PARAMETRIC ARCHITECTURE

TOTAL FLUIDITY

THESIS REPORT SUBMITTED TO FACULTY OF ARCHITECTURE, MANIPAL UNIVERSITY

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I would also like to thank my committee members, Professor Nandineni Rama Devi, Professor Nancy and Professor Kala C M K for their guidance on this report.

Finally I would like to acknowledge and dedicate this report to my family, especially to my parents for their continuous support and motivation.

CONTENTS

1. INTRODUCTION

1.1 Parametric Architecture

Parametric architecture is a new and evolved style of architecture. Its computer and technology aided design which is used as a tool for various design projects. It is defined by parameters which are set by the designer be it in form of a small scale project or a major urban scale design. It is a form of computer aided design (CAD) which helps designers in optimising and improving their designs. Over the years various design interfaces have been developed to revolutionise parametric modelling and allowing freedom in design.

Italian Architect Luigi Moretti was one of the first architects to work on parametric architecture by using mathematics to create new shapes. In 1957 he founded the Institute for Operations Research and Applied Mathematics (IRMOU) in order to find parametric modelling for new form generation by using mathematical theories in design.

The design develops according to the set parameters. The final form is a result of the parameters selected for the design process. The range of parameters can vary from natural environment dealing with a building or the software aiding in designing a structure.

Parametric designing allows easier three-dimensional modelling and gives the freedom of modifying the design at any stage of design depending on the convenience of the designer. During the process of design, one may need to change certain things used in the earlier stages of the design process. Changing the previous steps manually and then modifying the design according to the changed steps can be time consuming. Parametric modelling using algorithms can simplify, and make this process faster without compromising on the quality of the design.

In Parametric architecture, as defined by Architect Patrik Schumacher, *order is not achieved by repetition but by using similar elements in design*. This gives a building a very unique and interesting form. Such unique elements can be easily computed using parametric tools for design. Parametric Architecture is being used for form finding in many aspects of architecture. Various parameters help the designers to find interesting forms in architecture with the help of technology.

In the present scenario where fast construction is a necessity, parametric architecture has helped solved this problem by giving data required for analysis and construction. Parametric Architecture has broadened the scope of form finding in architecture, allowing construction of complicated structures with ease. (Schumacher, Parametricism as Style - Parametricist Manifesto, 2008)

The introduction of the term '*Fluid*' in the definition of architecture, which still seems to be helplessly clinging to an old fashioned notion of techtonics both in functional and economic terms, is new and innovative. Buildings today no longer be viewed as being merely the visible three dimensional result of a linear solution - seeking process. In our increasingly complex society, solutions as difficult they are to find, are what we should aim at. Method involves a consistent form-to- program heuristics, i.e. form-selects-function instead of function-selects-form. Development of project thus extensively relies on post-rationalization. The projects oscillate between play and analysis and aim at elaborating new form-function relations.

The prevalent institution and communication patterns of society have undergone increased changes during the last 30 years. Social communication has become dynamic, differentiated and intensified. Accordingly, modernist urbanism (Zoning) and modernist architecture (Serial Monotony) have experienced a fatal crisis. To inherit limitations of the linear models of expansion that characterized faradism became apparent both in terms of the ecological, the socio-economic as well as the urban crisis of the 1970s. Even while the use of internet and mobile devices has increased, the demand for face-to-face communications - mediated by architectural and urban spaces has increased as well.

Hence for my research, I have decided to consider *Fluidity* as a parameter in the building construction in India. The main idea is to understand how a building, in simple terms behave like fluids. What are the elements that can be modified or manipulated to achieve a free flowing behaviour and how this behaviour can affect the building typology and built environment. Parametric architecture helps a designer to manipulate spaces or forms in ways which are difficult to imagine visually. And as it is the age of contemporary and digitalised architecture, the change from linear models to experimental and innovative forms and expressions is inevitable. By using a parametric approach, I believe that I can have a thorough understanding of the parameter and in the future can implement this concept.

1.2 Definition of the terms

Parametric Design- It is a tool used for designing structures and building elements based on certain parameters, chosen by the designer, with the help of Computer Aided Design Technology.

Fluidity - Appearance of a building to be flowing or the flow of people inside a building similar to a fluid.

Computer Aided Design (CAD)- It is the technology which simplifies and assists a designer in modifying, analysing, optimising or presenting a design.

(Schumacher, Parametricism - A New Global Style for Architecture and Urban Design, 2008)

1.3 Research statement

Manipulation and modification of different forms and spaces to behave and appear similar to that of a fluid.

A building can either appear and function in the same way or it can appear and function in different ways. The ideal initiative in this case would be to adopt the opposite thinking i.e. function-follow-form instead of the traditional and rather common form-follows-function. To think of a building behaving in a liquid manner is not easy but with the use of parametric architecture, I believe that it can be achieved. To simplify the notion, parametric architecture consists of various parameters but in this case the parameter is fluidity.

1.4 Aim

The complexity of buildings varies with the site constraints and the purpose behind which the building was created. Parametric approach helps in bringing out solutions quickly. The main aim of the research is to observe and study how a building can be designed to be like free flowing liquids with the help of parametric design approach.

1.5 Objectives

1) To understand thoroughly the concept of fluidity.

2) To understand what is parametric architecture.

3) To study and understand how spaces and aesthetics behave with each other.

4) To understand how fluidity can be depicted in spaces and buildings.

5) To experiment and see how different spaces and forms can be manipulated.

6) To study how an architect or a designer implement this concept in his design (through what medium, e.g. software, computer aided design).

7) To understand how this concept is feasible in the current architectural scenario.

1.6 Focus of the study

The focus of my study would be to consider fluidity as a parameter and with the help of parametric design approach, design a podium of a high rise building to behave and appear like fluids.

1.7 Research questions

1) What medium(software) is used to work towards this concept ?

2) What can be done to the exterior elements like form, facades, etc. to appear like fluids ?

3) Can this concept be made practical ?

4) What materials can be used for this concept ?

5) Can this concept accommodate green spaces and sustainability measures ?

6) How do this concept contribute to the architectural world ?

1.8 Relevance of study

Time is constantly changing and so are the rules and relations in architecture. With new generations, new styles and ideas emerge. The world is going up day-by-day as new innovative ideas are implemented, new technology is getting discovered and most importantly people and their lifestyle constantly evolving. With new technology and new set of users, the need of evolution in architecture is inevitable. The shift from pre-historic to gothic to modern and finally to present day contemporary architecture is very prominent. Everyday there is a need for something new and different from the previous day. All in all humanity constantly seek ways (methods) to improve their living conditions and thus resulting in making a our world a better place to live in.

1.9 Methodology

- Understanding parametric architecture
- Usage of technology as a design tool
- Study of algorithm generation in grasshopper
- Creating different kinds of geometry and forms using grasshopper.
- Finally how to create fluid surfaces using grasshopper.

Case Studies

- Building typology for every building.
- Which element of the building resembles fluidity.
- How is the relation between form and function.
- What are the other parameters used with fluidity.
- Softwares used for designing the building.
- What materials are used to construct the building.
- Impact of the building.

- Generating algorithm and showing the history of form development.
- Showing of different algorithms of surface development.
- Creating different options of the podium to display different all concepts.
- Optimizing the design through accommodating daylighting, energy sustainability and weight reduction of the building.
- Creating a list of different materials that can be used to implement the design.
- Finally ending the design with an observation on different possibilities of built environment that can be created through the building.

2. LITERATURE STUDY

2.1 Parametric architecture

Parametric architecture is a vast topic and includes all the design areas such as urban design, interior design, street design, fashion design and even installation art.

2.2 Parametric design tool

Contemporary designers are working with various Algorithms as the model of computation to use it as a tool for their design challenges. An Algorithm is a set of rules and instructions in a step by step procedure to calculate, process data and do a defined task. For any form of data given as input, an algorithm will perform its predefined operations and calculate the required result. Similarly, a design algorithm will also provide a design output if being given relevant data as input. In conventional architectural design practice, there are different parameters like Site, Area Program, Building Type, Facilities, Beauty, Structure or even Bye Laws which should be considered while going through the process of design. In algorithmic processes it is attempted to transfer these parameters (input information) into algorithms to generate design solutions. What is currently known as Algorithmic, Parametric or Generative design software is the platform to do such design processes in computers via Computer Aided Design software.

Parametric designing is possible with the use of software which can take in data set by the designer and process it to form various shapes. Such flexibility in design in not possible through all design software. The most important software for parametric design is Grasshopper®, which is a plug-in of the 3D modelling software Rhinoceros. Grasshopper® is a visual programming language developed by David Rutten at Robert McNeel & Associates which was released in September 2007. Grasshopper® runs on 3D modelling software, Rhinoceros 3D, version 4.0 or higher.

Grasshopper helps in generating algorithms for parametric design and does not need the knowledge of programming or scripting, but still allows designers to build form generators. Grasshopper interface consists of a node based editor, which connects different components and passes on data via a connecting wire. The connecting wire join the output grip of one component to the input grip of another component. (Sasaki)

Grasshopper provides flexibility in design process in various ways-

- Procedure Automation

- Geometry definition through mathematical functions
- Parametric model generation which allows large and quick changes in the initial geometry of the model.
- Ability to quickly obtain complex shapes through geometrical elements.

3D modelling in Grasshopper in based on Algorithms, which allows the freedom of changing features of any design by modifying the data in any given parameter.

An algorithm is a sequence of steps which gives a result from various input data. Algorithms are based on logic and are made by humans and carried out by computers.

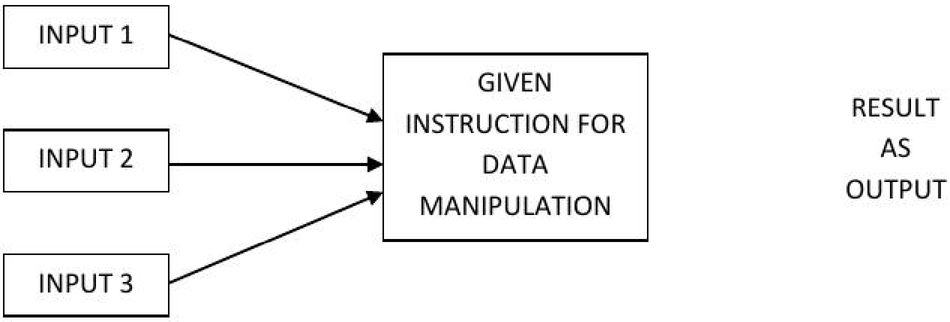


Fig. 2.a Basic illustration of an Algorithm

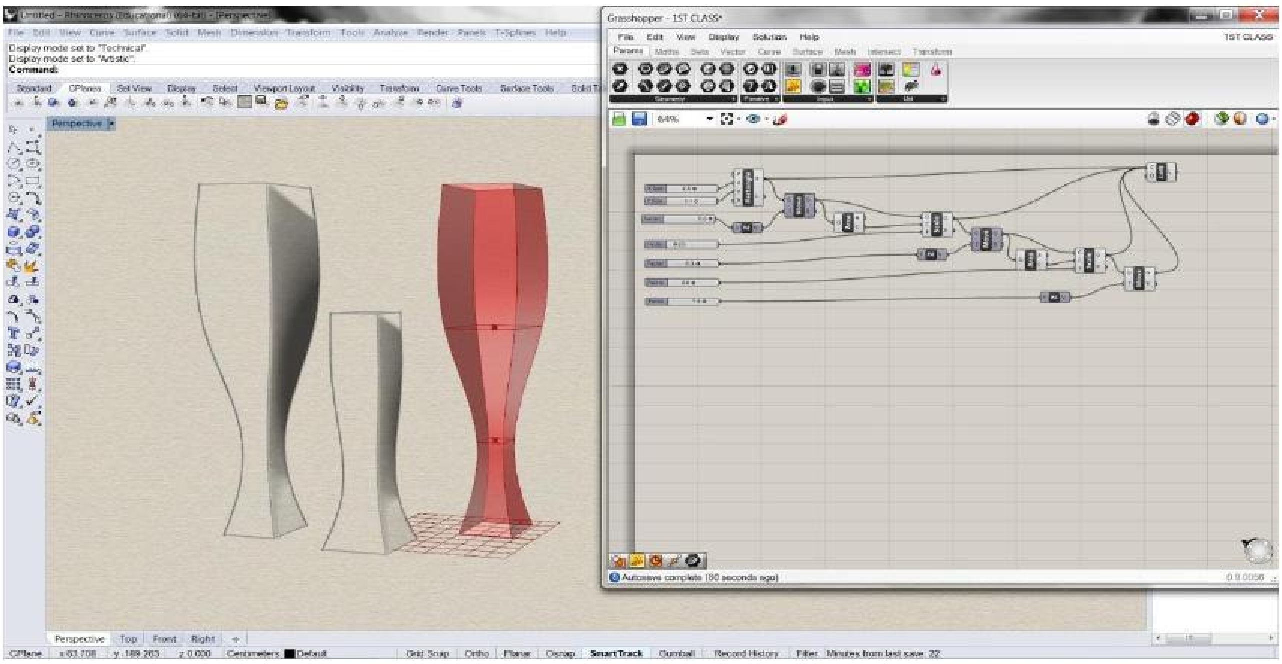


Fig. 2.b A Simple Algorithm

2.3 Basic understanding of a fluid surface

So the first step is to open Rhino modelling software and then in the command box type 'Grasshopper' and a command box opens.

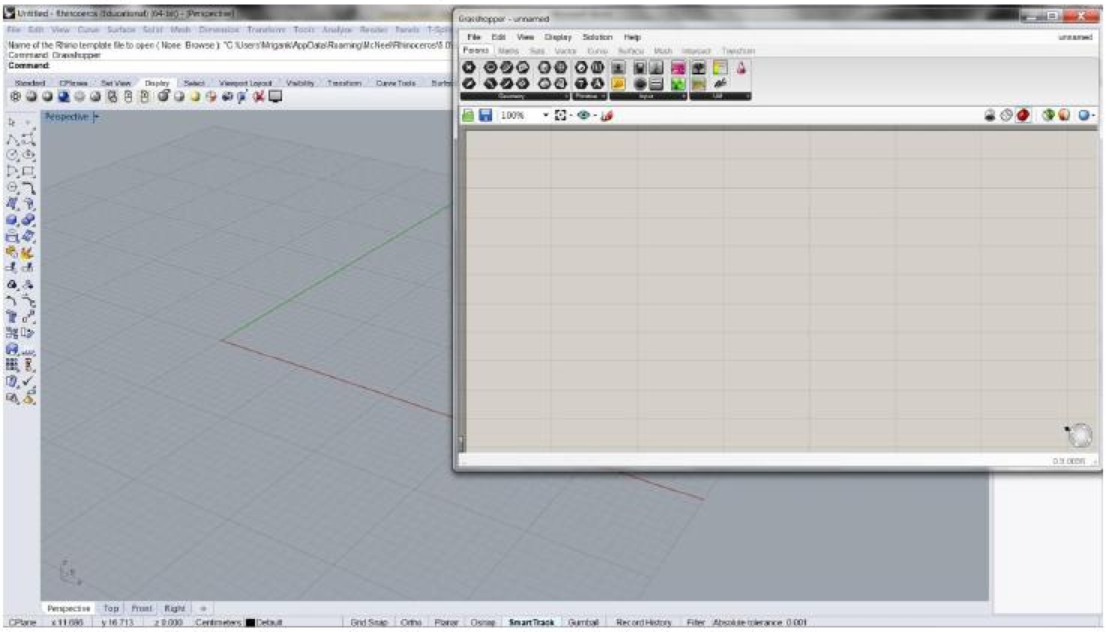


Fig. 2.c. The Grasshopper canvas

On the left background is the viewport in rhino and the right side box is the grasshopper plugin. On the top in the plugin, those are the different tools with which one can work and the grid in the bottom is called the canvas.

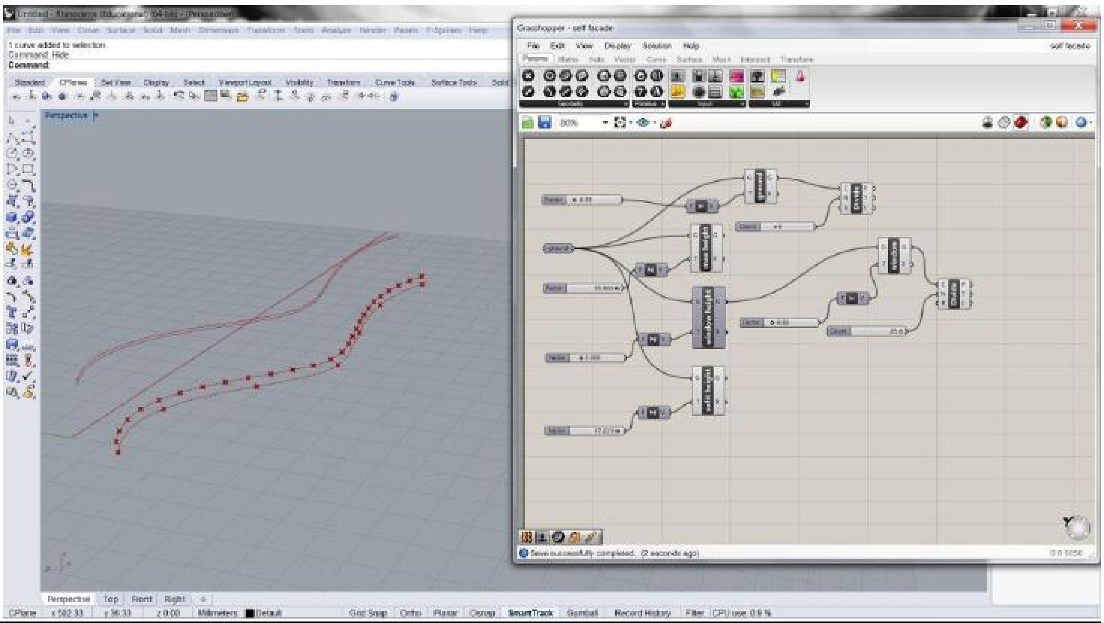


Fig. 2.d. Setting and dividing the curve

(Senske, www.youtube.com, 2011)

So this is the first algorithm in which a curve is made in rhino. Then using grasshopper, the curve can be copied on the z-axis using the 'Move' component. Then the curve can be divided using 'Divide curve' component to get a series of points.

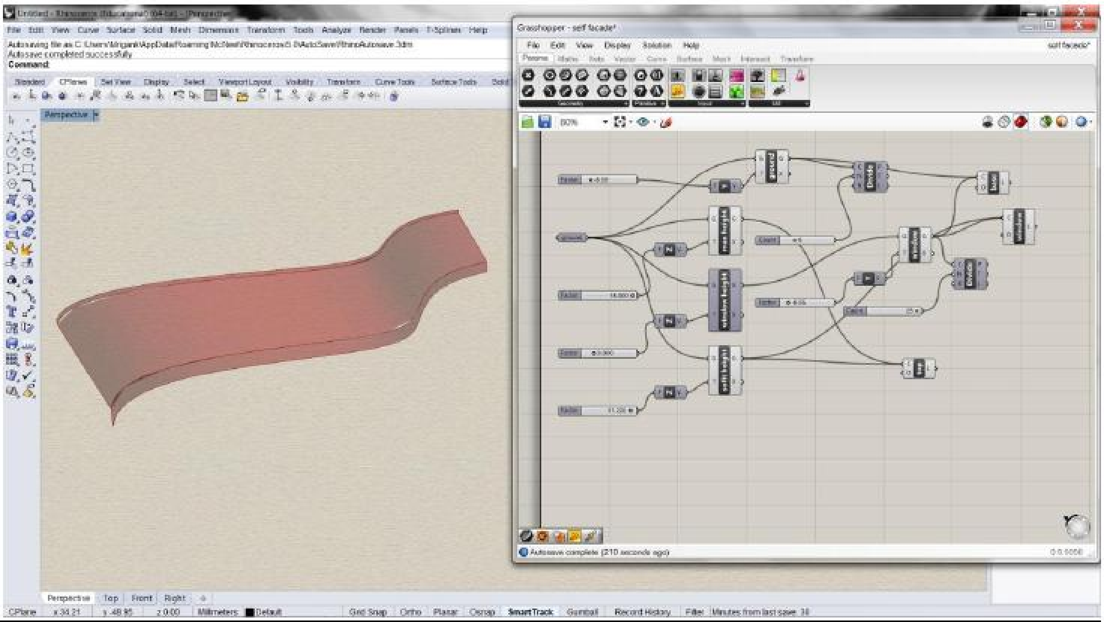


Fig. 2.e. Creating the surface out of curves

The next step is to make the surface using the curves. For that the 'Loft' component can be used and to make the surfaces we just need to join the different lines with the loft.

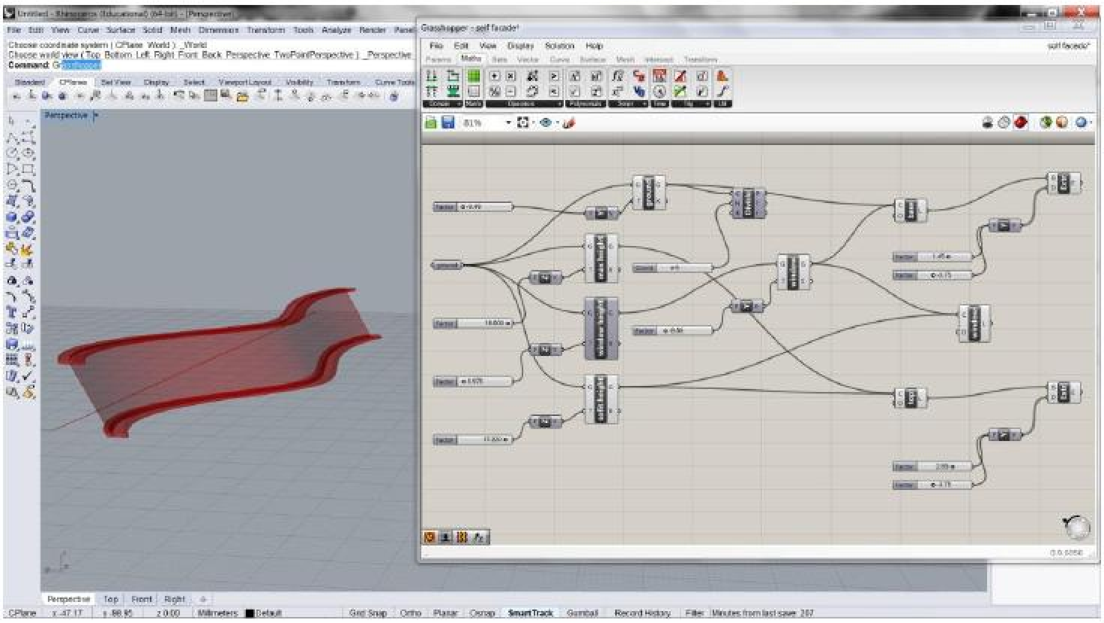


Fig. 2.f. Creating the geometry

Now we need to extrude some elements for the base and the soffit. So the 'Extrude' component is used here with a number slider to increase or decrease the extrusions. (Senske, www.youtube.com, 2011)

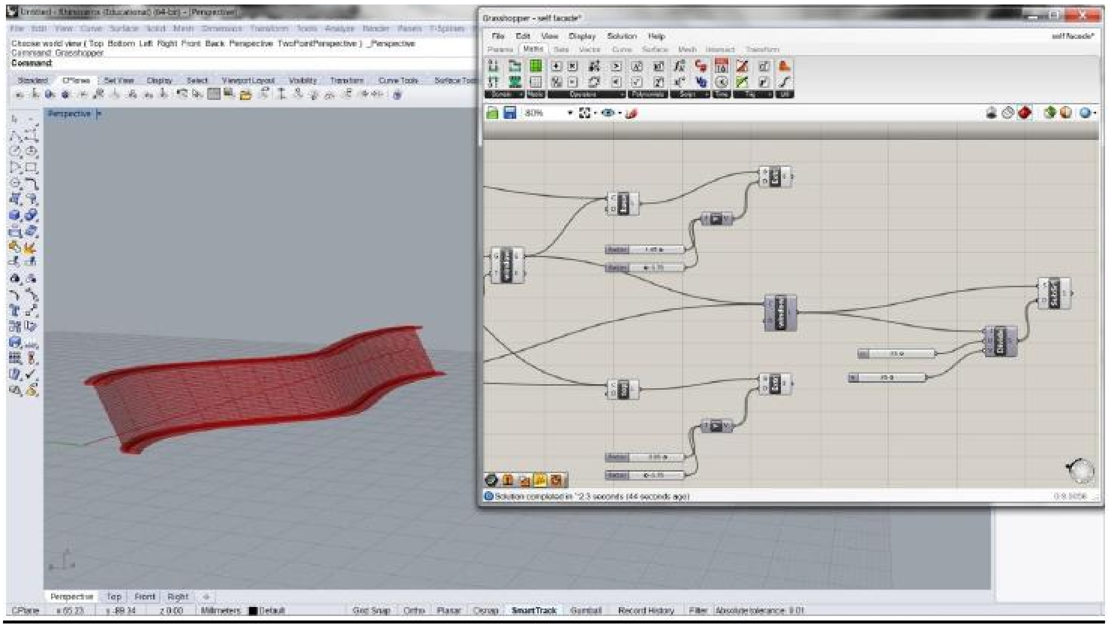


Fig. 2.g. Dividing the Surface for windows

Now to make a panel on the surface for glazing, we use 'divide surface' component and attach it with 'isotrim' which has SubSrf written on it. This divides the surface in the number of segments and that can be controlled using the number slider.

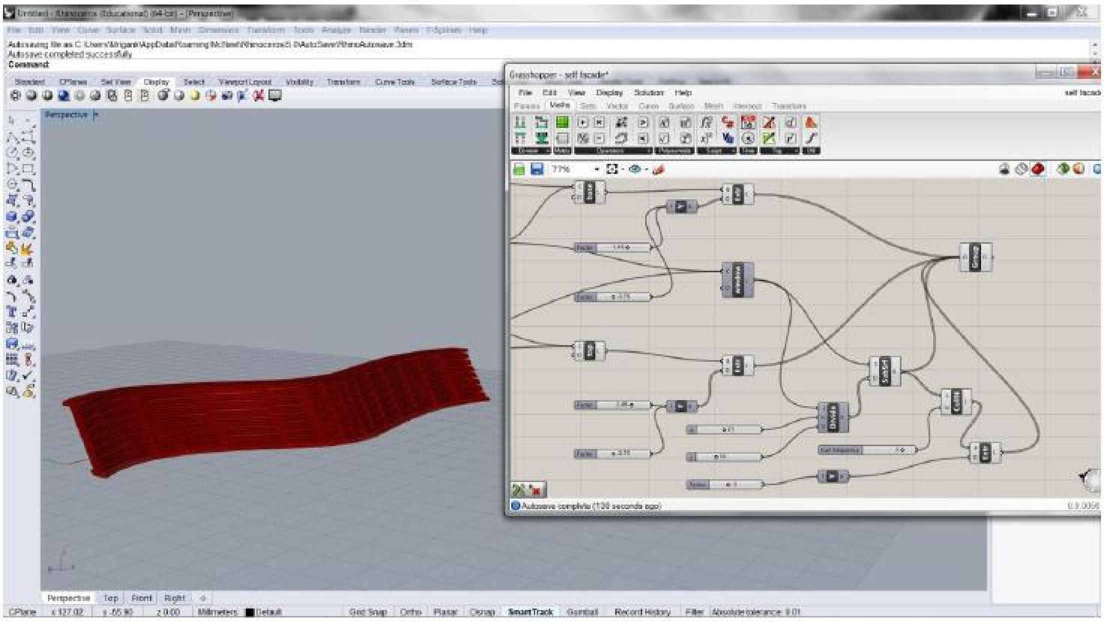


Fig. 2.h. Modelling the final form

Now the segmented surface can be designed using a component called 'Culln' which creates patterns in the segments and that also can be parametrically controlled using number sliders. All we need to do now is group all this together and bake it to get a final rendered image of what we have created here.

Fig. 2.i. Rendered Initial Stage

The following series of figures shows the rendered images of the fluid surface at every stage of creation. Although this is a very small zone but the idea needs to be cleared before we proceed.

This representation can be manipulated more so flexibility in the software gives us a upper hand. More we experiment, more ideas can emerge through various geometries.

Fig. 2.j. Rendered computing facade pattern

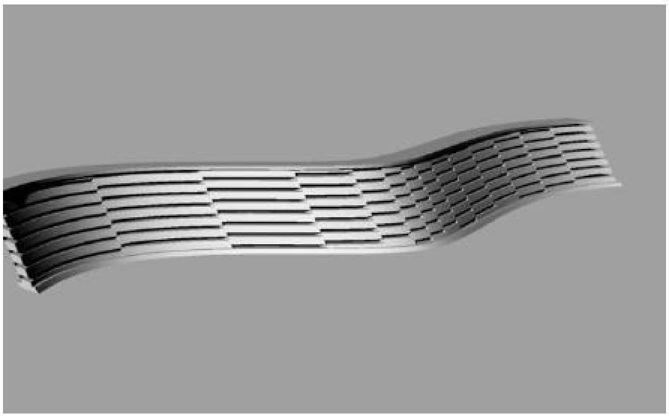
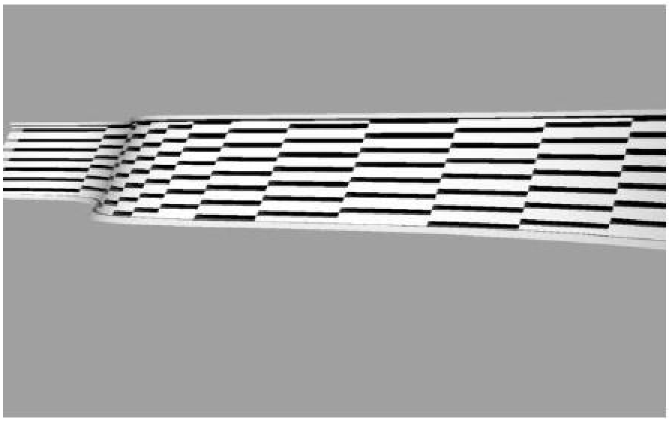


Fig. 2.k. Rendered final facade pattern

Through commands like twist, scale, move, rotate, loft, extrude, Brep, Deconstruct etc. one gets a complete control over the parameters on which the design is based on. Hence it is termed so evidently as Parametric Architecture.

Apart from the modelling, Rhino is a excellent software for simulation of the grasshopper model. Finally a model can be rendered using a lot of renderers available for rhino such V-Ray which is considered as the best renderer apart from Maya. (Senske, www.youtube.com, 2011)



3. WHAT IS FLUIDITY IN ARCHITECTURE ?

3.1. Fluids, Flow and Fluidity

To understand what is fluidity in architecture, we need to understand the meaning of the term 'fluid'. Fluids in literal terms are matter which have the ability to flow. Through science we understand the difference between solids and fluids and the reason why solids cant flow and fluids can. In simple words, the molecules in solid matter are closely bound due to their strong intermolecular forces and thus they stay rigid but fluids on the other hand have molecules with weaker intermolecular forces and thus they are loosely bound which allows the matter to flow.

Fig. 3.a. Whirlpool

Fig. 3.b. Sand dunes

Fluidity is simply the behaviour of fluids or any other matter which depicts the behaviour of fluids. This behaviour can be different and unique in different ways. A whirlpool will have a concentric movement of all the molecules of water but sand dunes on the other hand have a gradual linear movement of sand particles. Both can be defined as fluid movements but both depict this behaviour of flowing through space which is called fluidity.

This movement of particles which happens in different ways in different matters can be observed to be very diverse and unpredictable. We cannot say how the particles will move by just simply looking at the particles. Though mathematicians and physicists are able to do that through multiple permutations and several combinations, but a regular person instead of looking at how the fluid is moving, will appreciate and notice the beauty of the matter. The emotions and feelings which gets created due to fluids is something very vivid and amazing. Since centuries water has been considered as an element of calmness and soothing. There is a reason why people enjoy waterfalls, beaches, lakes and rivers. All have water in it but all of them have their own individual and distinct aura. The atmosphere that gets created due to the fluids is one of the reasons that this fluidity style got evolved in architecture. (Projects, 2011)

3.2. Fluidity and Architecture : Fluidity in Architecture

It is not enough to change the world, it also must be interpreted.........

Günther Anders

The concept of fluidity was present since the time architecture was born. Although the idea wasn't so clear and prominent but the early man when started constructing shelters had a certain understanding of the concept which could be defined as 'Fluidity and Architecture', where the buildings and structures which were designed and constructed had involved water (The first fluid matter known to man at that time) somewhere or the other. If we look back in history, the Egyptian designers while constructing their palaces always made sure that there was a flow of water in the interiors which would come from the river Nile so that the water can be used for domestic chores and also could be used for cooling the interiors. As time went by and architecture bloomed, this concept of including the use of water in buildings took different forms by different designers and builders all over the world. And even now, when the world has developed to such a great extent, the original idea of using water in the building for cooling is still retained which can be seen in projects like B.V. Doshi's office in Ahmadabad.

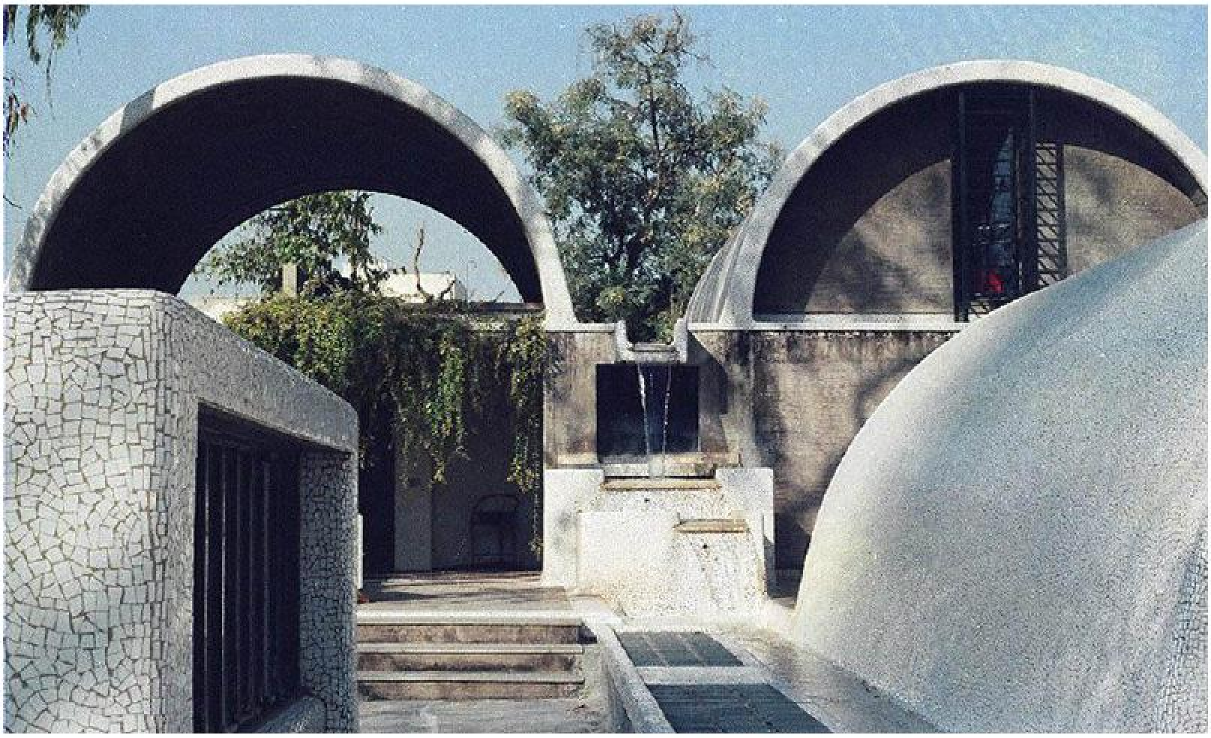


Fig. 3.c. B.V. Doshi's Sangarth in Ahmadabad

Contemporary architecture suggests that fluidity is something which can be used beyond the aspects of functionality part of a building. Till now only the physical effects of the water was used inside the buildings but what happens if we design a building to behave like water. What happens if a building gets designed in such a way that the functionality, aesthetics, landscaping etc. resembles the behaviour of water or any other fluids. These questions were the initial start of a new style of architecture: **Fluidity in Architecture.**

3.3. Fluidity in Architecture

With all the questions that started this style, more questions emerged as in How will this concept be applied, how can buildings be designed to resemble fluidity, how will those buildings be constructed, how will it affect the building psychology but the most important question that still needed to be answered was Why we needed fluidity in architecture ?

As architecture evolved, architects and designers were on a hunt of uniqueness in their designs. That is one of the major reasons that this concept got introduced. The idea was simple: Get inspired, be innovative and design unique. Though this idea initiated the evolution of the concept,

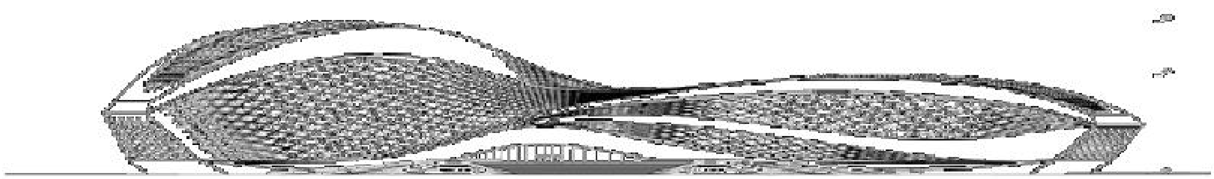


Fig.3.d. Chengdu Contemporary Art Centre (CCAC) by Zaha Hadid Architects

the derivative was to find how much an architect can explore with the spaces. How much can a form be twisted and manipulated by an architect. The initial approach towards design was inevitably 'Function follows Form' instead of 'Form follows Function'. So the concept automatically became focused on the form experimentation and manipulation.

The main challenge with this concept was how will the design become functional with the form. Traditional architectural methods involved a process in which the functionality of the design was understood thoroughly before the form was worked out. That gave a clear cut definition of the design with different levels of manipulations happening at every stage of process. But in this case, the form gets developed first, so arrangement of spaces so that the functional requirements of building is met becomes the fun part. Also a critical point should be noted that while designing, the building is considered to be an integrated block which consists of all the spaces.

To work out unpredictable conditions with forms and spaces that normally would be difficult to visualize. And to create, observe and analyze those unpredictable conditions, softwares became the tool instead of pen and paper. Through softwares one can create 3d models efficiently and while modifying can see the changes happening which gives an edge to the architect. (Projects, 2011)

3.4. Where is Fluidity ??

As this concept started developing, designers thought where all fluidity can be used apart from form. Till now only the building form could get inspired from water shapes and patterns. So the architects and designers started looking into more fields and experimented with them to incorporate this style.

3.4.a. Form and Building Profile

Fig.3.e. Zany Beko, Downtown in Belgrade, Designed by ZHA

Fig.3.e. Olaya metro station, Designed by Gerber Architekten

3.4.b. Urban Design and Urban Planning

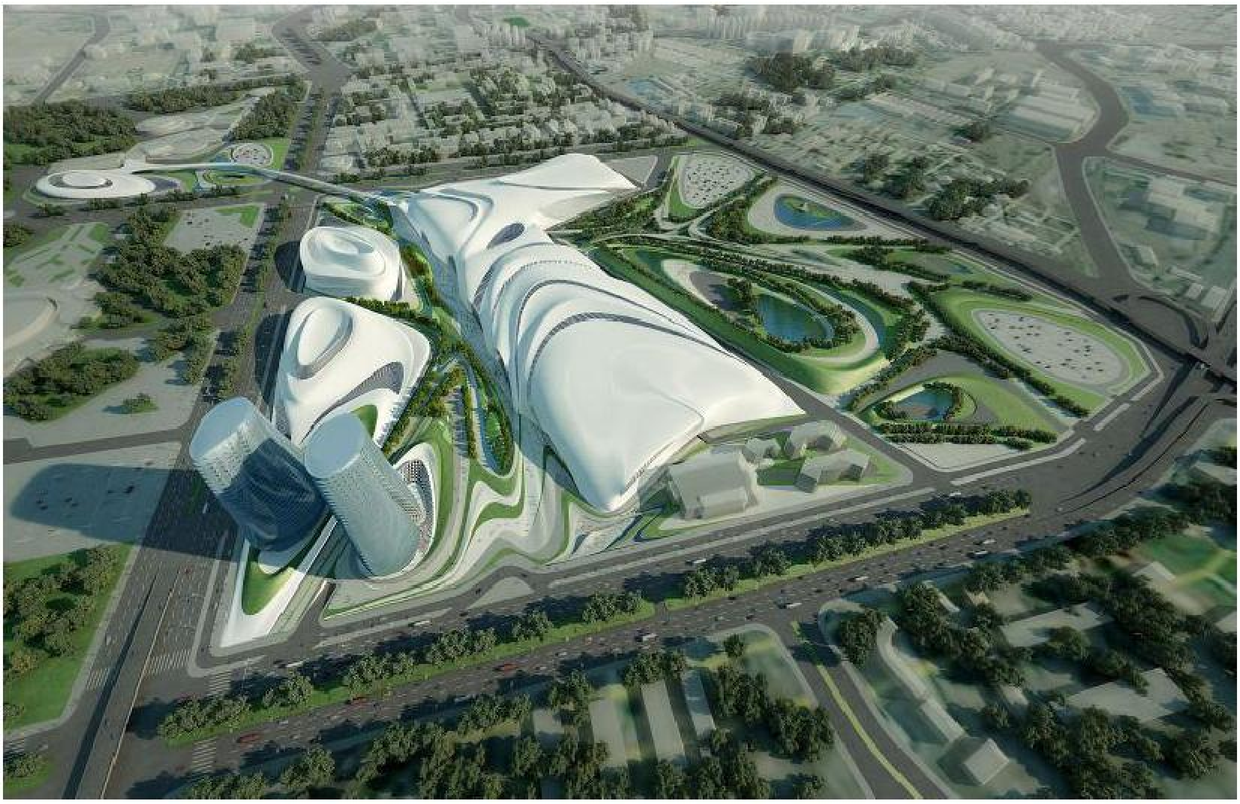


Fig.3.f.i. Cairo Expo City, Designed by ZHA

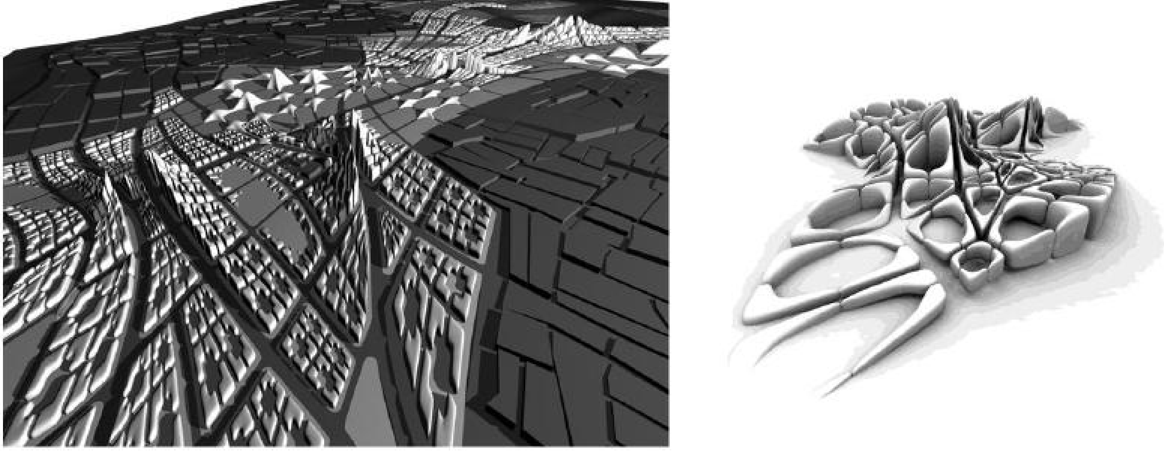


Fig.3.f.ii. Kartal-Pendik Master Plan, Istanbul, Turkey, Designed by Patrik Schumacher

3.4.c. Interior Design and Installation Art

Fig.3.g.i. Geometry Fluidity House Villa Design Concept, Designed by Jürgen Mayer H Architects.

Fig.3.g.ii. Guangzhou Opera House, Designed by ZHA

Fig.3.g.iii. Mobile Art Pavilion, Designed by ZHA

It should be observed how the fluidity aspect is being incorporated in these designs. The different elements of every design are linked, stretched, scaled and finally integrated to incorporate the fluidity aspect. A beautiful social expression gets generated from this style portraying the integration of the various individuals to form one big society.

3.4.d. Landscape Design

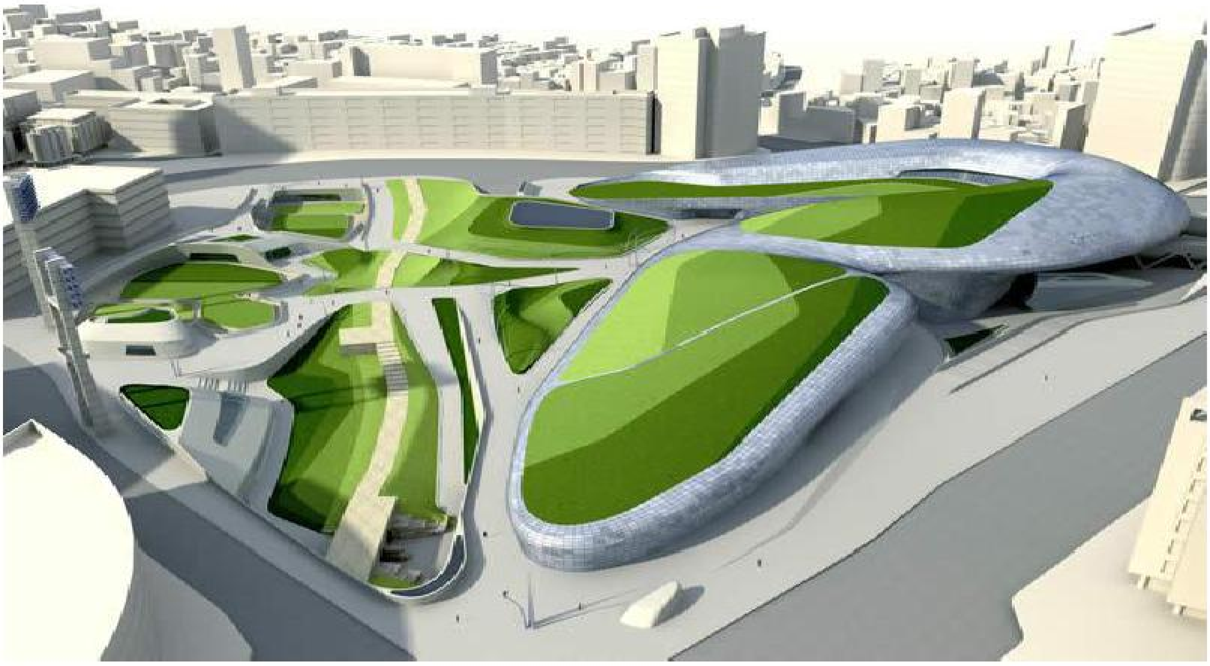


Fig.3.h.i. Dongdaemun Design Park and Plaza, Seoul, Designed by Zaha Hadid

Fig.3.h.ii. Designed by Thomas Buseck + Oliver v. Malm

Fig.3.h.iii. Fluid Pavilion, Designed by 3deluxe Studio

3.4.e. Product design, Fashion Design and more

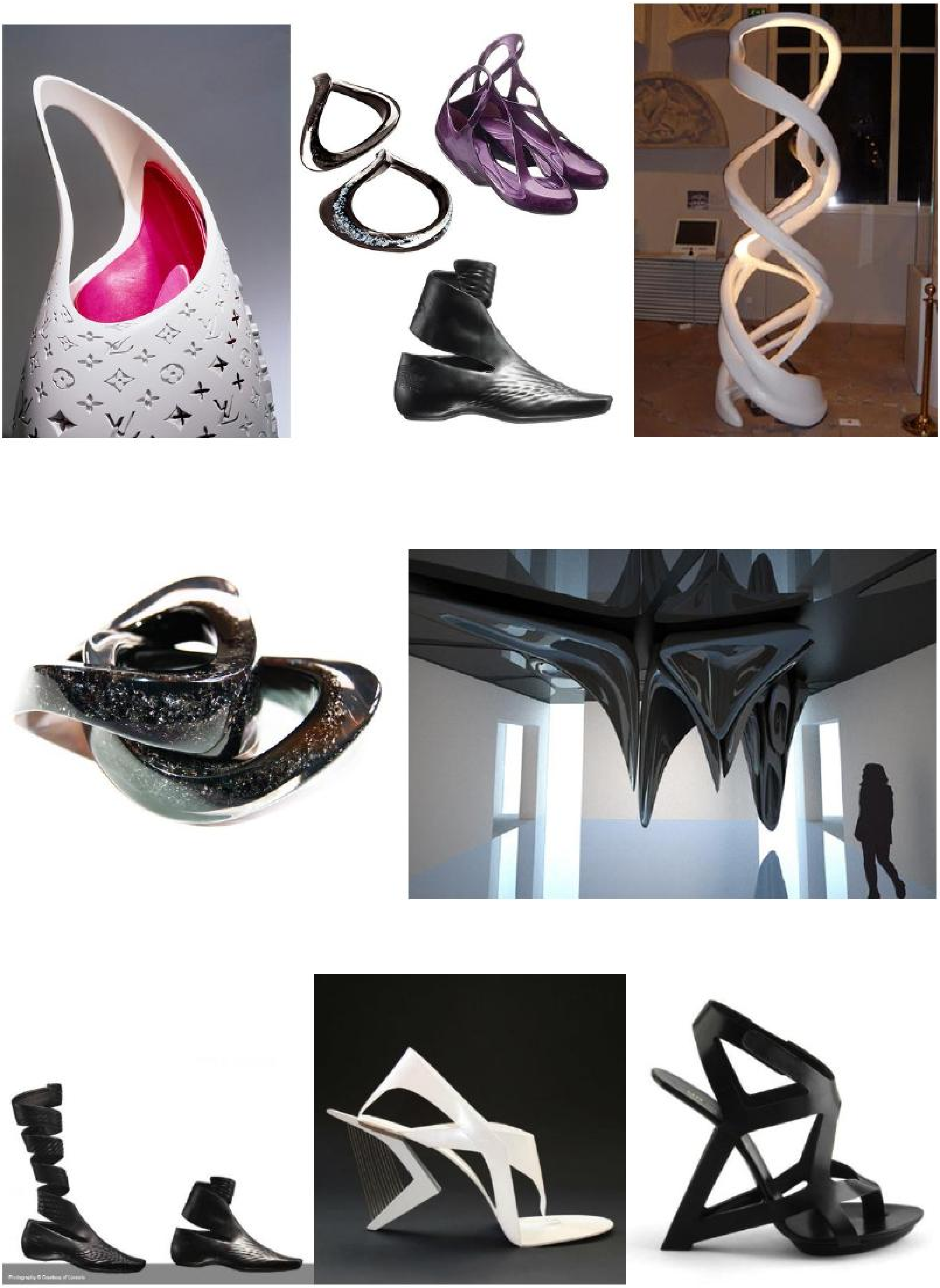


Fig.3.i. Fluid Products, Designed by Architect Zaha Hadid

4. THE FLUID ARCHITECTS

4.1. Architect Zaha Hadid

Born: October 31, 1950 (age 62), Baghdad, Iraq

Parents: Mohammed Hadid

Awards: Pritzker Architecture Prize, Stirling Prize, Structural Steel Design Awards

Education: American University of Beirut, Architectural Association School of Architecture

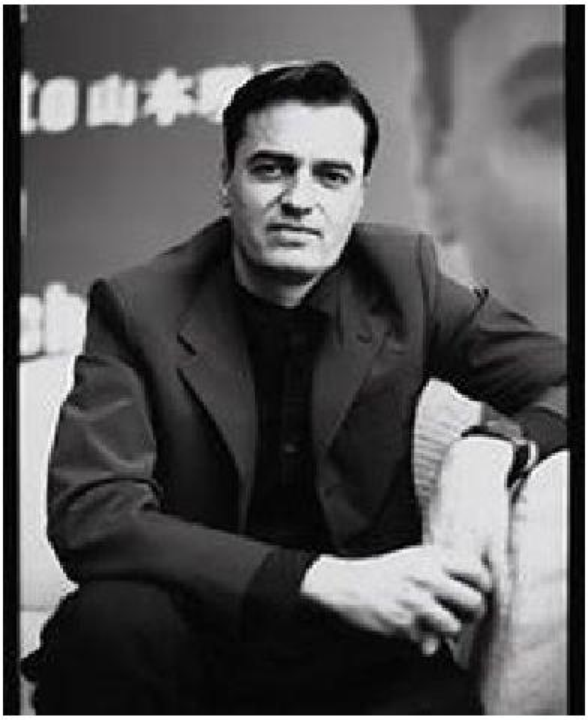
Dame Zaha Mohammad Hadid, DBE (born 31 October 1950) is an Iraqi-British architect. She received the Pritzker Architecture Prize in 2004—the first woman to do so—and the Stirling Prize in 2010 and 2011. Her buildings are distinctively futuristic, characterized by the "powerful, curving forms of her elongated structures with multiple perspective points and fragmented geometry to evoke the chaos of modern life.

Dame Zaha Hadid has taught at prestigious universities around the world, including at the Harvard Graduate School of Design, where she was the Kenzo Tange Professorship and the Sullivan Chair at the University of Illinois at Chicago's School of Architecture. She also served as guest professor at the Hochschule für bildende Künste Hamburg (HFBK Hamburg), the Knowlton School of Architecture at Ohio State University, the Masters Studio at Columbia University, and the Eero Saarinen Visiting Professor of Architectural Design at the Yale School of Architecture.

From the year 2000 on Dame Zaha Hadid is a guest professor at The University of Applied Arts - Vienna, in the Zaha Hadid Master Class Vertical-Studio.

She was named an Honorary Member of the American Academy of Arts and Letters and an Honorary Fellow of the American Institute of Architects. She has been on the Board of Trustees of The Architecture Foundation. She is currently Professor at the University of Applied Arts Vienna in Austria. (Hadid) (Zaha Hadid)

4.2 Architect Patrik Schumacher



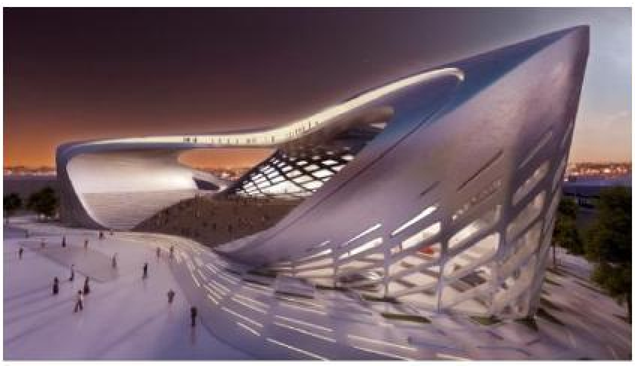
Work: Founder Director**,** AA Design Research Labs

Partner at Zaha Hadid Architects since 1988

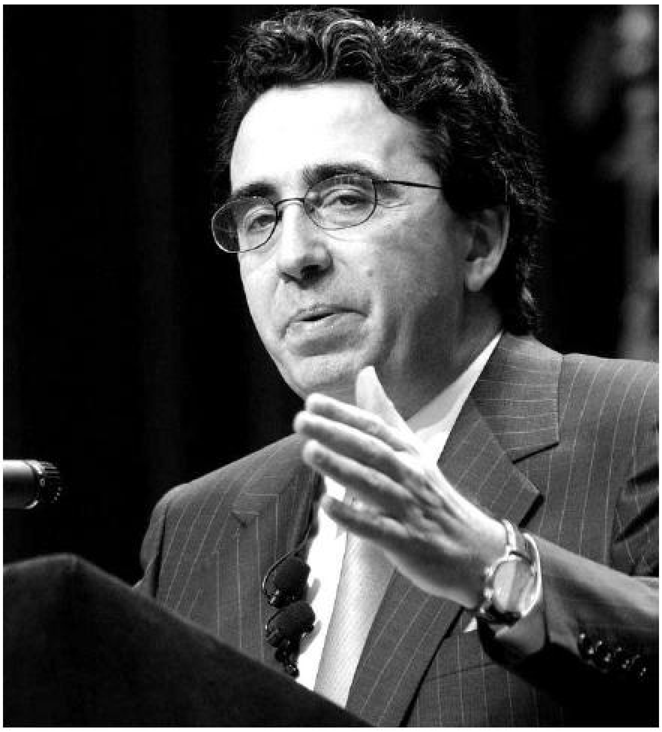
Education : Schumacher studied philosophy and architecture in Bonn, London and Stuttgart, where he received his Diploma in architecture in 1990. In 1999 he completed his PHD at the Institute for Cultural Science, Klagenfurt University.

Patrik Schumacher joined Zaha Hadid in 1988. In 1996 he founded the "Design Research Laboratory" with Brett Steele, at the Architectural Association School of Architecture in London, and continues to serve as one of its co-directors. Schumacher has co-taught a series of post-graduate option studios with Zaha Hadid at the University of Illinois at Chicago, Columbia University and at the Graduate School of Design at Harvard University. Since 2004 Patrik Schumacher has been tenured Professor at the Institute for Experimental Architecture, Innsbruck University. Currently he is a guest professor at the University of Applied Arts in Vienna. Schumacher's contribution to the discourse of contemporary architecture is also evident in his published works and interviews which can be viewed at www.patrikschumacher.com. (Patrick schumacher, 1989)

Patrik Schumacher played a vital role in revolutionising **Parametricism** and **Parametric architecture.** He was also involved with Zaha hadid in flourishing deconstructivisms style and has written several books on parametricism, urbanism and free market urbanism. He won the **Stirling Prize** in 2010 for MAXXI centre of Contemporary art and architecture in Rome.



4.3. Architect Santiago Calatrava



Born: July 28, 1951 (age 62), Benimàmet, Valencia

Artwork: Infinite Spirit, Il Dente, Bou, Times Capsule, Bird I, Torso, Palme, Wave, Fruit, Eye

Awards: AIA Gold Medal, IStructE Gold Medal, Prince of Asturias Award for the Arts

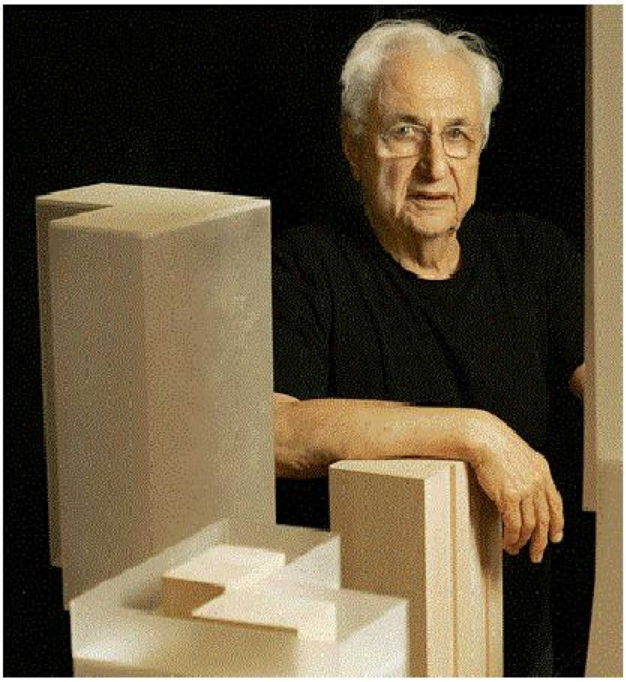
Education: ETH Zurich, Universitat de València, Polytechnic University of Valencia

Santiago Calatrava Valls (born 28 July 1951) is a Spanish architect, sculptor and structural engineer whose principal office is in Zürich, Switzerland. He has offices in Zürich, Paris, Valencia, and New York City (where he now resides).

Calatrava's early career was largely dedicated to bridges and railway stations, with designs that elevated the status of civil engineering projects to new heights. His Montjuic Communications Tower in Barcelona, Spain (1991) in the heart of the 1992 Olympics site, as well as the Allen Lambert Galleria in Toronto, Canada (1992), were important works and turning points in his career, leading to a wide range of commissions. The Quadracci Pavilion (2001) of the Milwaukee Art Museum was his first building in the United States. Calatrava's entry into high-rise design began with an innovative 54-story-high twisting tower called Turning Torso (2005), located in Malmö, Sweden.Calatrava has designed a futuristic train station, the World Trade Centre Transportation Hub, at the rebuilt World Trade Centre in New York City. As of 2013, a modified, somewhat cost-reduced version of his design is under construction.

Calatrava has defined his style as bridging the division between structural engineering and architecture. In his projects, he claims to continue a tradition of Spanish modernist engineering that included Felix Candela, Antonio Gaudí, and Rafael Guastavino, with a very personal style that derives from numerous studies of the human body and the natural world. (htt1) (htt2) (Santiago Calatrava)

4.4. Architect Frank Gehry



Born: February 28, 1929 (age 84), Toronto, Canada

Books: Schizophrenia: A Case Study of the Movie a Beautiful Mind - Second Edition, More

Awards: Pritzker Architecture Prize, National Medal of Arts, More

Frank Gehry's buildings, including his private residence, have become tourist attractions. His works are cited as being among the most important works of contemporary architecture in the 2010 World Architecture Survey, which led *Vanity Fair* to label him as "the most important architect of our age".

Gehry's best-known works include the titanium-covered Guggenheim Museum in Bilbao, Spain; MIT Ray and Maria Stata Centre in Cambridge, Massachusetts; Walt Disney Concert Hall in downtown Los Angeles; Experience Music Project in Seattle; Weisman Art Museum in Minneapolis; Dancing House in Prague; the Vitra Design Museum and the museum MARTa Herfordin Germany; the Art Gallery of Ontario in Toronto; the Cinémathèque française in Paris; and 8 Spruce Street in New York City. But it was his private residence in Santa Monica, California, that jump-started his career, lifting it from the status of "paper architecture"—a phenomenon that many famous architects have experienced in their formative decades through experimentation almost exclusively on paper before receiving their first major commission in later years. Gehry is also the designer of the future Dwight D. Eisenhower Memorial.

(Frank Gehry) (Isenberg, 2009) (Sketches of Frank Gehry)

5. THE TOOLS OF FLUID DESIGN

As it can be observed that these designs are highly complicated and it would be very difficult to visualize them using just pencil and paper. Inevitably softwares plays a very important role in the creation of these designs. And as we will move forward with the chapters, one will notice that the softwares often tend to manipulate and modify the designs on its own. So the architect would be getting different perspectives towards his own design which gives an upper hand to parametric architecture.

5.1 Grasshopper and Rhino

We all are familiar with the 3d modelling software Rhinoceros. Grasshopper is a plugin for the software. Rhinoceros is a very efficient 3d modelling software which allows us to make curved and semi curved surfaces. But sometimes editing those curves becomes a real headache. Grasshopper gives us a upper hand in this matter.

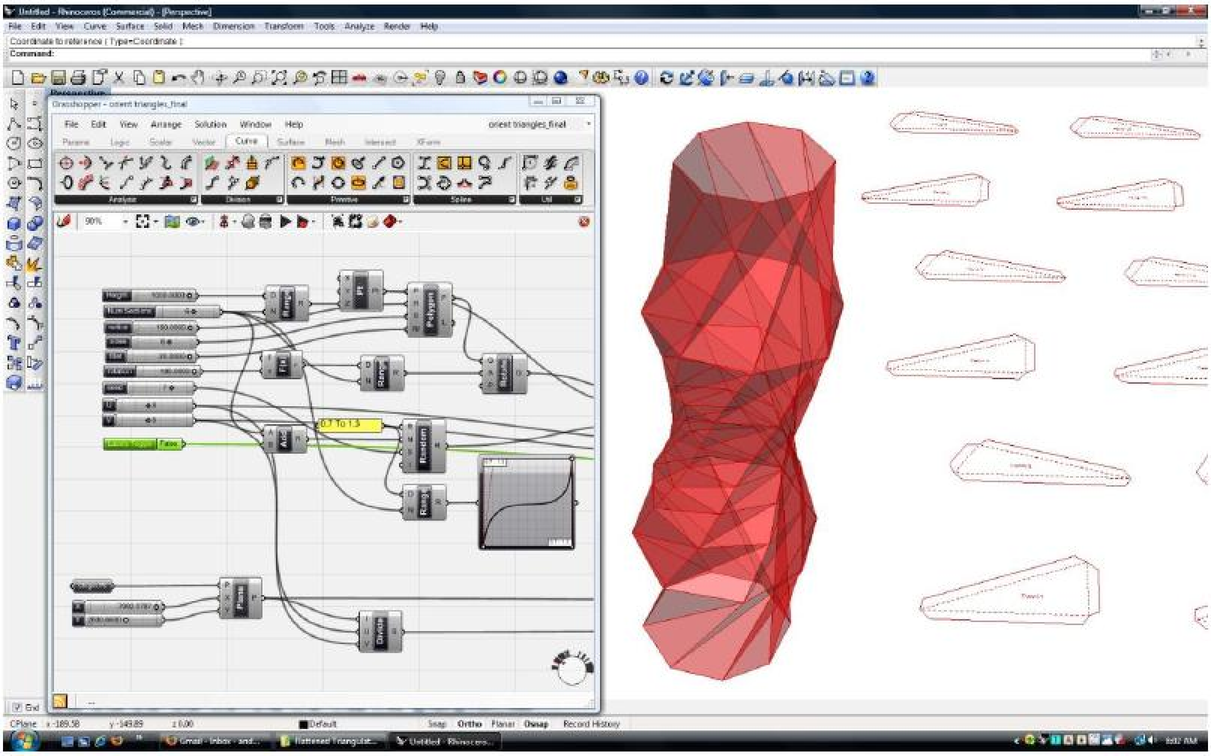


Fig.5.a. 3D Modelling, Grasshopper, Nick Senske, UNC charrlotte

In the above figure, the small window on the left side is the grasshopper canvas and in the background is the perspective viewport of Rhino. Grasshopper allows a designer to create designs on the rhino viewport using algorithms which we work on the canvas. As it can be seen above, this entire set of components (grey coloured rectangles) is one algorithm which represents the red coloured model on the viewport. The components become the parameters which can individually be changed according to the designers wish and thus it becomes a part of parametric architecture. Also we can work on grasshopper and rhino on one viewport consecutively without disturbing the individual ones. That helps in identifying the glitches and take quick actions.

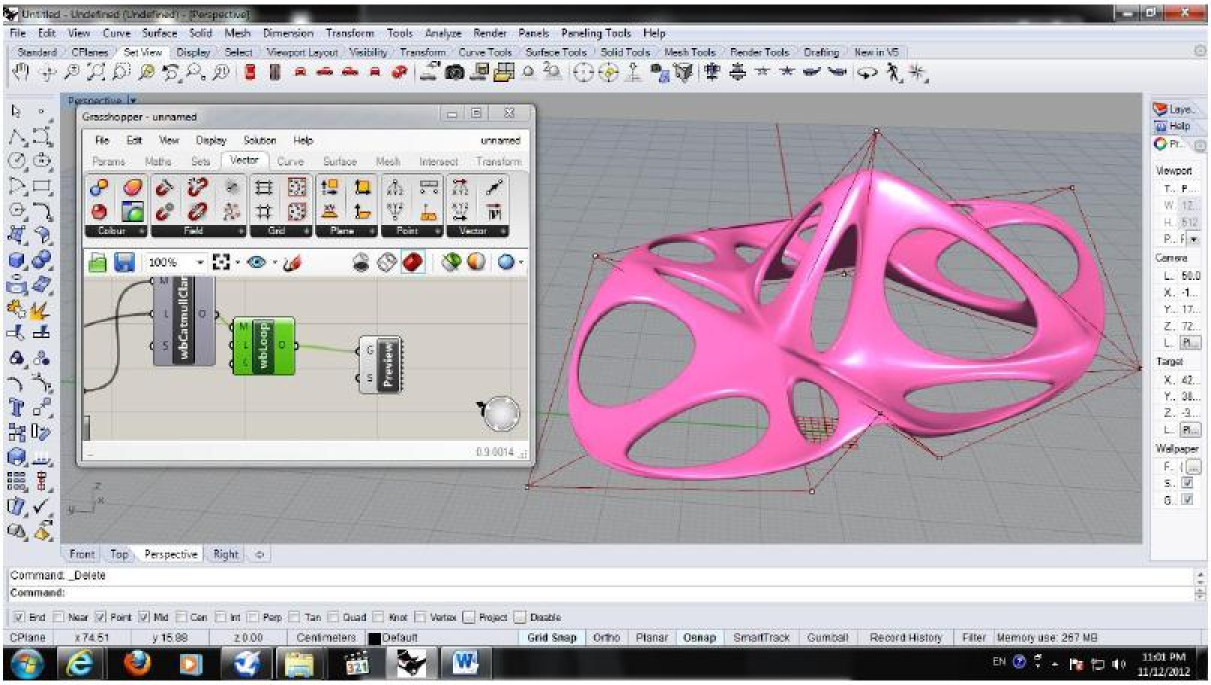


Fig.5.b. Oval Fluid Mesh model, Grasshopper, Nick Senske, UNC charrlotte

Grasshopper has a diverse component library which lets a user choose the parameters efficiently according to his/her choice of modifying their designs. As it can be observed that this design has been made by interlinking the different point at various positions in the initial stage. So we get a very good flexibility in controlling the form and its details.

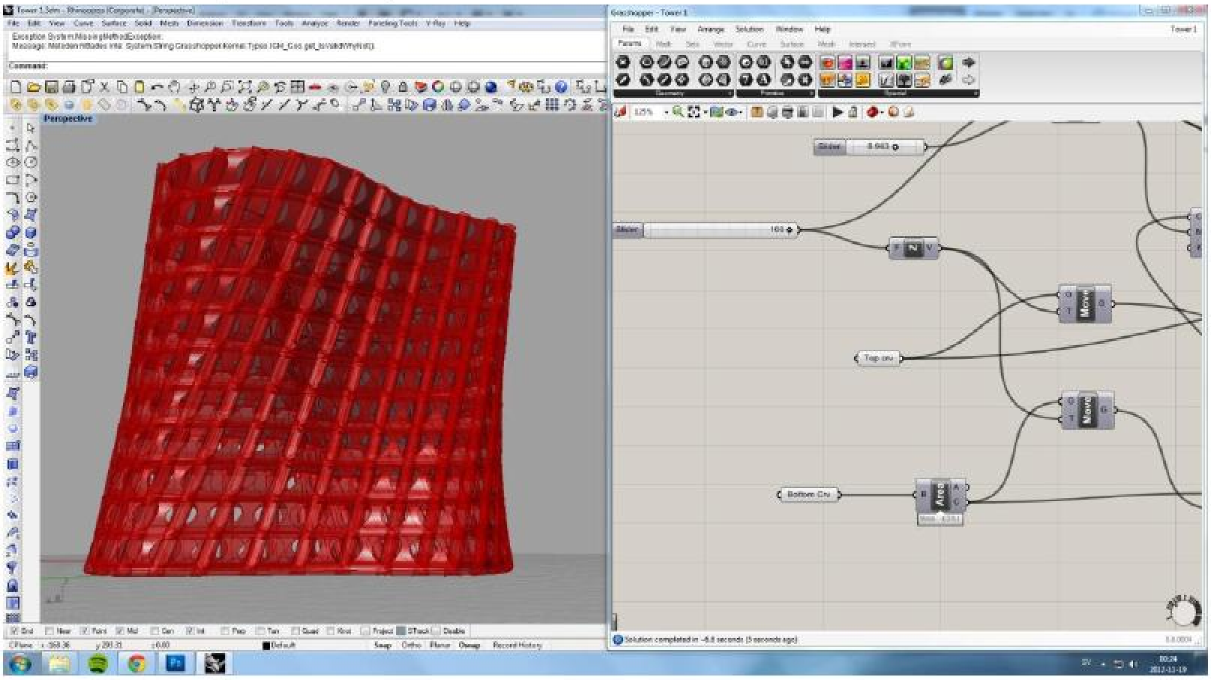


Fig.5.b. Bending Surface model, Grasshopper, Nick Senske, UNC charrlotte

Through these parameters, one gets an accurate and precise building form. At the end, one has to just group all the parameters and loft it to make it one geometry which then allows us to bake it to create a solid 3d model. (Senske, www.youtube.com, 2011)

5.2 Autodesk 3ds Max

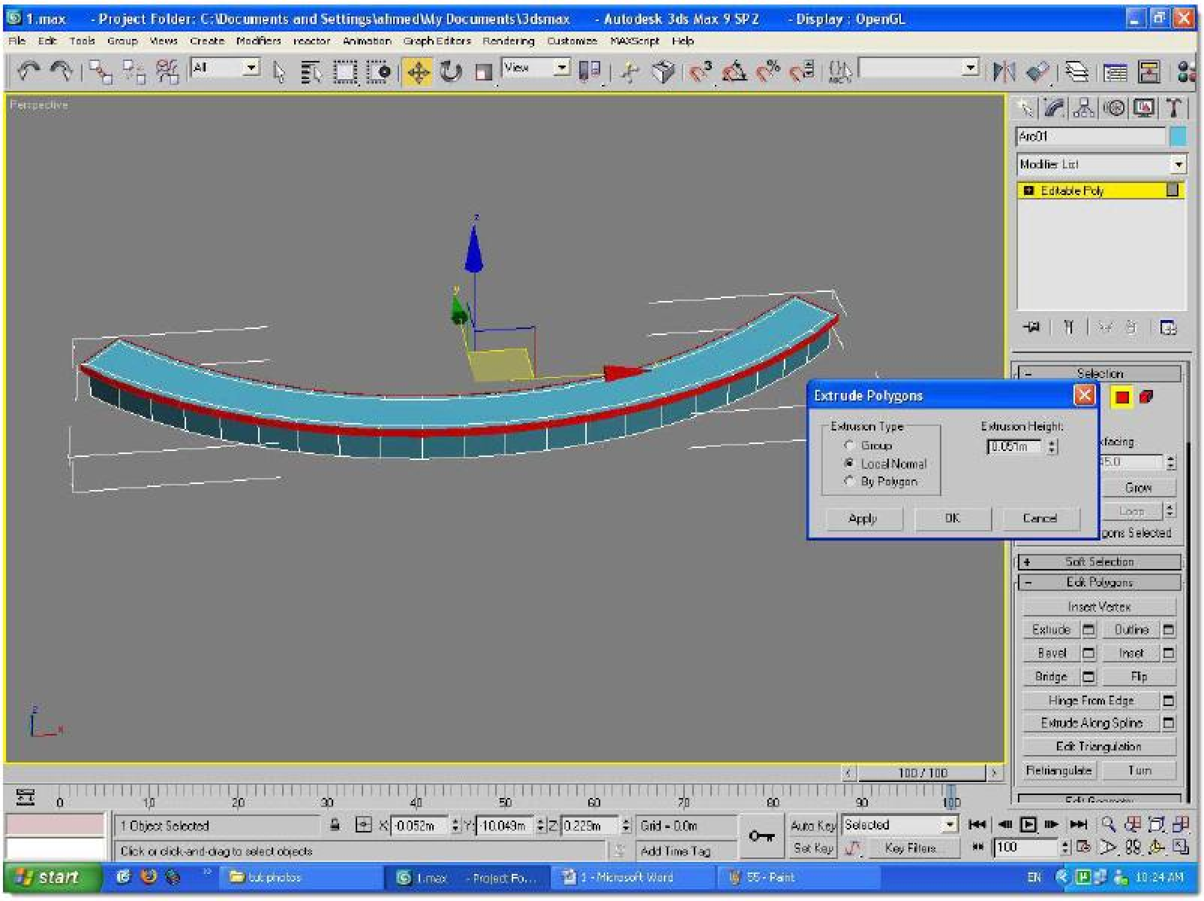


Fig.5.c. Bending solids, Autodesk 3ds Max

Autodesk 3ds max is one of the most commonly used softwares for 3d modelling due to its user friendly interface. Form build-up is quick and precise through the command bar on the right hand side. Form manipulation is done using dividing the form into segments which are represented by the white lines on the block. The number of segments decide the number of bending points. Through the command box the deformations can be smoothened and curves can be produced. (Senske, 3ds max, 2010)

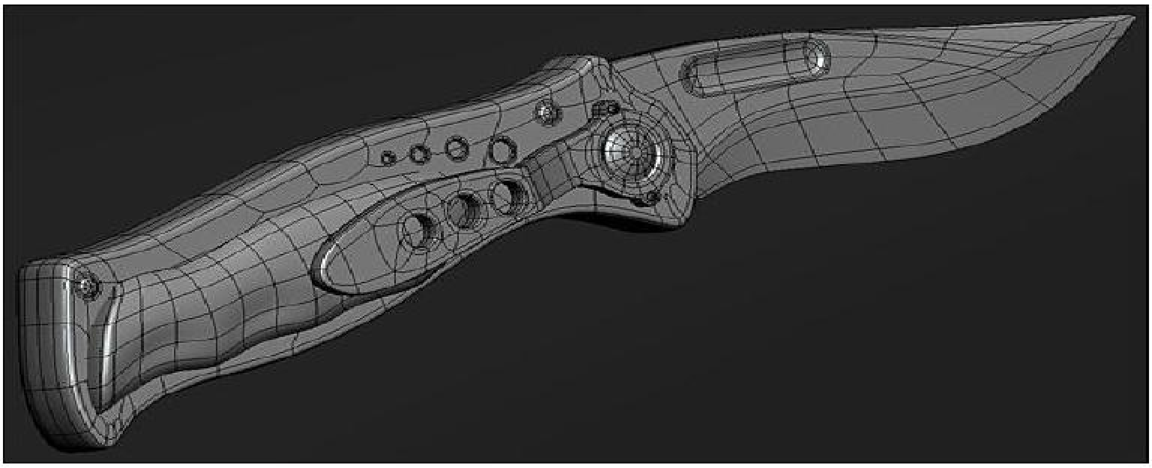


Fig.5.d. Knife model dynamics, Autodesk 3ds Max

5.3 Wolfram Mathematica

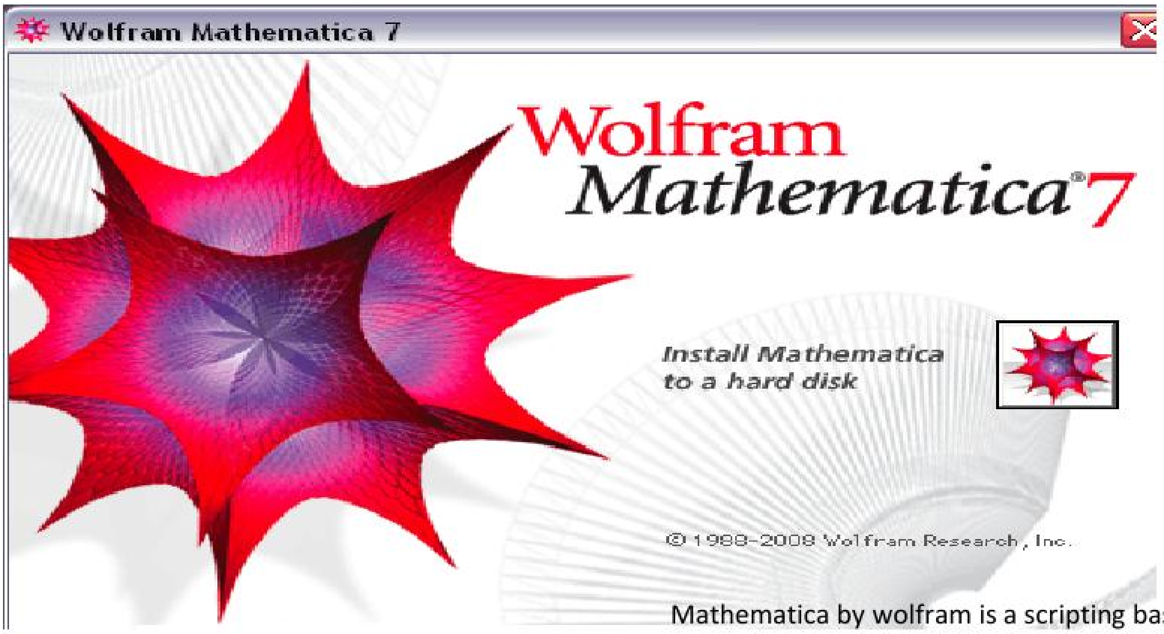


Fig.5.e.i. Logo of Wolfram Mathematica

Mathematica by wolfram is a scripting based 3d modelling software which is used to find any kind of engineering solutions through mathematical coding and equations.

It takes inputs in terms of equations and scripts which involves calculus and high understanding of mathematics and then it delivers the output according to scripts. In this case, the scripts and equations becomes the parameters instead of the components in grasshopper.

Compared to grasshopper it is complicated but the output quality is extremely precise and accurate. (Mathematica)

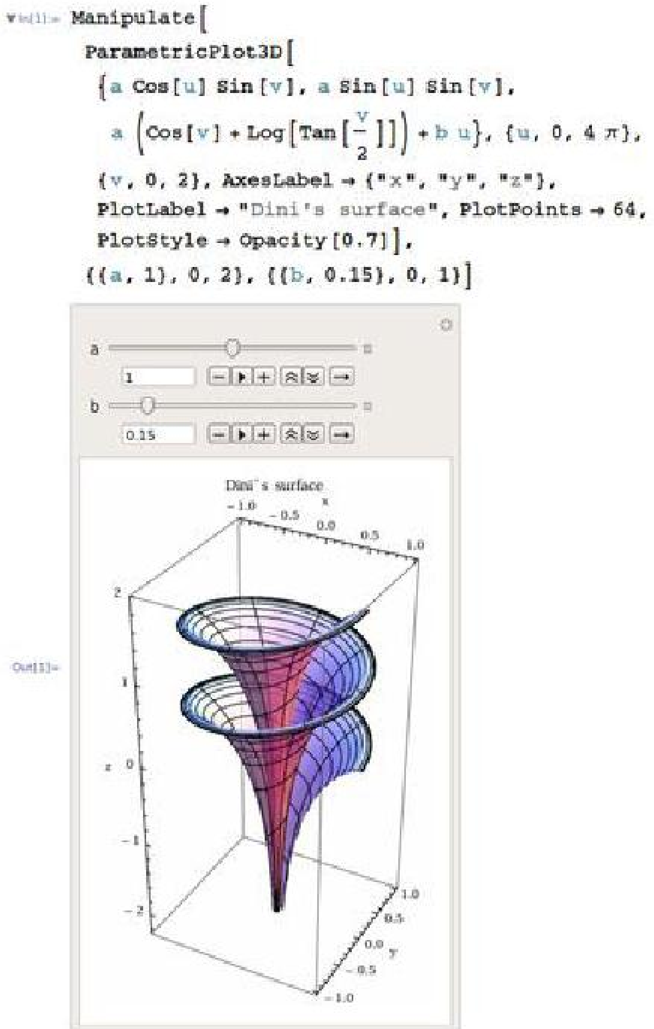


Fig.5.e.ii. Modelling in Mathematica

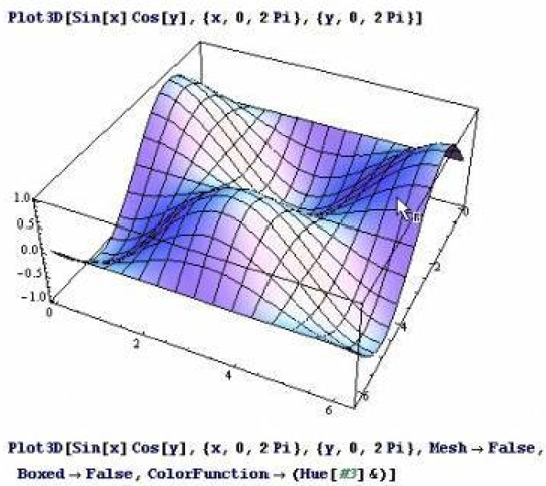


Fig.5.e.ii. Bump effect in Mathematica

6. FLUIDITY IN BUILDINGS

Let's take a look into some of the projects that has incorporated this style. The main aim right now would be to analyse the buildings and observe how the concept is being applied.

6.1. Concept of a Airport, Designed by Thomas Buseck, Project coordinator P. Schumacher

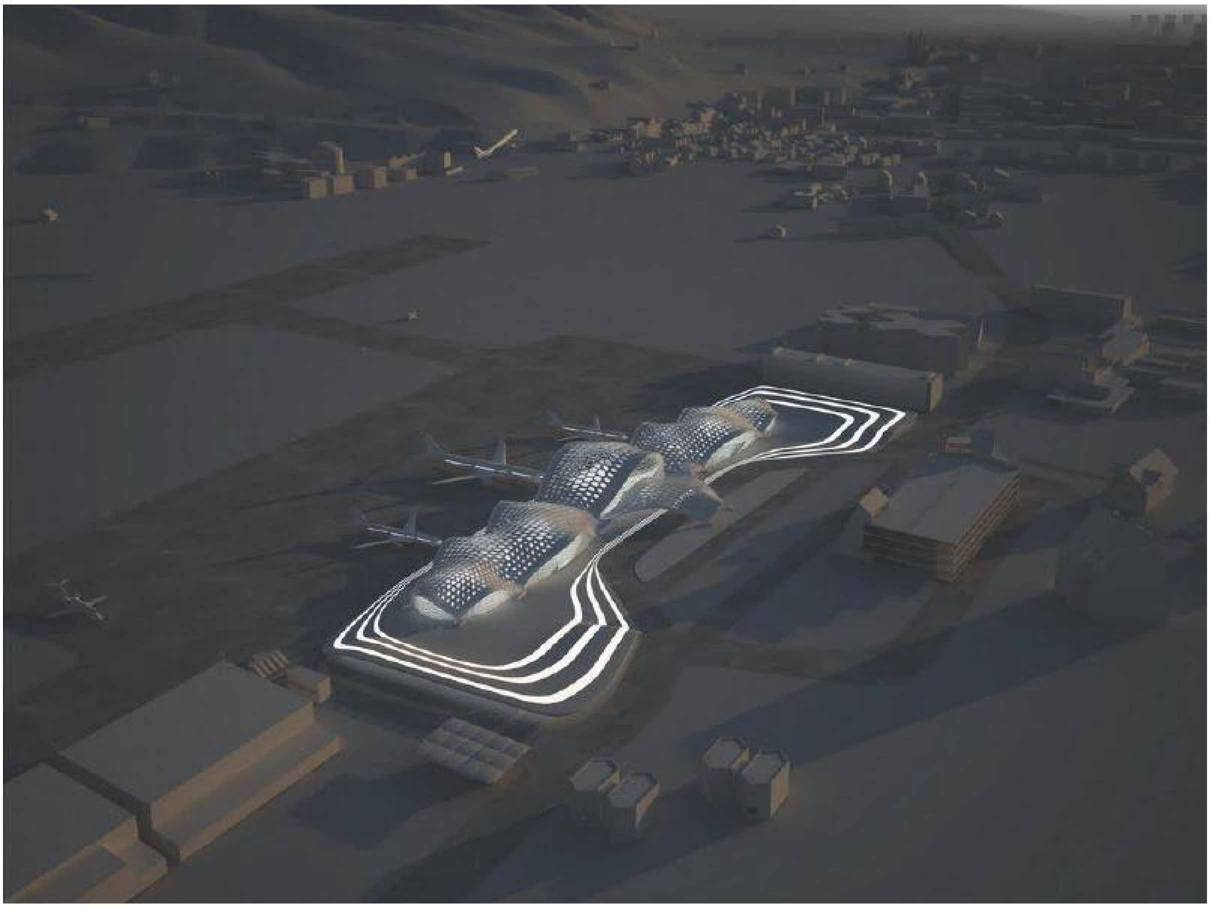


Fig.6.1.a. Airport design, Innsbruck, Austria

First of all I would like to thank Thomas Buseck for sharing his portfolio on his blog and giving his ideas and knowledge of parametricism and fluid architecture while designing this project.

The project requirement was to design a new passenger terminal for Innsbruck Airport. Buseck had Structural Design in his major in that semester so he chose Airport where he believes the design context is not as important as the structural stability. In other words, he wanted to keep a simple design and experiment more with the structure which he justifies by not working much on the design development but manipulating the structural engineering to create a fluid expression.

(Thomas Buseck)

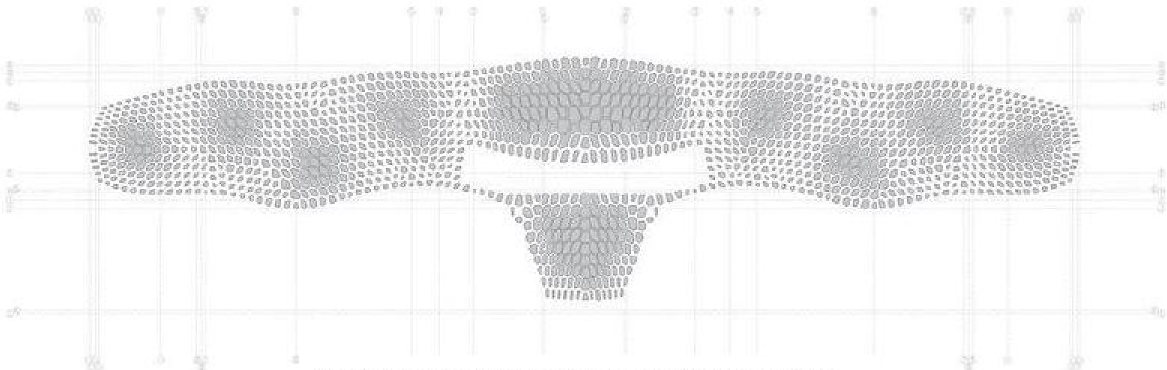
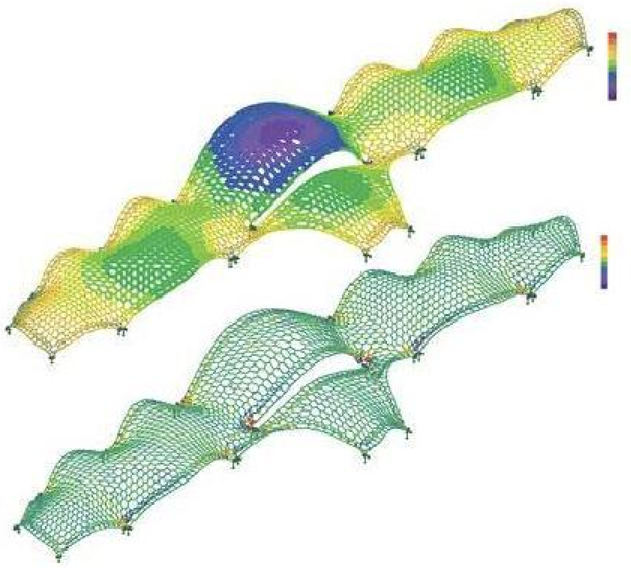


Fig.6.1.b.i. Roof Plan of the Passenger Terminal

His main work in this project is with the roof and how it can be made to form like waves. As it can be observed that there is a variation in the densities of the units. This clearly says that wherever the density is more, there is trough formed and where its less, crest is created.



With the help of Geometrygym and Grasshopper, the designer was able to create a lattice structure which consists of small shells alternatively.

The columns are located between every two troughs making them points of vertical loads. The density of lattice gets concentrated between every two troughs to transfer the loads to the columns.

(Thomas Buseck)

Fig.6.1.b.ii. Roof dynamics designed in grasshopper

1. Acrylic Glass 40mm thick
2. Pressure Plate
3. Clamping rubber
4. Mechanical Reinforcement
5. Contact pressure point
6. GRP 1.8mm cover
7. RHS 140x140x12.5
8. Panel XPS 100 mm

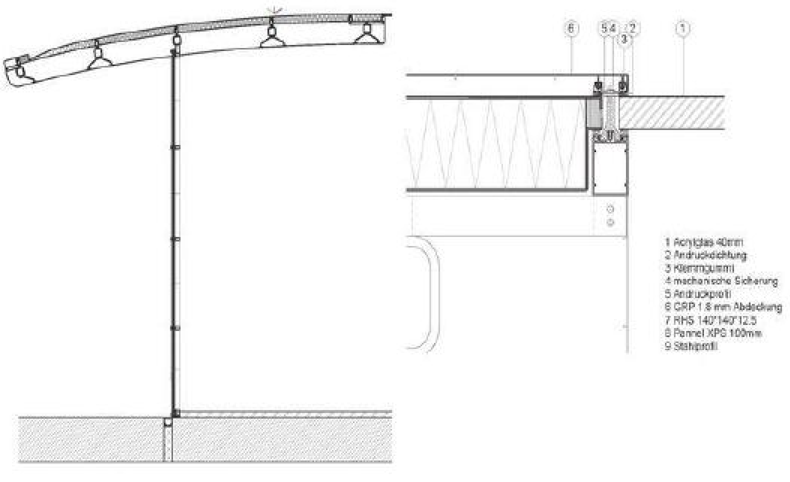


Fig.6.b.iii. Construction technique of the glass facade

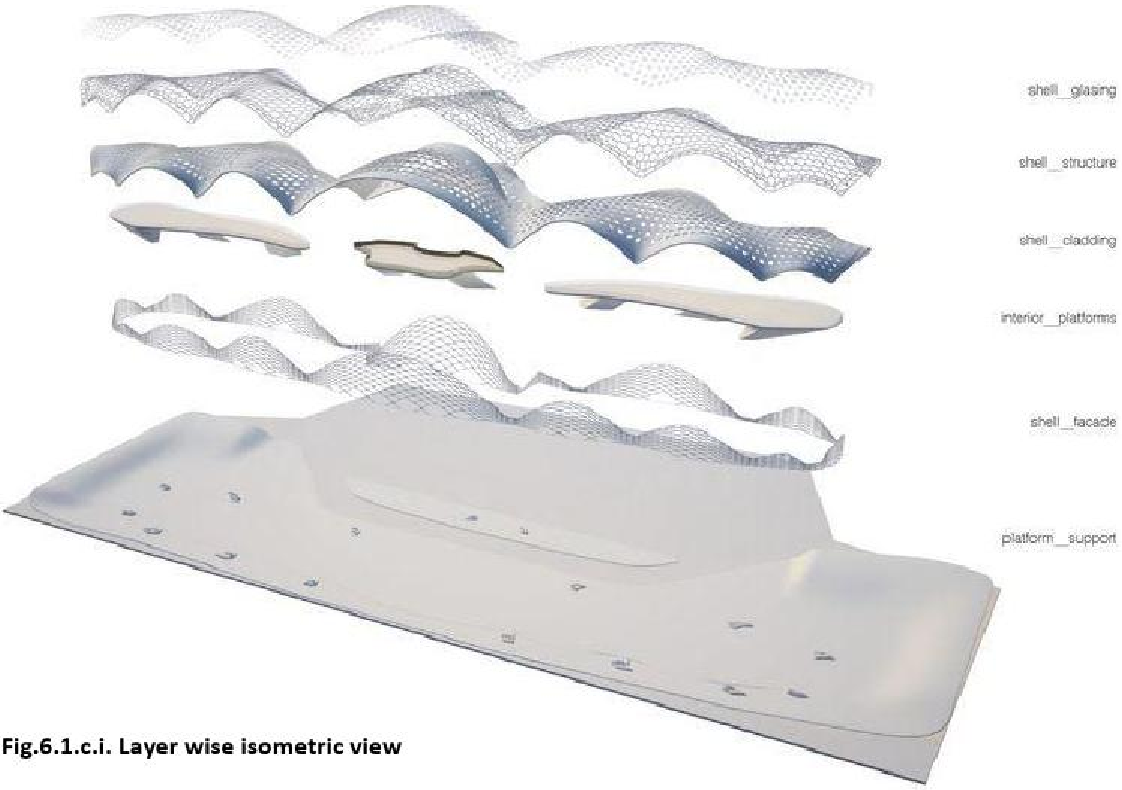


Fig.6.1.c.i. Layer wise isometric view

Through this diagram the designer explains through layers, how the roof gets formed. The facade follows the crest trough arrangement and is made of acrylic glass. The roofing system above the platform consists of three layers: shell cladding, shell structure and the glazing shell all arranged in such a way that that the gaps formed due to the lattices gets retained for natural sunlight. And as the site location is in Germany, the designer used aluminium cladding. This not only helps in storing thermal energy inside the building but also is a light material and substantially reduces the dead load. (Thomas Buseck)

Fig.6.1.c.ii. View from the entrance of the terminal campus

Fig.6.1.d.i. View from the Rear side of the Terminal

It should be observed that the daylighting conditions are excellent in this design and the facade just blends with the roof. This is a very important feature of fluid architecture. The roof and facade are two different designs but at the end they get integrated and becomes one. (Thomas Buseck)

Fig.6.1.d.ii. View of the Facade from front

Fig.6.1.e. View of the Interiors

The climate of Austria remains extremely cold most of the year. The designer kept that in mind and thus created this pattern on the roof allowing a lot of sunlight inside the building. This in turn increases the internal thermal temperature of the building which is a major energy sustainable measure in that climate. And this pattern gets compatible with the roofing system and form. Thus energy sustainable measure being taken with fluid style gets prominent here. (Thomas Buseck)

6.2 London Aquatic Centre, Designed by Zaha Hadid Architects

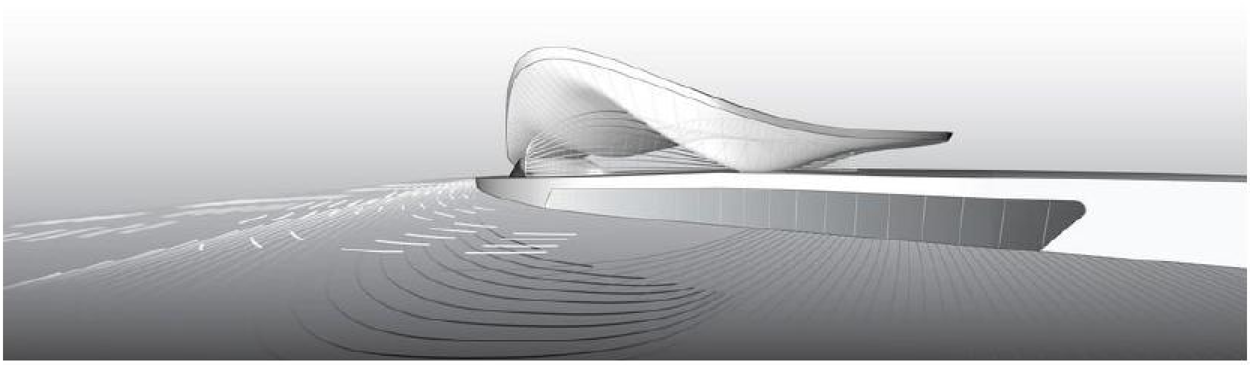


Fig.6.2.a.i. Rendered view of the building

- **Client:** Official Development assistance (ODA)
- **Design Category:** Leisure and Stadia
- **Architect:** Zaha Hadid Architects
- **Main Contractor:** Balfour Beatty
- **Location:** London, Britain
- **Value:** £3.5 million
- **Construction Value:** £2.4 million
- **Construction Period:** June 2008 to July 2011
- **Workers:** Around 40,000
- **Capacity:** 2,500 permanent, 15,000 temporary
- **Main Pool Volume:** 180,000 cu m

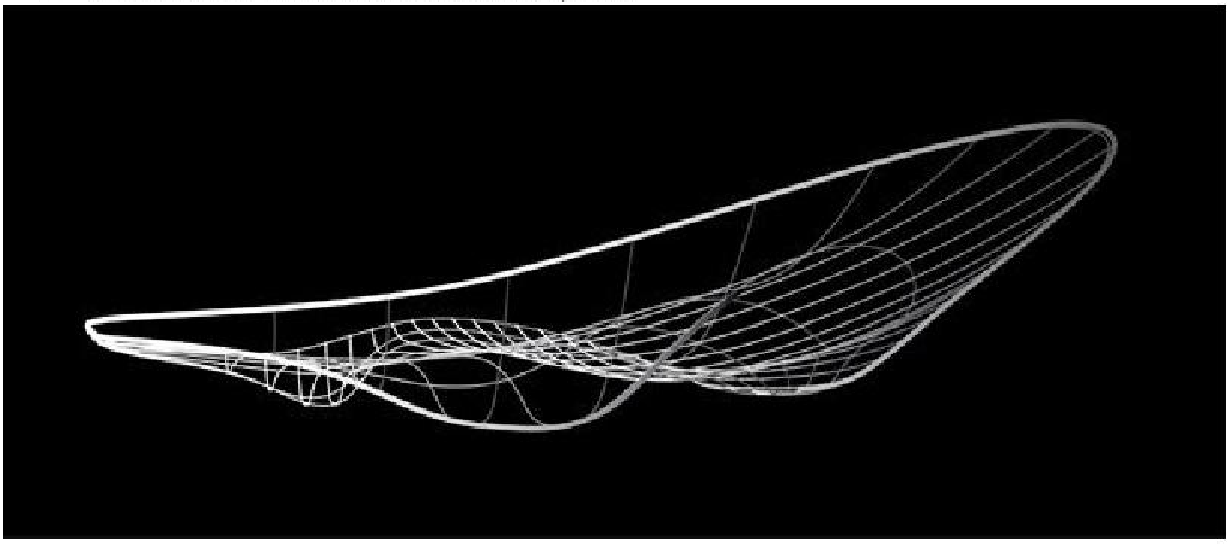


Fig.6.2.a.ii. Concept drawing made using Mathematica

Architect Zaha Hadid is world renowned architect and is famous for challenging building forms. Her extensive knowledge in mathematics gives her an upper hand in understanding curves and fluid geometries. Her inspiration in this design was to evoke the notion of a swimmer breaking the water. the striking wave-form roof smoothly sweeps upwards from the south edge before curving gently down at the northern side. A subtle upwards curve also features at both the eastern and western tips of the roof to further emphasise the structure's fluid design. (Aqua centre , 2011)

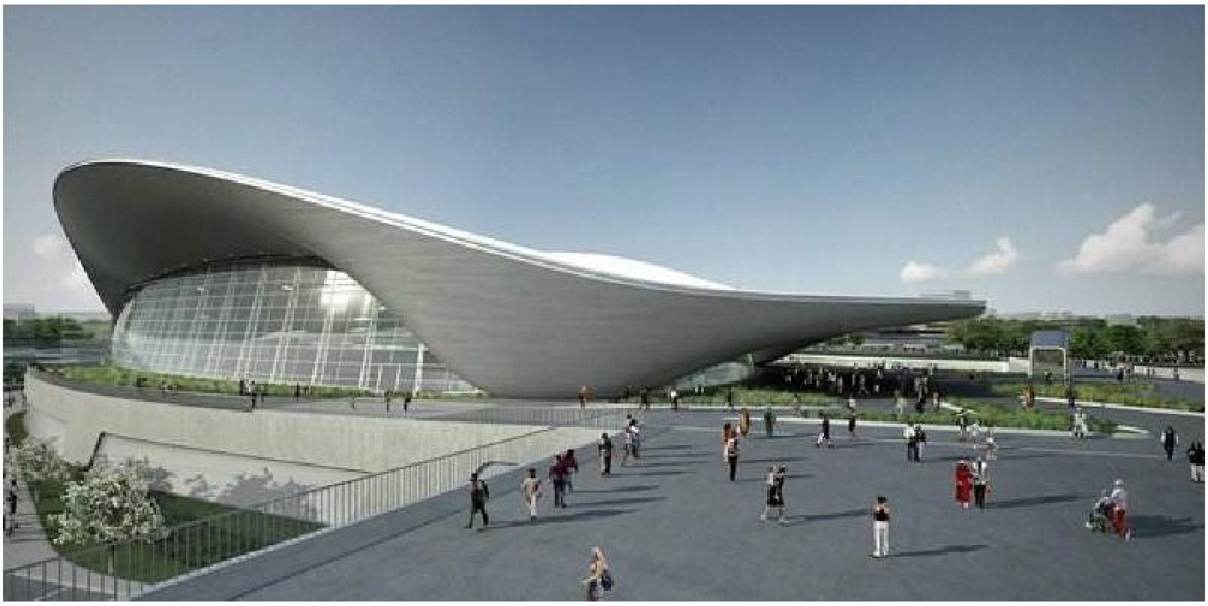
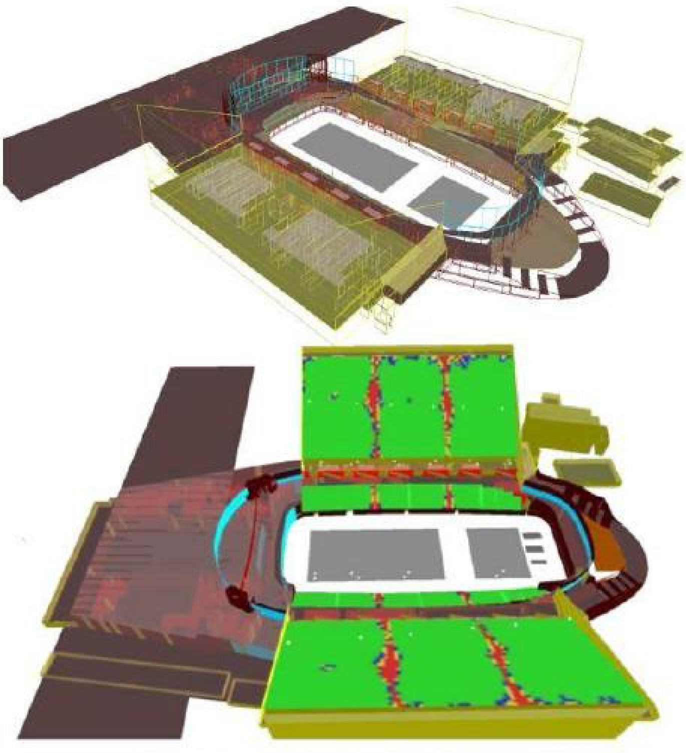


Fig.6.2.b.i. **Rendered view of the Aquatic Centre**

The Aquatics Centre hosted all swimming events for the 2012 summer games with capacity for over 18,000 spectators during the games. After the Olympics two temporary seating stands was removed and reduced the capacity to 2,500.



Top – Detailed 3D prediction software model
Bottom – Detailed 3D soft Handover Prediction

Fig.6.2.b.ii. **Detailed 3d model using grasshopper**

- Complete public and operational coverage within the building and immediate exterior.
- A high density solution capable of meeting the voice and data demand for2012 Olympics Games as generated by the public, VIP guests (inclusive of IOC) and key stakeholders
- Robust and dedicated coverage to all back of house areas.
- Capable of supporting all current technologies for all UK mobile operators.
- High carrier counts for all mobile operators and full ICNIRP compliance for all antennas.
- A dedicated In-Building DAS solution with excellent availability on the seating tiers and external microcells providing coverage to spectator holding areas.

(London Aquatics Centre)

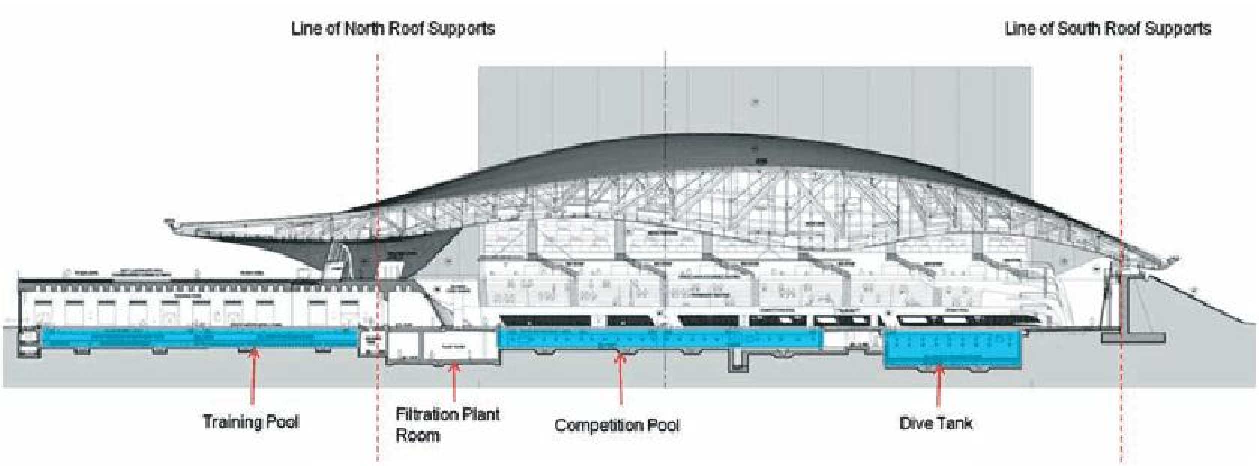


Fig.6.2.c.i. Section along the North-South Axis

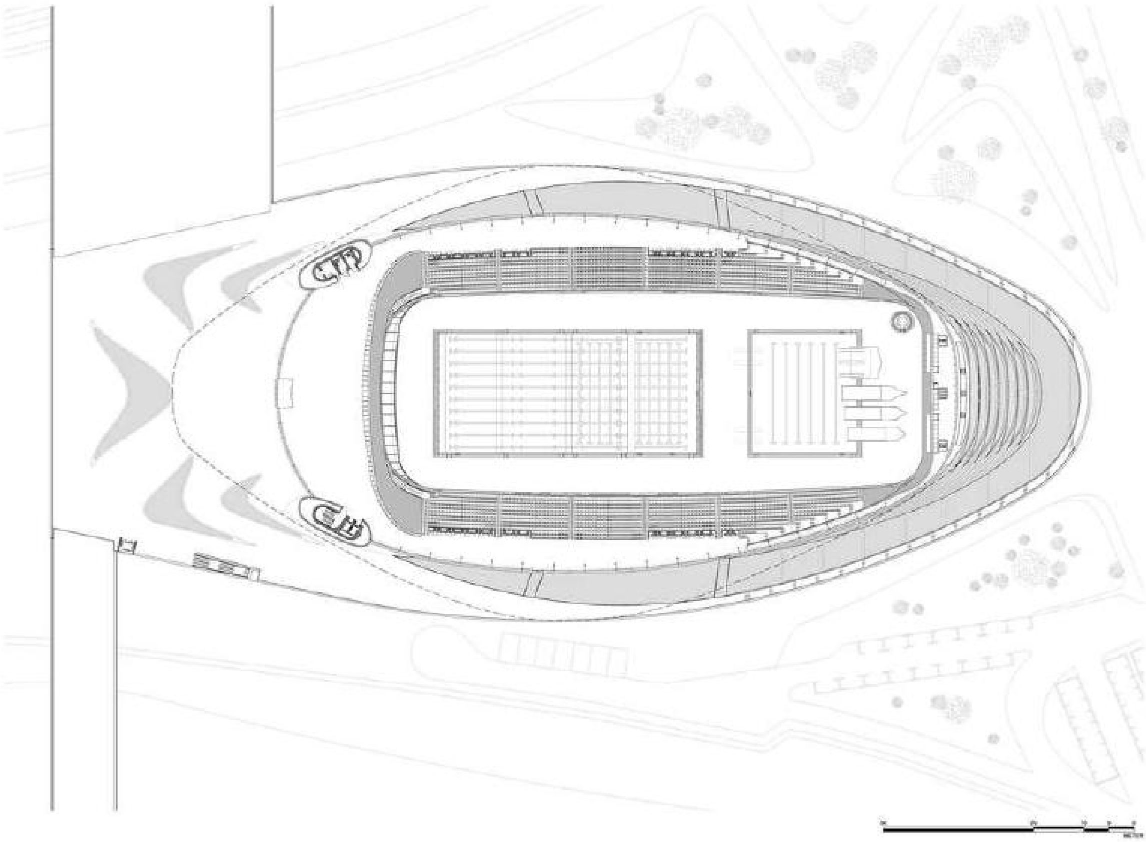


Fig.6.2.c.ii. Ground floor Plan

It must be noted here that the roof of the building was designed to form a fluid structure inspired by the notion of swimmers breaking the water but the functionality of the design has been carefully achieved. (Aqua centre , 2011)

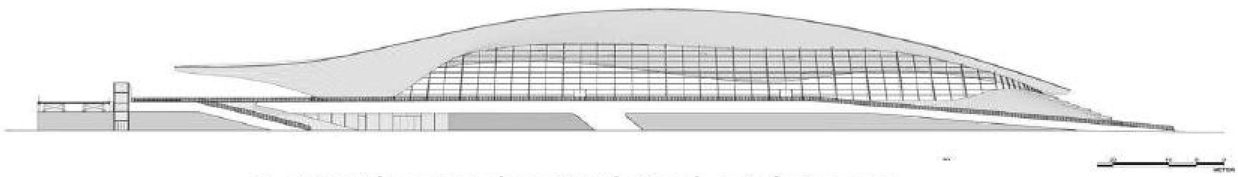
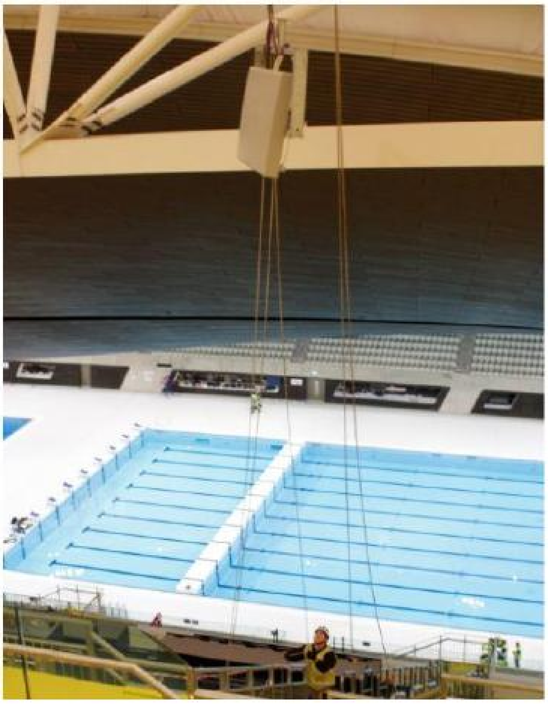


Fig.6.2.d. **Elevation along North-South axis facing east**



The build programme for this project was complex due to the tight access window between the start on site and the test event schedule. A phased approach was used to maintain system availability during the various build stages.

The build programme consisted of the following:-

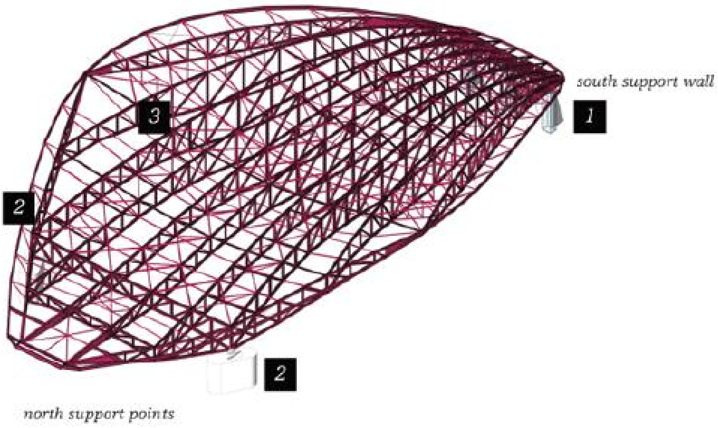
- 3weeks for all seating bowl antenna and steel work installations
- 2weeks for all roof void remote unit installations
- 2 weeks for bowl feeder and fibre rigging and for internal BOHDAS installation
- 2 weeks for bowl antenna optimisation and active equipment commissioning

THE SOLUTION

- 12 seating bowl sectors
- 8 internal DAS sectors which provided coverage to athletes and officials areas, operational areas and VIP lounges
- 3 microcell sectors.
- 3 Km of coaxial feeder cable (1/2"to1 5/8")
- 7.5Kmoffibre cable
- 98antennas (36withinthebowl)

The structural system of the roof was a challenge. Firstly it should be observed that the roof is supported on the major columns. These columns take all the vertical load coming from the trusses. The truss system is installed on the edges of the roof to achieve the curve shape of the roof.

(Olympics2012) (Arch daily, 2011)



How the roof structure works

The whole roof structure is supported on just three points: a wall at the south (1) end and two concrete cores to the north (2).
Despite its complex shape the roof is made up from relatively simple two dimensional elements.
The fan trusses (3) run in a north-south direction and are shaped to clear the diving (4) and competition (5) pools.
The trusses incline outwards from the centre like a fan, the two outer trusses (6) act as inclined tied arches which create two cantilevered wings on either side of the building for the temporary seating.

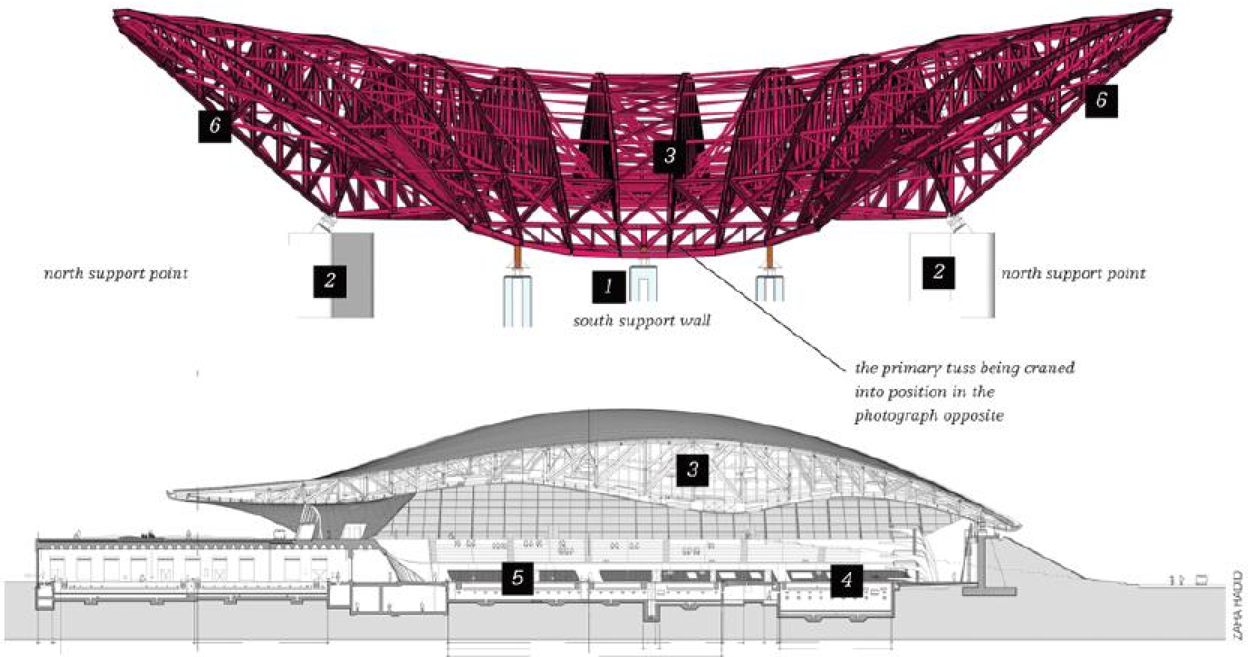
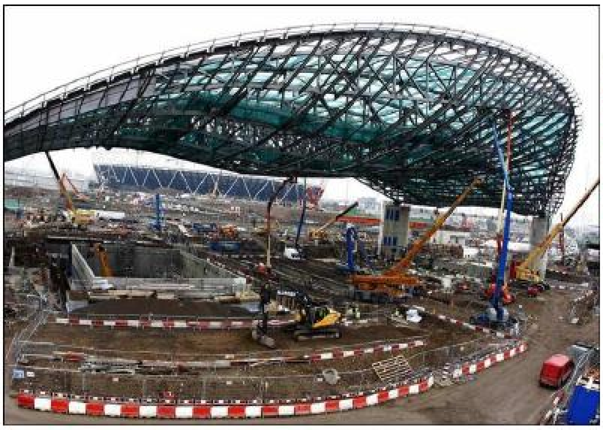


Fig.6.2.e. Elevation along North-South axis facing east



Energy Efficiency

An energy model was built early on in the design to assess in detail the building energy loads and to assist in understanding where the predominant loads were and which were less significant. The model evolved with the design and formed the basis of both the Part L carbon emission calculation (as required for Building Control and to demonstrate Olympics Delivery Authority efficiency targets) and of building energy modelling in use in accordance with the ODA requirement. The Aquatics Centre improvement on Building Regulations Part L 2006 is 49%, based on the as-built commissioning data, but prior to the legacy installation (such as the building air permeability test). This is broken down into 16.5% from efficiency measures in building services systems and the remainder from the district heating and power systems. (Smooth as Water, Strong as Steel: The Undulating Roof of London's Olympic Pool)

The base thermal model was also used to prepare more detailed energy performance modelling calculations to assess the building more closely to its intended use, outside of building regulations requirements. A carbon emission comparison with other UK 50 m swimming pool venues was carried out. This information is from the existing building's Display Energy Certificate results. Each venue differs in area and function, for example, many contain more dry area sports facilities, which will naturally reduce the energy demand. (Design boom Aqua centre, 2011)

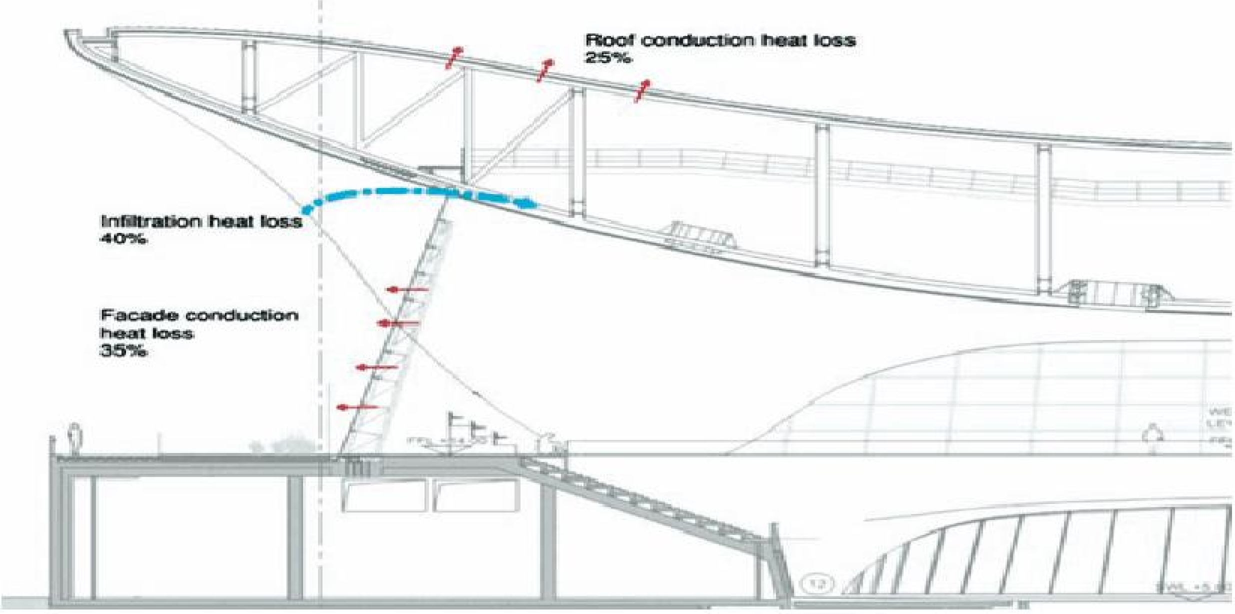


Fig.6.2.f.i Section of the roof

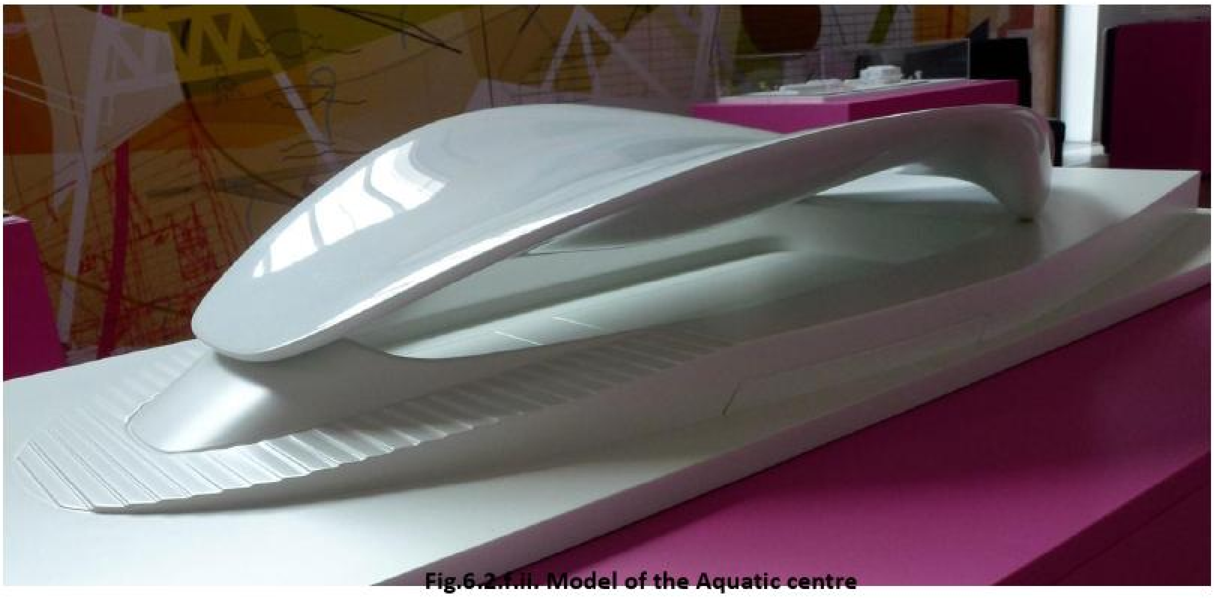


Fig.6.2.f.ii. Model of the Aquatic centre

6.3. Aqua Tower, Chicago

Fig.6.3.a. Aqua Tower in Chicago, U.S.A, Designed by Jeane Gang of Studio Gang Architects

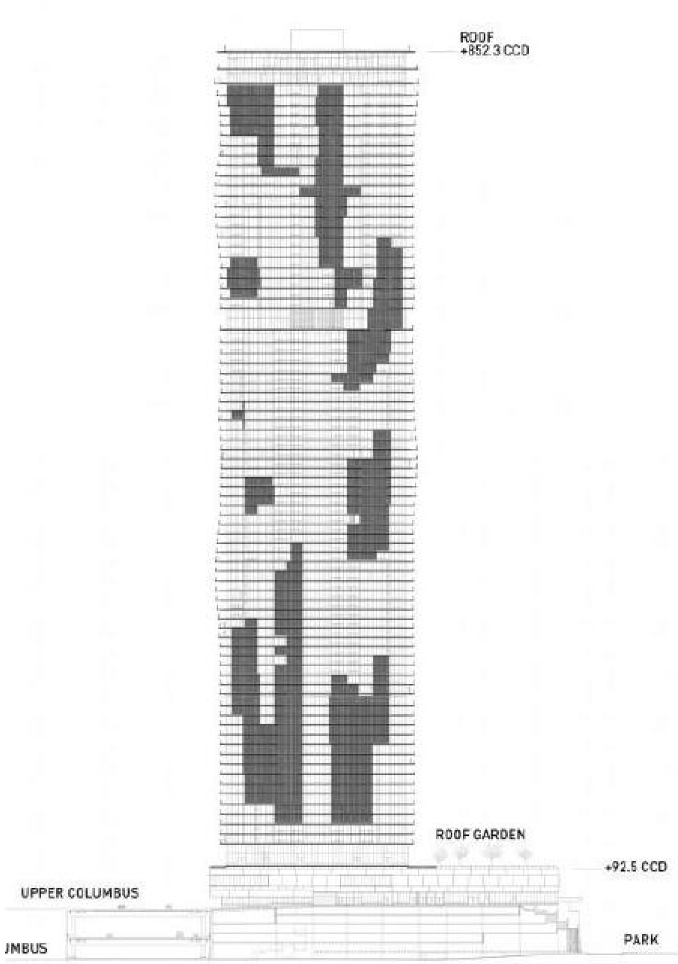


Fig.6.3.b.i. Section of the tower

Firm: Studio Gang Architects

Developers: Magellan Development group

Structural engineer: Magnusson Klemencic

Main Contractor: James Mchugh Construction Co.

Location: Downtown, Chicago, U.S.A

Construction Period: 2007 to 2009

Construction Cost: US$300 million

Owners: Aqua Realty Holdings LLC

Height: 261.8m (859 ft)

Floor count: 82 and 1 basement

Floor Area: 1,990,635 sq. ft.

(Aqua tower)

The aqua tower is a classic example of how the fluid architecture concepts can be incorporated in linear buildings. Architect Jeane Gang wanted to design a high rise building which would be inspired from high rise building from modern style of architecture and also somehow include the fluid aspect to make it appear like fluid architecture. It formed a unique structure and added more beauty to the city's skyline.

Fig.6.3.b.ii. View of the facade

To add the fluid touch to the building, she used concrete material beautifully in creating Ripples which she made the balconies for the apartments.

These ripples comes out of the glass facade and makes it appear like its flowing in the vertical direction. Again it must be noted that even here the interlinking of the fluid surface with the linear surface makes it one integrated block.

Fig.6.3.c. Aqua tower while it was getting constructed

To capture views of nearby landmarks for Aqua's residents, Gang stretched its balconies outward by as much as 12 ft (3.7 m).The result is a building composed of irregularly shaped concrete floor slabs which lend the facade an undulating, sculptural quality. Gang cites the striated limestone outcroppings that are a common topographic feature of the Great Lakes region as inspiration for these slabs.

The building contains 55,000 sq ft (5,100 m^2) of retail and office space, in addition to 215 hotel rooms (floors 1-18), 476 rental residential units (floors 19-52), and 263 condominium units & Penthouses (floors 53-81). Aqua is the first downtown building to combine condos, apartments and a hotel. Strategic Hotels & Resorts had agreed to acquire the first 15 floors of hotel space upon completion of the building, but terminated its $84 million contract for the space in August 2008, citing significant changes in the economic environment.

It includes one level of parking below ground. The building's eighty-story, 140,000 sq ft (13,000 m^2) base is topped by a 82,550 sq ft (7,669 m^2) terrace with gardens, gazebos, pools, hot tubs, a walking/running track and a fire pit. Each floor covers approximately 16,000 sq ft (1,500 m^2). The Aqua was named the Emporis Skyscraper Award 2009 skyscraper of the year, and was shortlisted in 2010 for the biannual International Highrise Award. (Diesenhouse, March 1, 2007.)

Fig.6.3.d. Aqua tower while it was getting constructed

The concrete forming technology behind Aqua's unique exterior design is Aluma's revolutionary Hi-Flyer system. The Hi-Flyer column-hung shoring system capitalizes on the advantages of traditional column-hung systems, while introducing new features that deliver significantly greater efficiencies. Used in combination with specialty castelite beams, the Hi-Flyer has enabled engineers to cantilever up to 14 feet without transmitting any load onto the balcony below. This is a critical component in creating the dramatic balconies that are perhaps the buildings most distinguishing characteristic. (Novak, 2010)

As the buildings' floor plans shift between retail, hotel and residential levels, design changes have created new complicated **concrete formwork** requirements. The Hi-Flyer is flexible enough to accommodate the transitional mechanical changes while fulfilling demanding time schedules. Aluma Systems is also intricately involved with the project to help maximize the Hi-Flyer's performance. Aluma's Engineering and R&D Teams have created Hi-Flyer accessories specifically for Aqua. Highly skilled Aluma concrete forming specialists assembled the units onsite and provided operators with training on the system. With outstanding versatility and performance the Hi-Flyer is delivering many critical time and labor saving efficiencies. "Through using Aluma's Hi-Flyer Shoring System, we have achieved an outstanding 3 day pour cycle. Its efficient design completely eliminates the need for re-shoring and our overall production time has improved by 30%," said Paul Treacy, Concrete Superintendent for the Aqua Project. (Lutz, Friday, 24 September 2010)

6.4. Tile of Spain, Installation

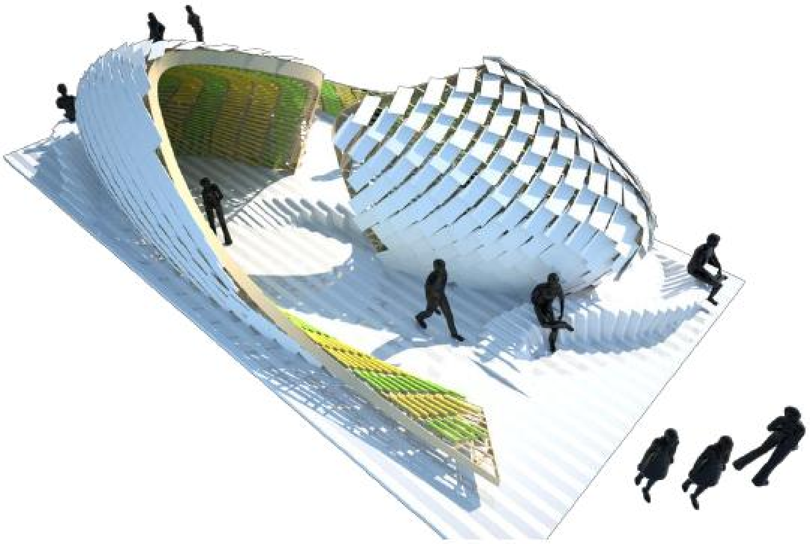


Fig.6.4.a.i. Isometric rendered view of the installation

Architects: José Ramón, GGlab + Paulo Flores

Design Team: Andrés Arias, José Ramón Tramoyeres, Paulo flores, Danilo Spiga, Povilas Cepaitis Lluis Enrique, Diego Ordoñez, Carlos Piles, Alberto Seller, Jaume Verdeguer, Miguel Rus, Arense Zaragoza.

Consultants: Cast on Cast (parametrization, optimization and digital manufacturing)

Fluidity Exposition: MADE – Milan, Italy 2011 , Cevisama – Valencia, Spain 2012

According to the architect, today's global society requires a greater continuity between the public and private, between indoor and outdoor spaces, from which new synergies arise, and lead to more dynamic urban spaces with a better relationship between cities and their inhabitants. Fluidity uses the characteristics of ceramics to respond to these needs, creating urban elements characterized by a double skin, in other words with an outer side, composed of elements that decontaminate the air, and an inner side consisting of extruded ceramic tubes. The floor is flexible, forming waves that move in synergy with the various layers of the skin. Walls, ceilings and floors interact with each other. (Tile of spain expo installation, 2011)

"The public space of the future is varied, composed of elements which interact with one another through the use of diverse materials and various building systems, leading to design projects with versatile functions"..........Ar. José Ramón

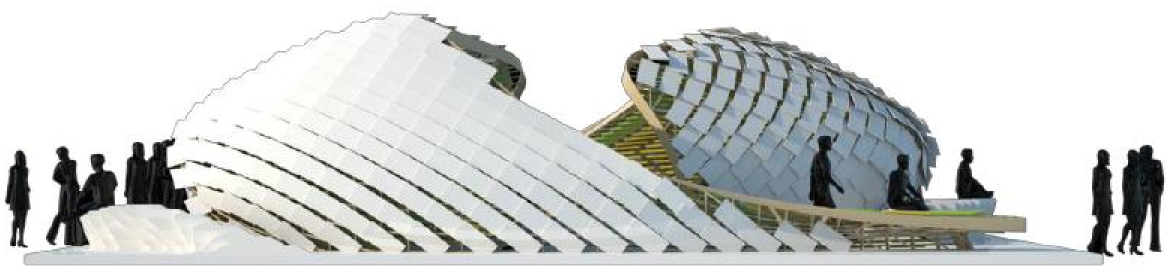


Fig.6.4.a.ii. Elevation of the installation

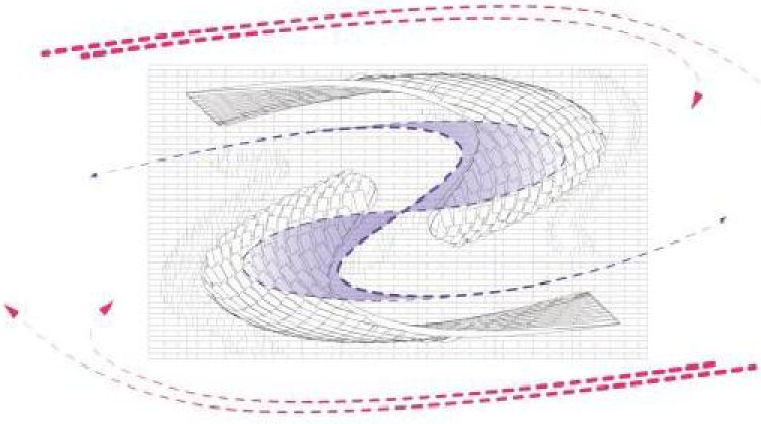


Fig.6.4.a.i. Isometric rendered view of the installation

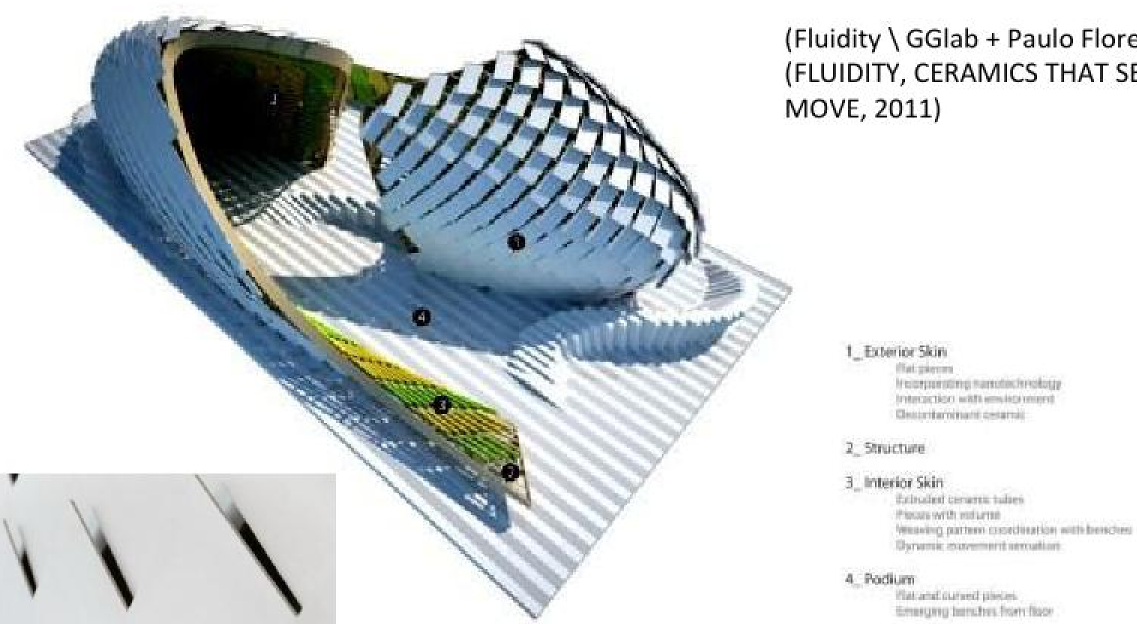
The adjacent figure shows how the designer had interpreted the circulation pattern. It seems as if the designer was looking for a dynamic pattern of flow of circulation and through extensive manipulation achieved this.

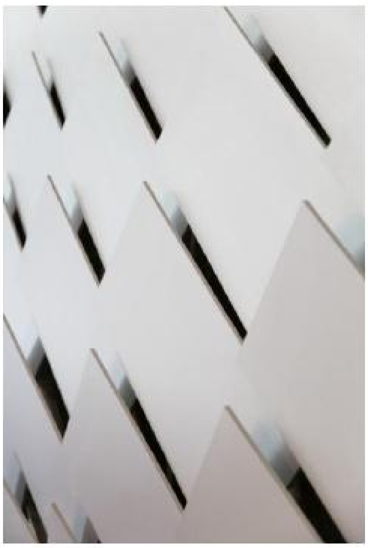
The ideology behind this form is an approach towards a better connection between the indoor and outdoor spaces in urban development and how an integrated design module (in this case installation) can be created to allow such movements.

CONSTRUCTION

The public space of the future is a varied space, composed of elements which interact with one another through the use of diverse materials and various building systems, leading to design projects with versatile functions.

(Fluidity \ GGlab + Paulo Flores, 2011) (FLUIDITY, CERAMICS THAT SEEM TO MOVE, 2011)





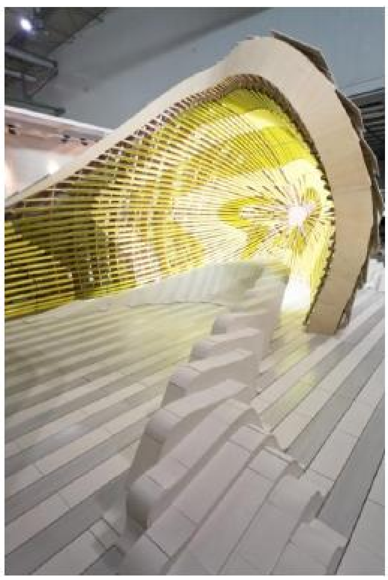


Fig.6.4.a.ii. Construction method of the installation

8. COMPARATIVE ANALYSIS

To understand the concept and form development, an analysis of fluid buildings is imperative where it will be based on parameters defining the samples. Because every fluid building has been designed by different designers and through different form manipulation techniques using various softwares, it becomes a challenge to understand the building dynamics.

PARAMETERS	**AQUA CENTRE**	**AQUA TOWER**
BUILDING LOCATION	LONDON, UNITED KINGDOM	CHICAGO, U.S.A
BUILDING TYPOLOGY	EXPO BUILDING BUILDING FOR INTERNATIONAL SWIMMING EVENTS, LEISURE AND STADIUM	RESIDENTIAL BUILDING CONTRIBUTING TO THE SKYLINE
ARCHITECT	ZAHA HADID STUDIO AR. ZAHA HADID	STUDIO GANG ARCHITECTS AR. JEANE GANG
THE IDEA	EVOKE THE NOTION OF A SWIMMER BREAKING THE WATER	FLUXING THE FLUID DYNAMICS TO THE MODERN STYLE HIGH RISE BUILDING
SOFTWARES USED	GRASSHOPPER, RHINOCEROUS, MATHEMATICA ETC.	MATHEMATICA, EXCELSHEET SIMULATION, GRASSHOPPER, SCRIPTING
BUILDING SPAN AND SIZE	SITE AREA : 36,875 SQ. MT. BUILTUP AREA : 80,713 SQ. MT. HEIGHT : 45 MTS.	BUILTUP AREA: 184,936 SQ. MTS. HEIGHT : 261.8 MTS
FLUID CHARACTERISTICS	THE ROOF IS THE MAIN FLUID ELEMENT. APART FROM THAT THE INTERIORS BLEND WITH THE ROOF WHILE THE FALSE CEILING IS A FLORAL PATTERN.	IT'S A SIMPLE MODERN STYLE HIGH RISE TOWER WHERE THE PATTERN OF BALCONIES ARRANGED IN A SMOOTH FREE FLOW LIQUID FORM. IN THIS CASE ONLY THE FAÇADE SHOWS FLUIDITY.
MATERIALS USED	R.C.C., GLASS, STEEL FOR REINFORCEMENT OF WALLS, STEEL FOR TRUSS SYSTEM	R.C.C. FOR STRUCTURE, STEEL FOR REINFORCEMENT, P.C.C. FOR FLUID BALCONIES
CONSTRUCTION TECHNIQUES	THE ROOF IS SUPPORTED ON THREE COLUMN SUPPORT WITH THE TRUSSES RUNNING ALONG TO SUPPORT THE CONCRETE LAYERING	THE FLOOR SLABS ARE DESIGNED TO FORM ALTERNATE RIPPLE PATTERN ON EVERY FLOOR USING NUMERICAL SIMULATION IN CONCRETE.

Table 1.1 Analysis of Aqua centre and Aqua tower

Although the concepts are not constructed but the essence of fluidity in a buildings is very well retained in them. The method of designing and the process of forming ideas out of mixing spaces and forms with each other through various softwares is established. It must be noted again that fluid style can be achieved through intensive software simulations and algorithms. The Algorithms form the codes for every design. Every design has its own unique algorithm which the designers retain as copyrights measures.

PARAMETERS	AIRPORT CONCEPT	TILE OF SPAIN, ITALY
BUILDING LOCATION	INNSBRUCK, AUSTRIA	ITALY, ROME
BUILDING TYPOLOGY	EXPO BUILDING	INSTALLATION ART
ARCHITECT	AR. THOMAS BRUSECK STUDENT UNDER AR. PATRIC SHUMACHER	AR. JOSE RAMON G.G. LAB + PAULO FLORES ARCHITECTS
THE IDEA	BUILDING BLENDS IN WITH THE LANDSCAPE	CONTINUOS FLOW BETWEEN INDOOR AND OUTDOOR SPACES
SOFTWARES USED	GRASSHOPPER, GEOMETRYGYM	GRASSHOPPER, MATHEMATICA, EXCEL SHEET SIMULATION PLUGIN
BUILDING FOCUS	ROOF DESIGN, STRUCTURAL EXPLORATION	MATERIALS AND FORM
FLUID CHARACTERISTICS	ROOFING SYSTEM COMPATIBILITY WITH THE FLOOR FORM. ROOF DESIGN WITH 3 LAYERS OF ROOF PATTERN	ELEMENTS OR MATERIALS WHICH CAN DEPICT THE DYNAMISM OF MOVEMENT BETWEEN SPACES
MATERIALS USED	FERROCEMENT, P.C.C. , R.C.C. FOR STRUCTURE, GLASS PANELS	CERAMIC PANELS, TUBULAR CERAMICS,TEXTURED TILES
CONSTRUCTION TECHNIQUES	3 DIFFERENT PATTERNS OF ROOF PLACED ONE OVER THE ANOTHER TO CREATE A FLUID SHELL ROOF KIND STRUCTURE.	EXTRUDED TUBULAR CERAMICS FOR INTERIORS, TILES RUNNING THROUGH THE FLOOR EXTRUDING AT CERTAIN POINTS TO FORM BENCHES,

Table 1.2 Analysis of Airport and Tile of Spain

8. CONCLUSION

The times are constantly changing and it won't wait for anyone. Since the start of our world, times have changed, situations have changed and so have the people. With so many parameters changing constantly over time, the architecture also evolved. From Egyptian, Byzantine and Mesopotamian to Gothic, renaissance to modern and post-modern and now contemporary to dynamism and parametricism. There is always a need of change in architecture style and methods when there is change in human needs and human evolution. But the important thing that needs to be learned is though there has been extensive changes happening in architecture and building industry, the past should not be forgotten and the things that it taught must always be there in the back of mind .

It's been a while that fluid architecture has been introduced and the concept took some time for people to understand. But now more and more people are adopting fluidity in their designs due to its advantageous features. Due to softwares now, designers can easily visualise complex dynamics in a design and also get a better understanding of their own designs. Every point, line, curve or geometry have a certain mathematical calculation or equation which can take complex turns in fluid designs. But the softwares now allows a designer to design a structure while it automatically does the calculation for that structure. This gives a advantage to the designer on control of the design parameters.

The fluid characteristics can be easily observed at first glance. Surfaces don't have any 90 degree clear cut angle. All the elements of the surface would be connected and there is no essence of any beaks or cuts in between. The most important observation in a fluid inspired building is that the entire building is considered as one integrated block. There are no individuality to the complex and the block is treated with patterns, shapes and geometries in order to achieve fluidity.

The essence is what matters here. The form forming method and how from lines to curves and geometries gets formed with predictability is important. Even if the building represents only a fragment of aesthetic appeal, sometimes the pattern in which the blocks are formed becomes a fluid characteristics. Sometimes it's not even about the building and rather it's becomes more prominent on the other characteristics. Circulation pattern, wall design, openings, shafts, windows, etc can also work as depicting fluid characteristics.

Fluidity is a style of architecture and not a method. The design process always had critical stages which every designer must follow. While designing in this concept, it might get neglected or overlooked. Even now architects and designers are exploring more into this concept attempting to discover new methods and techniques. Fluidity is a broad and wide subject which can be candidly explored, studied and implemented.

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