. These tools let architects and designers create their own tools. Let's face it, each project H Architecture has been working on is unique with its own challenges. There is no one piece of software that can do everything architects need it to. However, by creating our own tools, we can tailor our software to work for us.

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