FREE-FORM GEOMETRY IN ARCHITECTURE

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Abstract

Free Form means – the language of geometry in the field of architectural description its special geometry, new, mysterious, and light, which required new innovative space or department to present the power of this term. The specified function should be placed in the prescribed, geometrical form. Only good teamwork between architects, designers and structural engineers enables resolving issues related to creating and building freeform structures. Free form Geometry alone is not able to provide solutions for the entire process of thinking, but a pure geometric understanding is a remarkable step toward a successful realization of such a project (Pottmann H 2007).

Free-form geometries in architecture were considered one of the most significant phenomena in modern design with the technical developments of material properties and the digital designing tools in contemporary architecture, subsequently, this process makes architecture more creative and at the same time flexible and breaks away from regularity. Free-Form parametric geometries can bring and spire new concepts in contemporary architecture now and in the future.

Keywords: Free form geometry, Parametric design, Deconstructivism, Grasshopper, Tensegrity, Light tensile structure.

INTRODUCTION

Architectural styles and forms since antiquity, inclusive of Modernism, have thus been aimed at geometrical control via simple geometric solids like cubes, rectangular prisms, cylinders, pyramids, and semi-spheres. Euclid's Elements remained a standard up to the 19th century, and this idea continued until the 20th century, the straight lines and the right angles were the main tools in architectural design, as we know now, this concept is limited in terms of classical geometry. Classic geometry is a branch of mathematics concerned with shape, size, positions, and properties. Originated earlier as knowledge concerning one-dimension (length, bar), two-dimensions (area, surface), and three-dimensions (volume, space), with elements of formal science. Static shapes are often straight with horizontal lines and may appear quiet and active shapes are diagonal with orthogonal lines. This behaviour of traditional interpretation of geometrical design was caused by a lack and ignorance of the existence of computational and material characteristic tools. The principles behind this "computation" have also been computationally recreated and are now in principle available to designers.

Designers are attempting to change all proposal requirements into shapes and spaces by adopting processes and a series of aim-oriented steps. However, a proper design means that it has an identity where all components agree with the context and requirements of modern and future times. This problem requires designers to understand and analyse sets of relationships between parameters and components. One of the useful tools for producing architectural designs is to convert aims into abstract shapes. In its long history, algorithmic plan as a form-finding strategy, permitted designers to oversee complex non-standard associative geometries, recommending a move from the computerized representation of frame to its efficient representation into a parametric demonstration through code. Modern geometry became more attractive in the architectural design process with great innovations from form-finding stages to the final fabrication. Besides, the various pieces of simple form or shape can produce complicated and complex geometries through the effects of joints. As it is known, the basic elements of standard shapes are line and plane, positive-curved line guides the spherical geometry, while a negative-curved line guides hyperbolic geometry. Analysis of free-form findings categorizes them into folded, blob and formlessness geometries. Instead of a style or a device, the parametric model is best characterized in numerical terms; in practice, it joins the organizational logic of the shape and the topological associations of its parts so that a change in its constitutive parameters will invoke a concerted overhaul of the complete demonstrate, and, iteratively, formal, and structural varieties.

Folded geometries emerged and became popular in the contemporary era, they had inspired by several architects to create three-dimensional models (geometry) from two-dimensional sheets (surfaces). So, folded geometries are formed by repeating some of the approximate prototypes of polygonal geometric forms. Blob geometries have free-form, irregular, and unfamiliar compositions that consist of plane surfaces.

Fig. 1. Blob form of BMW Bubble Pavilion in Germany https://archello.com/project/bubble

Formlessness geometries can be considered as an advanced and developed geometry of the de-construction movement which has changed the forms, spaces, and the overall definition of geometry inspired by the nature (Pottmann H 2007).

Free-form geometries were considered one of the most significant phenomena in modern design with the technical developments of material properties and the digital designing tools in contemporary architecture, subsequently, this process makes architecture more flexible and breaks away from regularity. Free-Form geometries can bring and spire new concepts in contemporary architecture now and in the future.

1 INDUSTRIAL REVOLUTION (1840-1900)

Iron and glass techniques, lightness, transparency, openness in urban facades, large windows in metal frames, steel skeleton construction and elevators.

2 20th CENTURY

Modern - Austrian Adolf Loos - Goldman & Salatsch department store

2.1 Futursim and Constructivism

- Italy - ideas and artistic direction - futurism (future)

2.2 Constructivism

The Russian abstract art movement developed by Kazimir Malevich c. 1915, was characterized by simple geometric shapes and associated with ideas of spiritual purity.

Constructivism - Constructivism was formed in 1915 by Vladimir Tatlin and Alexander Rodchenko as an early twentieth-century art movement. Constructivist art was abstract and austere, with the goal of reflecting modern industrial civilization and urban areas. In favour of the industrial assemblage of elements, the movement disregarded decorative stylization. Constructivists were associated with Soviet socialism, the Bolsheviks, and the Russian avant-garde, and were proponents of art for propagandist and social reasons. Constructivist architecture and art significantly influenced twentieth-century modern art movements, including the Bauhaus and De Stijl movements. It had a significant impact on architecture, sculpture, graphic design, industrial design, theatre, film, dance, fashion, and, to a smaller extent, music.

Constructivism was a post-World War I extension of Russian Futurism, particularly Vladimir Tatlin's 'counter reliefs,' which were first shown in 1915. The term was invented by sculptors Antoine Pevsner and Naum Gabo, who produced an industrial, angular style of work, with geometric abstraction influenced by Kazimir Malevich's Suprematism. Gabo's Realistic Manifesto of 1920 coined the term "constructivism." The word was used as the title of Aleksei Gan's book Constructivism, which was published in 1922.

2.3 Constructivism - Soviet Union Brothers Vennochi - Noi Trotsky

2.4 Expressionism and Rationalism - Peter Behrens - AEG Turbine Factory

Expressionism - Expressionism is a modernist movement that began in Northern Europe around the turn of the twentieth century, initially in poetry and painting. Its defining characteristic is to depict the world purely from a subjective point of view, dramatically altering it for the emotional effect to elicit moods or thoughts. Instead of expressing physical truth, expressionist artists aimed to communicate the meaning of emotional experience. Expressionism arose as an avant-garde movement prior to World War I. During the Weimar Republic, it was particularly popular in Berlin. Expressionist architecture, painting, literature, theatre, dance, film, and music are only a few examples of what the style included.

“German émigré Mathias Goeritz published the Arquitectura Emocional in translation to English it was called Emotional Architecture manifesto with which he declared that "architecture's principal function is emotion".”

2.5 Expressionism and Rationalism- Walter Gropius, Adolf Meyer - Fagus factory

- Ernst Ludwig Kirchner (6 May 1880 – 15 June 1938) was a German expressionist painter and printmaker.
- During WWII, Nazis destroyed or sold more than 600 pieces of his work, it was branded as degenerated, because of the expressionist style he used.
- He committed suicide, one year after the destruction.
- He was one of the founders of the artistic group called die Brücke, or the Bridge, along with other artists or architects.
- die Brücke is an expressionist style, which was created in Dresden, Germany in the year 1905, it is called die Brücke because it symbolizes the connection of expressionist artists in Europe – a bridge.
- The artists wanted something new, something that was more about feelings and emotions, rather than the academic painting type, which was supposed to capture and describe the reality of the world, the same as we see it, this style does not mirror the reality that much, as the ones before
- The content was emotionally based, expressing the feelings of the subject or the artist.
- They expressed themselves with some key features of the style, for example, the extreme contrasts, clear saturated colours, thick brush strokes, usage of light or the space without any shading or modelling.

2.6 Expressionism and Rationalism

Bauhaus - Weimare 1919 Walter Gropius – Bauhaus

1.7 Modernity (1900-1945)

New constructional systems, materials and way of life that was emerging. The most daring execution of a glass facade in this period is Mies van der Rohe's design for a high-rise in Berlin (1922), with no structural function in front of the facades.

The volume no longer appears transparent and light, but almost opaque, the building must be

plain and simple. Before modernism, all conscious compositions were designed, and the divisions of architectural styles were further governed by symmetry and a system of simple ratios. Since modernism, asymmetries and arbitrary proportions have become feasible.

3 SECOND HALF OF THE 20TH CENTURY PERIOD (1945-2000)

Reinforced concrete, wide-spanning, thin membrane structures, and other progressive construction techniques and did not consider the fulfilment of functional requirements.

All conceivable geometric forms could now be enclosed with unswerving regularity, without operable windows and reliant upon artificial air-conditioning.

3.1 Arch

We also include the arch among the planar structures. Nowadays, they are most often used as supporting elements (e.g., bridge girders), but it also serves as an architectural element - the shape of a parabola, which has the highest load-bearing capacity from a static point of view. Arches have already appeared in architecture in the ancient past, in Mesopotamia, then in Ancient Greece and Rome in the form of triumphal arches and aqueducts.

There is a very characteristic Romanesque arch or a Gothic broken arch in Slovak history. In Gothic, arches were often combined with arches.

Fig.3.1.1. Gateway arch. in St. Louis, USA

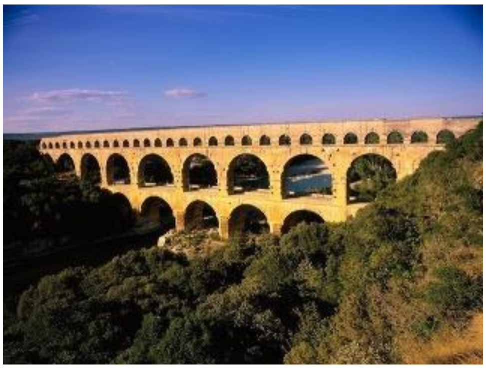

Fig.3.1.2. French aqueduct

http://gateway-arch-170279

Parametric, in mathematics, is a set of quantities expressed as an explicit function of a number of parameters, such as the formulas that describe the catenary curve: $x(a,t)=t$, $y(a,t)=a \cosh(t/a)$.

Subsequently, "a parametric model is a set of conditions that express a geometric model as explicit capacities of a number of parameters". This numerical definition of the parametric catenary curve characterizes the modified suspension models with strings and birdshot weights utilized by Antoni Gaudí to consequently recreate by simply means the course of the forces and in this way the numerous varieties of the frame of his Colònia Güell chapel, according to the set of results that determined from the parameters (string length, anchor point location, birdshot weight). Similar simple strategies for parametric calculations were afterwards clarified by Frei Otto at the Institute for Lightweight Structures (ILS), who utilized a few tests of form-finding and optimization methods, as reported within the ILS distributions. A parametric model is special not for what it does but rather for how it was made.

In this way, the utilisation of parametric models in the computerized plan permits architects to depict the geometry of their model (either orthogonal or curvy) with adaptability and make conditions between the components of the model, using particular rules and limitations. To make parametric models, designers utilize algorithmic editors that ordinarily consolidate visual programming dialects (like Grasshopper/Rhino3d, Max/MSP or Revit/Dynamo), to overcome the imperatives of the interface, and to design specifically, overseeing not the form (with the plan devices given by common program packages), but the code that produces the shape. In this way, the designer can define the associations of the parts of the parametric model into code, so that an alteration within the parameters that depict it'll, cause a facilitated general upgrade in this way watching the varieties of the created comes about.

An example of a parametric equation is the formulae that define a catenary curve:

$x(a,t)=t$, $y(a,t)= a \cosh(t/a)$

These two formulae meet the criterion of a parametric equation. Firstly, they express a set of quantities (in this case an *x* quantity and a *y* quantity) in terms of several parameters (*a*, which controls the shape of the curve; and *t*, which controls where along the curve the point occurs). Secondly, the outcomes (*x* & *y*) are related to the parameters (*a* & *t*) through explicit functions (there is no ambiguity in the relationships between these variables) (D. Davis, 2013). This is the origin of the term *parametric*: a set of quantities expressed as an explicit function of several parameters. An explicit function is a function whose output value is given explicitly in terms of independent variables. For example, the equation $x \cdot x + y \cdot y = 1$ is the implicit function for a circle. The function is implicit since the outputs (x and y) are defined in terms of one another. To make the function explicit, x and y have been defined in terms of an independent variable. Thus, the explicit function of a circle becomes x = cos(t), y = sin(t). Visual programming involves representing programs not as text but rather as diagrams.

Both Grasshopper and Generative Components are based on graphs (a mathematical name for a type of flowchart) that map the flow of relations from parameters, through user-defined functions, usually concluding with the generation of geometry. Changes to parameters or the model's relationships cause the changes to propagate through the explicit functions to automatically redraw the geometry.

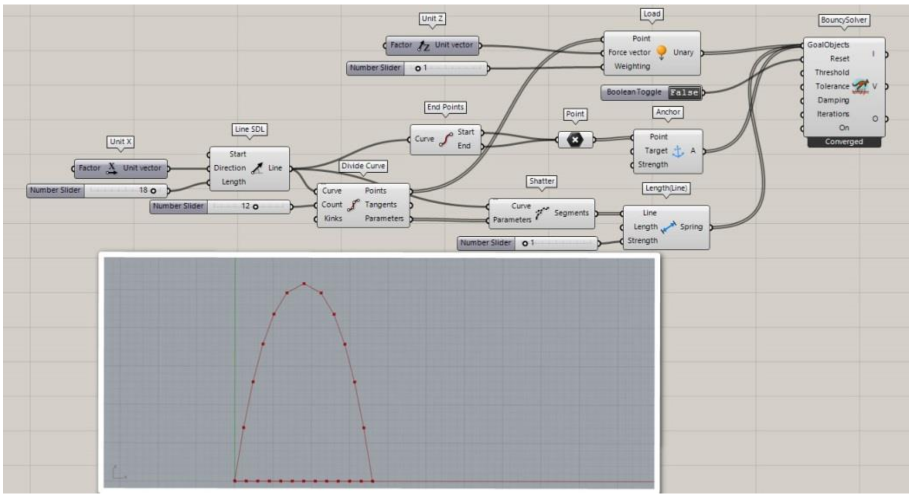

Fig.3.1.3. Grasshopper Script created by the authors

Form finding with kangaroo 2 in grasshopper. Kangaroo is a physics-based solver that is now included with Rhino and is embedded in grasshoppers like a plug-in for grasshopper. Used physics to create forms, gravity, tension, minimal surfaces, compression, relaxation, and optimization are known in the realm of physics.

3.2 Museum of Contemporary Art City

NITEROÍ, BRAZIL Architect: Oscar Niemeyer

The museum stands on a cliff in Niterói, near Rio De Janeiro, which lies at the opposite end of the bay. The construction was completed in 1996 and Oskar Niemeyer collaborated with Bruno Contarini on it. The main above-ground mass is formed by a part of the rotating conical surface.

3.3 Solomon R. Guggenheim City

NYC, USA Architect, Frank Lloyd Wright, Right-handed straight screw surface

The Guggenheim Museum was completed in 1959 in Manhattan, New York. There is a permanent collection of impressionists, modern and contemporary art, which is constantly expanding. The author of the design is the most famous American architect FL Wright. The ramp in the interior is formed by a clockwise straight screw surface.

3.4 One-Piece Rotating Hyperboloid

MCDONNELL Planetarium City: Sant Louis, USA Architect: Gyo Obata

The Planetarium is part of James McDonnell's Saint Louis Science Centre, one of the world's leading space education centres. The roof of the planetarium is formed by the surface of a rotating one-piece hyperboloid.

3.5 Meadows Museum City

DALLAS, USA Architect, Santiago Calatrava

Wave by Spanish artist and architect Santiago Calatrava in the Meadows Museum Garden.

A massive kinetic sculpture made of 129 steel bars encased in bronze over a black granite pond. It was manufactured in 2002. The surface is formed by a corrugated conoid.

3.6 Ball Surface

Erikson Globe Arena. Stockholm

3.7 Rotary Elipsoids

Light grid structures are particularly suitable for applications where large spans and low weights are required. This makes them potential candidates for architecture purposes. Usually, curved elements are aesthetically pleasing and functional, however, they are not easy to produce.

3.8 Rotating Hyperboloid

The original footbridge was destroyed in 1996 during a bomb blast, and in 1997 the restoration of the footbridge began according to the winning project. The new footbridge is formed by the area of a rotating one-piece hyperboloid. It is surrounded by a glass membrane, which expands above the street and acts very easily.

3.9 Anuloid

The area of the fourth degree created by the rotation of a circle around an axis which is in the plane of the circle lies on $(x^2 + y^2 + z^2 - r^2) = 4a^2 (x^2 + y^2)$

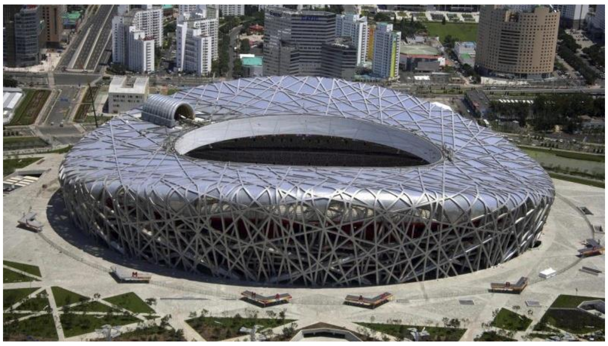

Fig.3.9.1.

3.10 Wall of the Nations City

ATHENS, GREECE Architect: S. Calatrava

The Wall of Nations is part of the Athens Olympic Complex. It is a sculpture made of steel tubes. The steel pipes are attached to the central axis. The surface consists of a corrugated conoid.

3.11 Research and Multimedia Center City

BASSANO DEL GRAPPA, ITALY Architect: Triaxial ellipsoid, Massimiliano Fuksas

The Nardini Distillery Research Centre project consists of two parts. The first part, containing the entrance hall and the lecture hall, is sunk into the ground. The second part protrudes above the surface and is formed by two elliptical bubbles, in which the research centre and laboratories are located. The fully glazed parts of the ellipsoids offer visitors a view of the beautiful landscape around Monte Grappa.

3.12 Los Manantiales Restaurant City

XOCHIMILCO, MEXICO, Architect: Felix Candela

Los Manantiales Restaurant was built in the south of Mexico City, in a recreation area called Xochimilcan, which means a place where flowers grow. The construction of the roof, the shape of which resembles a lotus flower, is one of the most beautiful buildings of the twentieth century. The roof consists of eight interconnected vaults of parts of hyperbolic paraboloids, situated above a circular floor plan. The restaurant was built on a peninsula between irrigation canals. The construction of the roof was thus reflected in the level between the flowers. Unfortunately, over the years, the level of the canals has dropped, and the gardens have been replaced by buildings. Much of the beauty of construction has been lost.

4 POSTMODERNISM (1980-present)

Postmodernist buildings combine new ideas with traditional forms to startle, surprise, and amuse its viewer. The postmodernist architecture of the late twentieth century featured a plurality of styles including high-tech, free-style classicism, neo-vernacular, classicism, and deconstruction. Postmodernism and deconstructivism focus on greater complexity but are still based on the same basic elements. However, these relatively recent styles allow for new ways of combining basic elements through random agglomeration, intersections, and substructures (Allen D Mar 2003).

5 LATE MODERNISMS

'Slick tech' look, the surface of these buildings is isotropic and endless, a grid of repeated shapes which might be extended infinitely, but which has, in volume, many subtle variations.

6 HIGH TECH

Most bearing members (steel, aluminium, and glass that combine with brightly coloured girders, and beams) of the building are prefabricated in a factory and assembled on-site. The interior spaces are open and adaptable for multiple purposes.

The structures and patterns were made for symbolic, theological, and philosophical purposes. Patterns are essential in Islamic architecture, based on its central metaphysical concept. The key aesthetic and ontological categories in Islamic philosophy, where the essence of wisdom consists of recognition and understanding, best-described patterns and ornaments in a complex hierarchical structure. The best example is the interior and furnishings of Moorish architecture. In the 13th century, at the Alhambra Palace in Granada (Spain), we find all essentially different types of patterns that can be created using an identical tile pattern. From the origins of the architectural "pattern book" (early 15th century Europe) to the present, in which patterns are increasingly important for architectural and space design, they enter the design process not only as a secondary decorative element but as a full part of it.

The importance of structures and patterns as a means of expression began to increase at the end of the 17th, and 18th centuries and culminated in the rise of global capitalism, the industrial revolution, and scientific projects in the 19th century. They are still aesthetically diverse, functioning as more sophisticated, but mechanically and functionally accurate. Theorists and architects, including Karl Friedrich Schinkel, John Ruskin, Alois Reigl, Christopher Dresser, and Louis Sullivan, have written ornaments. In the first period of pattern research and theorizing, 18th to 19th-century theorists sought to find ways to create infinite structures by observing simple species and their subsequent transformation into basic geometric elements. Modernist patterns and movements have also had a great influence on further importance and application, whether in architecture or urbanism. Although Christopher Alexander defined many new types of patterns and structures, as well as their practical application (such as fractals), these were not fully integrated and used in the next design process, whether architecture or urbanism.

Fig.6.1. The structure created by rotating and copying the basic geometric object (square) and its subsequent application to the pavilion object, also represents its construction, Serpentine gallery pavilion, London, design: Toyo Ito
https://www10.aeccafe.com/blogs/arch-showcase/2011/08/09/serpentine-gallery-pavilion-2002-in-london-uk-by-toyo-ito-with-arup/

The advantage of the use of linear surfaces in architecture is that the supporting structure can be composed of straight elements:

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• Unidirectionally curved elements (for expandable surfaces) - e.g., facade cladding of the NEMO Science Centre in Amsterdam (Renzo Piano, 1997)

• Networks of triangular or quadrangular surfaces - e.g., glass panes roofing the entrance to the TGV terminal in Liége-Guillemins, Belgium (Santiago Calatrava, 2007).

Architects such as Herzog & de Meuron, Jean Nouvel, Venturi Scott Brown, OMA, Zaha Hadid, UNStudio, ONL and MVRDV have revolutionized urban planning, architecture, and design, which is inextricably linked to the design of structures and patterns. Many other studios (including Future Systems, ALA, Klein Dytham, Reiser Umemoto, Lab architects, Sauerbruch Hutton, LAB [AU], NOX, Daniel Libeskind, FAT, MAKE, Hilde Und K, Juergen Mayer, David Adjaye, ETH Zürich and others) also operates in the digital architecture sector. The huge number of publications, exhibitions, workshops, projects and especially the work of young designers is proof that the architecture, spatial structures, and ornamental of the whole are more oriented towards a larger, more high-tech, conceptual, abstract, intangible function using new visual effects. These are new technologies that have allowed architects to expand the range of type elements with a precision that they have not been able to work with before and with the ability to move smoothly into their implementation. New software and technological solutions give a revolutionary way to deal with the design object more accurately, to create spatial structures, structures, and ornaments in relation to form and function. Depending on how and what software solution the architect or designer uses in his work, we can divide the creation of structures, patterns, and ornaments into three basic groups. These groups are directly dependent, as each uses the basic principle of dividing the area. Like the basic groups, the process of their creation consists of three phases - discretization of surfaces, its morphing with the application of genetic algorithms and parameters and the application of an ornament, which in many cases has not only aesthetic but also functional value.

7 DECONSTRUCTIVISM

The generated structure located on the surface of the solved object directly expresses (an idea or feeling) and absorbs the relevant data of the overall spatial construction of the surface of the object on which it is located. It is important to realize that parameterization, as a style, is an art program that is just developed gradually, especially from a simple to a more complex form and creation. Parametricism in the understanding of P. Schumacher transforms the technique of parametric design of structures into a new and convincing expressive articulation. An important contribution is the work of a group of the already mentioned circle of architects, such as Herzog & de Meuron, Jean Nouvel, Venturi Scott Brown, OMA, Zaha Hadid, UNStudio, ONL and MVRDV who use the means of parameterization and structuring of areas, thus starting a new, revolutionary way of creation.

Parametricism in the 1990s, after the introduction of digital design tools, includes the new related geometric entities of splines in the form of the Bézier Curve, Nurbs (Non-Uniform Rational B-Splines), allows for operations like lofting (morphing) and the compositional principle of affiliative adaptive deformation, which means the formation of emotional bonds with others.

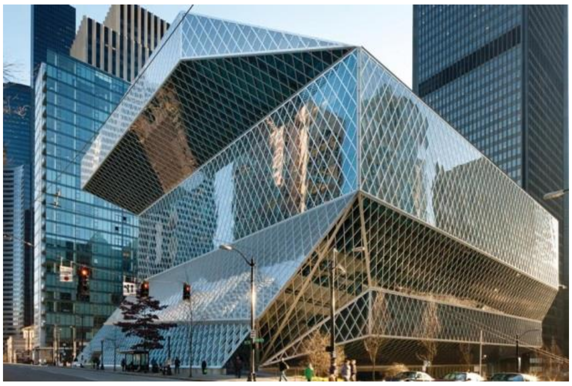

Fig.7.1. Public Library, Seattle by Architects Rem Koolhaas, OMA
https://www.archdaily.com/11651/seattle-central-library-oma-lmn

Guggenheim Museum, considered according to analysts and specialists, is a mixture form that is created from folded geometries (Foldism) and blob geometries, (Blobism). Its exception came from the absence of straight lines and flat surfaces on its structure, which is covered by polished titanium panels according to the architect's concept.

The Discretization and structuring of areas technologies have enabled architects to develop sophisticated surface panelling and structuring techniques. New possibilities are used mainly in the design and application of the building envelope: simple geometry, mosaic, material textures and layering, such as shading systems. Patterns and structuring have recently enjoyed a strong comeback. The architects tried to cope with the problem of using mass production, which allowed the use of modular construction. This type of construction allows projects more flexibility, especially those that would lose the unambiguous system unambiguous form that was at the beginning of the project design. Basically, it is about optimizing the area using a simple or complex network. The implementation of complex architectural free forms and many generations of panel designs remain demanding, both in terms of material and production.

Subsequently, these entities began to rebuild curves and surfaces, then offered great flexibility and modelled Isomorphic polysurfaces design systems in which complex surfaces are defined by multiple “blob” objects, (generate beautiful blub shapes) and feel much more dynamic. Then the architecture movement was referred to as folding and which was later re-theorized as Parametricism.

Folded geometries can be classified into two sub-categories, Rigid (segmented) folding geometries and Flexible (curved) folding geometries, according to their formations and the final expression using descriptive analysis. This allowed for a new kind of complexity that was based on the smooth integration of different forms into a seamless complex continuum achieving a style of ‘Deconstructivism’.

Abstraction and fragmentation are the most curious procedures used by Hadid to produce deconstructivism projects and imaginative spaces. Through her difficult study in creating space, she found abstraction as a research principle that is useful for creating and finding creative spaces, expanding as a measure of unlimited innovation (D‟Apuzzo A. M. 2011).

Fig.7.2. Flexible (curved) folding geometries of Al-Wakrah Stadium in Qatar
https://www.archdaily.com/tag/al-wakrah

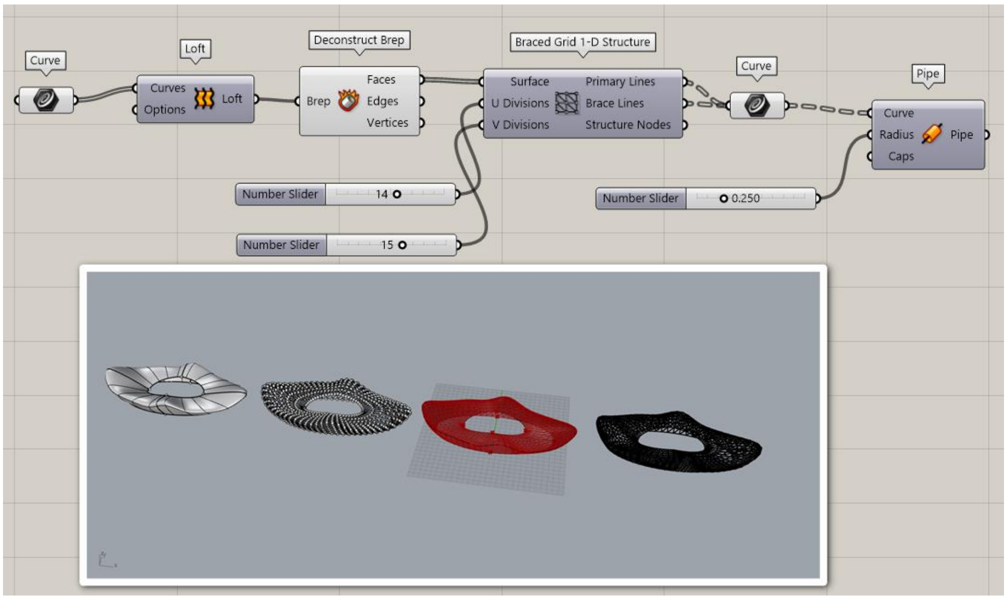

Fig.7.3. Grasshopper Script created by the authors

Abstraction is breaking down the paradigm of seeing things and managing them.

To paint in a unique way is to depict it in volumes and geometrical shapes and attempt to control its organization by covering or accumulation.

Additionally, fragmentation is to break the rules of known illustrative design which leads to creating the same engineering as mechanical mass generation as Hadid depicted it (Meades J. 2008). Hadid characterizes fragmentation as an application that takes after these forms „break the block, make it porous" at that point it makes „organizational designs which suggest a modern geometry" (Meades J. 2008).

She learned abstraction from the paintings of the supremacist Kazimir Malevich who used unique and geometric shapes to display his artwork. She claimed that abstraction provided her with a vision of the direction of the lines her works created by having the enthusiasm to take a line and visualize it as it "changes and deforms" it means distorting the shape or form of a project as it moves through the bands of "light and shadow" (Michaud J. (2011).

http://www.newyorker.com/online/blogs/backissues/2011/07/zaha-had id.html

In this grasshopper, we design by means of the weaverbird plugin, how you can use it to produce much of the mesh model as you can see here below, and to use this plugin to produce smooth mesh for the curve, points or surfaces, as well as we use plugin Cocoon with kangaroo too to create easily 3d model by means of curves and points, changing the position of curves and points will change the form and position of the entire structure.

The blob (meta-ball) system gives much more morphogenetic scope to algorithmic self-organisation, it is at the same time more versatile and complex organisational logic than nurbs modellers that are manipulated via pulling control points.

It is an approach to building design that attempts to view architecture in bits and pieces and may seem to have no visual logic. Deconstructivism used the geometry of collage, as a style in place of transparency.

Blob geometries, as a new type of free-form architecture, became noticeable landmarks with the progress and the developments of spatial structures. These irregular forms need innovative design processes and advanced technological and structural systems that vary from traditional and familiar systems. Blobs, which are distinguished as irregular geometry, are not instituted on Euclidean principles of plane surfaces.

With blobs (isomorphic polysurfaces) architecture received its first instance of the general concept of associative logic.

People usually wonder about the compatibility of Hadid's buildings with the surrounding.

Although they totally have different characters in both form and materials. The secret lies in the intense research Hadid does on the site and environment. Landscaping the building means not dealing with the project when designing as an isolated thing but trying to make it a complementary part of the urban zone image. The Layering and Play of Light technique enable Hadid to create amazing voids and spaces that meet her aspirations of architectural space. The last technique is applying the feature of seamlessness to go through every part of the project. Seamlessness and fluidity are noticeably prevalent characteristics in almost all of Hadid projects, especially recent ones. She gets inspiration for this technique from the complexity of form in nature, Arabic calligraphy, and the natural seamless flow of the landscapes.

7.1 NETWORKS and ORNAMENT in CONTEMPORARY DIGITAL ARCHITECTURE

Networks and subdivisions have been a basic feature of spatial design (interior, architecture, urbanism, and landscape architecture) since time immemorial. The patterns resulting from the interactions between these different systems are used in many dimensions, temporal, and spatial levels, including many natural and man-made patterns.

Combination of discretization of surfaces by primitive geometric shapes and morphed in the form of attractor, PGCC, Malaysia (image Asymptote: Asymptote - Hani Rashid + Lise Anne Couture - PGCC, Malaysia)

The properties of geometric shapes can be influenced according to the distance to other elements - the so-called attractors. A specific attractor can be a bitmap image, which can affect elements with one of its properties - e.g., the brightness value of specific pixels.

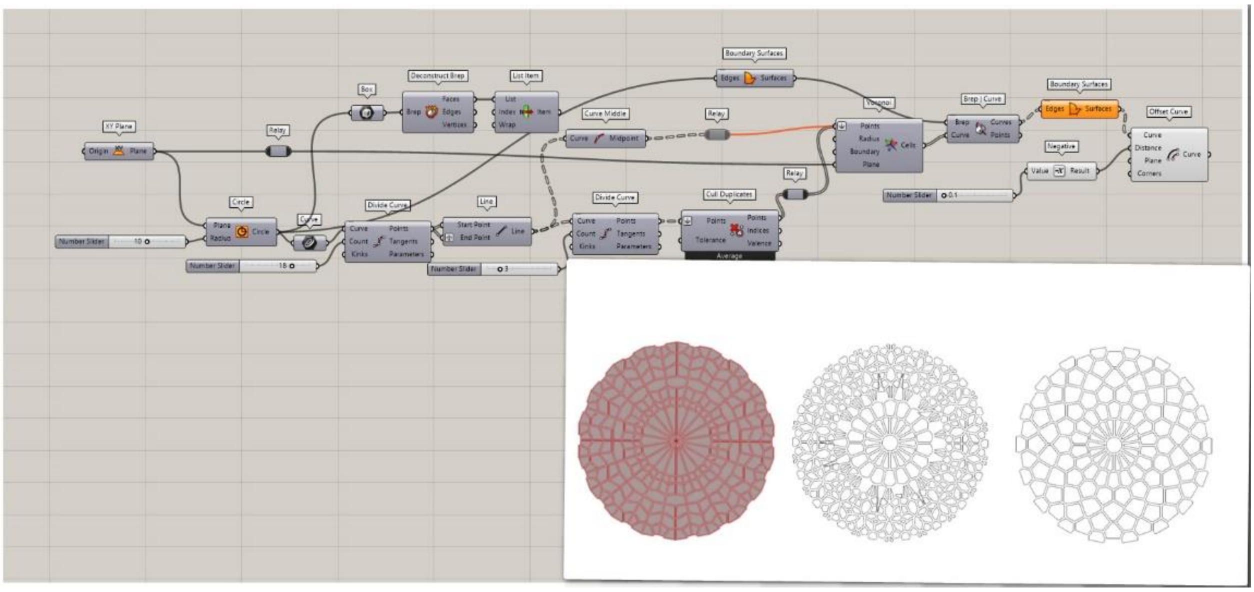

Fig.7.1.1. Grasshopper Script created by the authors

Parametric division and structuring of areas.

A hotel project designed using the latest technology. These parameters were the main factor in shaping the overall structure of the facade but also the construction of the building, Yas Marina Hotel & Yacht Club, Asymptote + Gehry Technologies, Abu Dhabi

How to create Form- Finding of parametric architecture and design. We begin with three different plans, using xz plan component, and plugin xz plan to a plane component by defining the values x and y, this step gives us one surface plan with xy values in the xz direction.

We copy this xz plane twice in the n y direction, to get three surface planes after that we must reparametrize the surface, this step allows us to pick one point on the first surface which is in the direction xz. Creating three different points on the xz geometry plan as surface number one, the first point is going to be on the bottom plane xz, the next point is going to be on the middle of upper chord edge of plan xz, and the third point is going to be on the right side on the bottom corner of the xz surface plan. This step allows us to move freely all three points on xz surface plan, Then we get three different designs, and after that, we interpolate the curves during this step we get the arch curve on each three surface planes, lofting all three arches together we get subsurface then we use hexagon component, with this component we can create a wireframing to subdivision u,v, then we use pipe component to define the dimensions of hexagon wireframe.

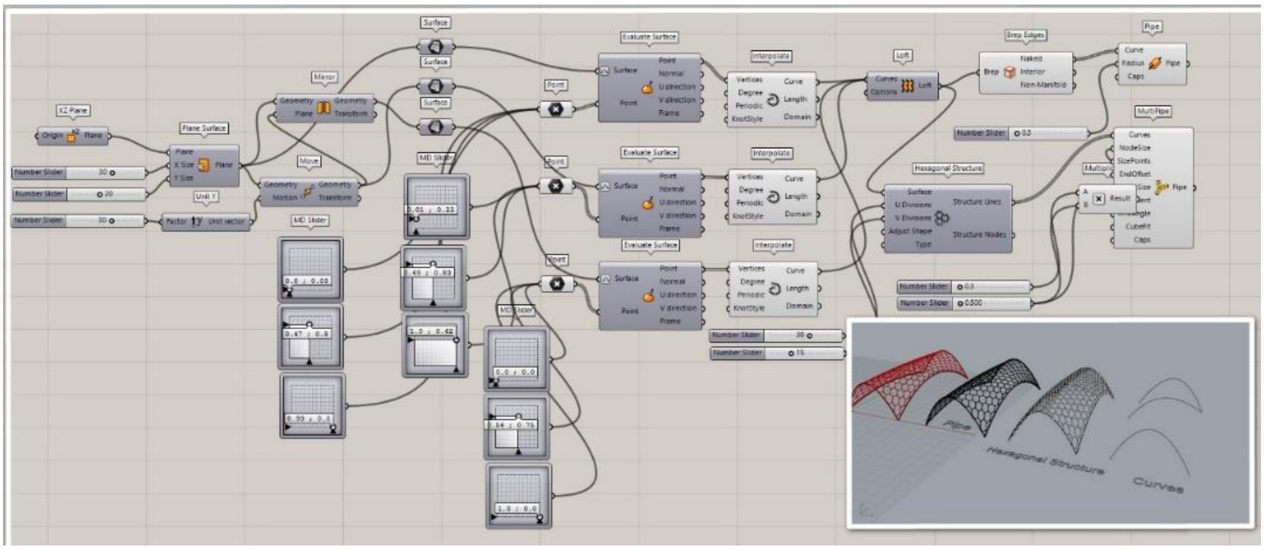

Fig.7.1.2. Grasshopper Script created by the authors

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7.2 Origami in Practice - Architecture

Origami – In ancient Japanese *ori* literally translates to *folded* while *gami* literally translates.

to *paper*. Thus, the term o*rigami* translates to *folded paper*.

Origami has roots in several different cultures. The oldest records of *origami* or paper folding can be traced to the Chinese. The art of *origami* was brought to the Japanese via Buddhist monks during the 6th century.

The Spanish have also practised *origami* for several centuries.

Early *origami* was only performed during ceremonial occasions (i.e. weddings, funerals, etc.).

Traditionally *origami* was created using both folds and cuts, but modern rules established in the 1950s and 1960s state that only folds shall be allowed.

Fig.7.2.1. The Sydney Opera House is likened to sea shellfish and ship sailors. https://www.boredart.com/2015/04/the-art-of-architecture-and-the-beauty-of-it.html

For centuries there were no written instructions for the origami figures, the methods were just passed from generation to generation.

The first book of how to make origami was published in 1797 it was called “How to Fold 1000

Cranes”. Another book was put into circulation in 1845 that contained a collection of approximately 150 origami models including many that are still popular today.

The Crane is the most popular origami figure, it is a sacred bird in Japan, and it represents peace.

The Japanese believe that if you fold 1000 cranes you will be granted a wish.

There has been a lot of mathematical study in origami which has led to several theorems and results. Thomas Hull has found links between origami and geometry, algebra, number theory and combinatorics.

Some of these theorems and results are.

Flat foldability

How to solve equations up to degree 4

How to fold the side of a square into 3rds, 5ths, and 9ths (Haga Theorem)

Other theorems have allowed paper folders to form shapes such as equilateral triangles, pentagons, hexagons, and golden rectangles.

8 LIGHTWEIGHT STRUCTURES

Lightweight structures used in various forms and variations can be seen in a broad spectrum of use. They may be of different shapes and sizes, internal, external, permanent, temporary, large, small, supported, membranes filled with air or stretched. These structures, developed over the years, together with advances in material engineering and technology, continue to progress and are now an integral part of architectural creation. These unique forms have played an important role in contemporary architecture, interior design, and various cultural events since the time they first appeared in the 1960s in Germany. At present, light constructions are designed and constructed independently of the geographic location. They could transform the space through their elegant form. Designing lightweight constructions to meet all criteria is a complex task. Every part is visible and constructive, relying on the proper functioning of all parts (Shawkat, S. 2019).

Architects and engineers are the creators of new spaces, forms and structures that are constantly improving. This creative activity connects architects and engineers on their way to the art of the world-famous German architect and structural engineer Frei Otto.

8.1 Tensegrity

I read in the literature that historians wrote and spoke at several conferences that Latvian artist Karl loganson in Moscow in 1920-21 exhibited a prism of tensegrity in Moscow, although this argument is controversial because Loganson's work was destroyed and vanished in the mid-20s of the Soviet regime, the photo of the exhibition survived. French architect David Georges Emmerich quoted the design logson as the precedent of his work. In the article "Snelson for the invention of Tensegrity" in Lalvani96, tensegrity pioneer Kenneth Snelson also quotes Russian constructivists whose members were loganson as inspiration for his work. The concept and art of "tensegrity" (the structures of "tensile integrity") was developed by American entrepreneur Buckminster Fuller. Fuller considered the construction of his dymaxion house from 1927 and the experimental building from 1944 as models of technology. in 1948, Kenneth Snelson, after completing lectures and Fuller's practice at Black Mountain College in North Carolina, created a catalytic contribution to understanding the construction of tensegrity when he collected his X-Piece statue (Snelson, K. 1965).

This model and the tensegrity pattern were followed by other models and publications of Fuller and other circles. Independent in France, in 1958, architect Emmerich explored the capabilities and forms of tensegrity and the combination of prisms into the more elaborate structures of tensegrity, which he described as "structures tendues et autotendantes" (pre-tensioned structures). Emmerich, Fuller and Snelson came cut with patent claims on various aspects of technology in the 1960s, and then all the pioneers formed one family and continued to develop the technology.

Snelson was mainly interested in art and art exploration of construction using tensegrity. All three created tower or mast design principles, which are still a source of beauty for admirers of tensegrity but have just recently found a practical application in the development of deployable structures. I think that part of the reason that the beauty and construction of tensegrity did not come into practice, even in circles where there was a strong interest in the practical application of tensegrity, is the clear lack of professional and intelligent workers as well as the precise tools for realizing their design and creation. Fuller's basic model of tensegrity patent has quotes of element length, but no indication of how lengths would be proposed. Probably the lengths were then calculated and parameterized, as measured by the length of the elements of the finished structure.

The main shortcomings and problems of the practical application of tensegrity technology for the practice these artists have identified are:
1. Low Load Response - "Relatively high deformation and low material efficiency compared to conventional, geometrically rigid structures."
2. The complexity of the production of details - spherical and domical structures are complicated to produce details of joints as well as the selection of suitable material for their realization, these factories can lead to production difficulties.

Kenneth Snelson also remembered David Geiger's "Cable dome" technology and Matthys Levy's space triangulated tensegrity dome technology, which provided many creative and practical applications of tensegrity in practice. Campbell94 discloses a description of these two compositions which are dependent on the peripheral anchor for their structural integrity.

The idea to have only tendons connected to struts is probably the most innovative concept of this type of structure resulting in extremely simple joints. Beyond the difficulty of form finding [Motro, 2003] the main problem of this type of non-conventional structure is the difficulty of manufacturing as the geometry of spherical and domical structures are complex. Another big disadvantage, similar, to all tensile systems, is the poor load response (relatively high deflections and low material efficiency as compared with conventional, geometrically rigid structures and the lack of resistance to concentrated loads.

Fig.8.1.1 models (Shawkat, 2020)

Frei Otto, the only true precursor of Parametrises, free-forms, as organic, nonstandard, irregular shapes, are the deformation of these mentioned earlier by changing the amount and direction of the depth. Architects, with novel imagination and digital tools, use both forms and shapes with their potentialities to represent the new. Hyperbolic paraboloid shape can be transformed into geometry by double curvature with twisted straight lines.

The doubly curved surfaces, of this geometry, have horizontal cross-sections with a hyperbola shape and vertical cross-sections with a parabola one. Various curvatures as positive, negative, and a mix of them have been shown and analysed. Due to graphical software programs that can produce new, irregular, non-standard forms under the principles of digital design.

Evolution is a process of gradual and long-term quantitative and qualitative changes that accompany the development of both living and inanimate systems as well as their regions and constituents. This defines the evolution of the dictionary of foreign words. And we are not far from the truth when we try to paraphrase this definition of the building structure.

Even in building construction systems, there is some evolutionary development, which results in the so-called modern light system. It is a system made up of the latest materials and construction systems. We could define a light modern system as a construction design, designed and built with the emphasis on maximizing the material and construction properties, provided the weight and volume of the structural elements are minimized.

When creating these systems, we mostly work with materials such as steel, aluminium alloys, and composite materials. Thus, we create various steel, cable, and membrane systems. The design of each such system brings with it new theoretical and constructional problems. Without their solution, they cannot be advanced, and their solution is always not easy.

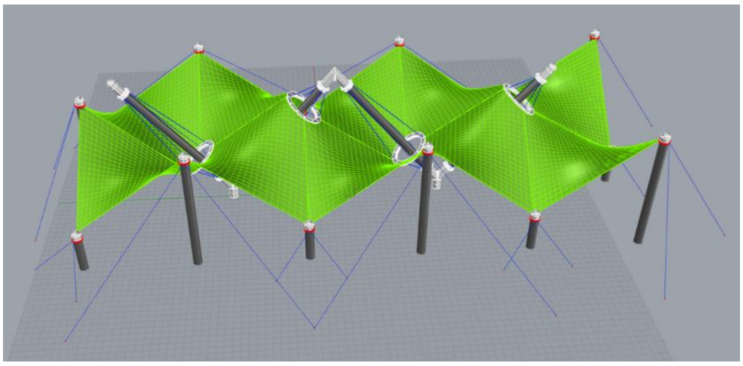

Fig.8.1.2. Lightweight steel prestress cables, created by the authors (Shawkat. 2019).

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Talking about modern systems of steel, wire and membrane has its merit. And that these systems are at the top of the current building options. Limits are given by the physical properties and laws of the material and the construction system. These must be fully considered and used in the creation of the modern system. In practice, we most often encounter the following issues:

• bars (struts) systems - stable problems of compressive and bent bars,

• cables systems - prestress, stiffness of the structure, the necessity of solving the theory II. order,

• membrane systems - prestress dynamic resistance, large deformation solutions.

8.2 Light Tensile Structure

Light tensile structures belong to membrane structures in so-called “free-form shapes”. We can consider them as an expression of modern fine art structural design, and architecture and they have a large potential to develop in the future. Tensile structures have negligible thickness compared to the other dimensions; it means that their static efficiency is based on their shape.

The creation and formation of new space which could not otherwise be accomplished by using conventional methods is common for all such edifices (Bletzinger, K.U., Wüchner, R., Daoud, F., Camprubi, N. 2005).

Because of the many advantages of this modern style, several permanent membrane structures have been officially approved and constructed around the world. The uses of these structures vary widely from sports facilities to exposition buildings. Such structures are becoming more and more recognized as an independent field of the fine art of structural engineering and architectural design.

There is an important and interesting interrelationship among the different types of lightweight structures: between manufacture and erection processes on the one hand, and geometry and load-bearing behaviour on the other.

Finding the minimal surface is defined by three criteria:

- Minimum surface is between any boundary

- Equal and opposite curvature at any point

- Uniform stress throughout the surface

A minimal surface may be anticlastic or flat. Anticlastic tensile structures are flexible membranes with double curvature and prestress is essential for stability.

A surface of flat or triangular boundaries is always flat. Flat membranes are unstable structures under load. Increased curvature increases stability.

Membrane structures are often referred to as textile structures. However, the actual membrane construction is far removed from the classic tent. The main difference is its exact geometric shape. For the functioning of the membrane structure, the exact geometric criteria must be computed.

The basic criterion is to maintain the concavity and convexity of the main directions of the membrane surface. Following this principle, we can talk about the basic four types of membranes:

• saddle-shaped (hyperbolic paraboloid)

• conical shape,

• Wave shape,

• vault shape.

Another criterion of lightweight membrane construction is its prestress. The correct geometric shape and prestress guarantee its stability, stiffness, and dynamic resistance. At the same time, it allows the structure to resist the effects on which it was designed, rain, wind, and snow.

Talking about modern systems of steel, wire and membrane has its merit. And that these systems are at the top of the current building options. Limits are given by the physical properties and laws of the material and the construction system. These must be fully considered and used in the creation of the modern system. In practice, we most often encounter the following issues:

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• cables systems - prestress, stiffness of the structure, necessity of solving the theory II. order,

• membrane systems - prestress dynamic resistance, large deformation solutions.

Advantages of a Tensile Fabric Building Structure (Pros and Cons of tensile Structures)

1. The installation of tension membrane structures is often faster and more cost-effective in comparison to traditional structures. The other factor that clearly puts fabric ahead of other materials is its clear span capabilities, Since the fabric has this amazing tensile capacity, the effect is to reduce the supporting framework to a minimum number of supports, all working efficiently as a whole system.

2. Due to the translucency tensile fabric building structures provide an abundance of daytime light underneath, making it an inviting and comfortable space below. The unique properties of light reflectance and transmission also offer exciting possibilities for lighting after dark.

3. Due to the unique flexible properties of the fabric membrane, tensile membrane structures offer architects, designers and engineers a wide opportunity to investigate shapes and create visually elegant and cone-shaped structures.

4. Tensile membrane structures have been demonstrated as low-maintenance projects for investors, but if properly engineered and installed are virtually immune to damage and weathering.

5. Due to the unique combination of design materials properties, structure, and environment, the longevity and durability of tensile membrane structures have been proven to withstand harsh and extreme climates and environments.

9 PRESTRESSED CABLE NETWORK OF THE ROOF STRUCTURE OF THE OLYMPIC STADIUM IN MUNICH, GERMANY

Fig.8.2.1.Frei Otto, Gunter Behnisch - Munich Olympic Stadium, 1972
https://malarkytect.wordpress.com/2015/03/14/munich-olympic-stadium-gunter-behnisch-and-frei-otto/

The realization of this construction was considered unfeasible by many experts in 1968. The very high costs and disproportionately large technical and technological problems that have characterized the implementation of this construction are a fact that is only partially related to the experimental nature of this construction (Schleicher, S., Lienhard, J., Fleischmann, M. 2010).

In the design of cable-prestressed roof structures of large spans in the future, the aspects of optimization and harmonization of architectural effects with the realization and construction possibilities and with the functional reliability of the structure must be considered more thoroughly. The roof surface is divided into many saddle-curved net elements, which act as load-bearing elements and at the same time ensure interaction with the edge cables. These are supported by supports mounted on prestressed cable elements and suspended at the edges at several points on the outer masts.

The architectural concept did not allow for the possibility of implementing supports in the space under the roof, and therefore it was necessary to create a primary cable system outside the roof's own net structure. The roof structures of the stadium (roof area 34,550 m2), sports hall (21,750 m2) and swimming pool (11,900 m2) create mutually independent load-bearing systems, which are interconnected by smaller connecting roof areas.

To determine the forces in the structure and to determine the final geometric shape and dimensions of individual elements, wire models were built at a scale of 1:25, on which experimental verifications of theoretical and computational assumptions, resp. results.

The mesh size is 75x75 cm. 19-strand cables were used, which are relatively rigid. The cables were connected to the construction site using rotating network nodes. The edge cables transmit forces between 80 and 590 Tons. The forces in the prestressing cables in the roof area reach 3500 to 1150 Tons. Due to the required high strength and durability, the main supporting cables were realized as parallel cable elements.

Heavy foundation blocks, underground walls and ground anchors were used during the foundation. The roofing is made of Poly methacrylic resin boards (plexiglass), which ensure sufficient transparency and fire protection.

During the realization of the roof, it was again confirmed the importance of a detailed consideration of the individual production and assembly stages and their consequences during the design. Mesh cable roof systems enable the realization of various geometric shapes of roof surfaces, creating a transparent roof covering and short assembly, resp. disassembly times.

The sizes of the required cable safety are given different values for different constructions. In the literature, safety values ranging from 2.5 to 3.5 can be found for roof structures, and values between 2.0 and 3.0 are given for bridges. During the construction of the swimming hall for the Tokyo Olympic Games, to increase the rigidity of this structure, the safety of the supporting ropes was designed to be 5.0. Various factors affecting the design strength and load-bearing capacity of the rope must be considered when determining rope safety. These factors are only rarely well known, so the designers recommend choosing Security 3.0. The safety of the rope support structure can be greater than the safety of the individual ropes because there is no linear relationship between the load and the forces in the ropes. As the ropes are characterized by a large surface area, it is necessary to ensure sufficient protection of the ropes against corrosion.

F. Otto recognized two diverse sorts: one with stationary supporting structure and another with mobile supporting structure. Pneumatic structures can moreover be classified as deployable membrane structures. In any case, it was fair at the conclusion of the moment half of the final century when engineers started to apply material as building fabric for large-span developments. The spearheading works of Frei Otto motivated plenty of membrane designs all through the world.

However, the view that these construction systems are economically advantageous due to their low weight may prove to be fundamentally incorrect. The economy of the structure is conditioned by the costs of the foundation and the economy of production of many elements forming the roof area. These facts must be considered when designing alternative solutions.

As it were exceptionally few know that a portion of the theatre of the Roman Colosseum (Amphitheatre Flavio) built at the beginning of the century had a convertible material roof [Ishii, 2000]. The structure of the umbrella is an old structure as well, but its rule is utilized in present-day versatile architecture.

10 DIGITAL ARCHITECTURE

Every revolution changes human history and lifestyle. Since architecture is only a small part of social evolution.

10.1 Media and Digital Screens

The teaching of digital planning requires encouraging definition and refinement; this may be accomplished through a centre on three topics comprising of:

1) **Ubiquity**, 2) **Parametric**, and 3) **Tectonics**.

In easier terms, a teaching of the digital plan ought to concern itself with individuals, rules, and things. The primary establishment, **ubiquity**, alludes to the reality that advanced data is quickly getting to be inserted into our everyday lives. It empowers collaborative intuition. Collaboration begins with basic casual intuition such as asking a question.

It creates assistance inside an organization through intradisciplinary work – such as a group of architects and structural designers working together on a project.

parametric concerns itself with the rules overseeing the plan preparation. “Parametric design may be a handle based on algorithmic considering that empowers the expression of parameters and rules that, together, characterize, encode and clarify the relationship between design intent and design response”.

Computational design is about manipulating thoughts, design concepts and processes of thinking in clearly defined steps and instructions that are routinely made by PC programming tools. It offers the architect control of the change of properties of objects and inputs into arrangements and diverse options appropriately with the least time required. It offers the architect control of the change of properties of objects and inputs into arrangements and diverse options appropriately with the least time required. As of now, the centre of computational models is essentially constrained to building execution, optimisation, and the user requirements of the design issue.

A parametric understanding of the planned issue has opened the possibility of examining the more profound conceptual as well as tectonic structures of our proposals and has advertised to users and clients a domain of conceivable outcomes instead of a managed solution.

The third establishment of a digital plan, **tectonics**, is concerned with the relationship of preparation to the item or from process to the final product. It advocates the see that engineering will continuously be implanted in its convention of consideration to material, assemblage, and detail (the convention of making).

The Japanese architect Toyo Ito has said that architecture must become a media suit to interact and mediate the information environment as clothing is an extension of our skin and the automobile is a mechanical suit or extension.

Jean Nouvel believes we want a new kind of space, which is at once the most minimal in expression and the most dynamic in potential. With the digital façade, there is no cause-and-effect relationship between the building and its use. The screen makes a fuzzy line between where the architecture ends and where the performance medium begins, giving the building great vitality.

The media facade wasn´t a part of the main construction design but was added afterwards. It is said to be the first complete transparent media facade. The highly developed led design was done by Lumino Lichttechnik. https://www.mediaarchitecture.org/page/31/

The building exterior or facade marks the transformation between exterior and interior, between the building and the urban space. They are not controlled by the real space they involve as part of the complete structure, but moreover, impact the space in and around the building. A facade is an essential part when observing a building from the outside and influences the interior. The facade gives a scale to the whole space around it.

View, lighting, ventilation, client comfort, a few building services and imaginable that loadbearing are all assignments the exterior may have to be solved. Building exterior plays a particularly critical part. To begin with and first, it gives security and protection. But its stylish and social work is fair as important.

11 INTELLIGENT ARCHITECTURES

Today's architectures contain more and more components that are "smart" and provide a high degree of flexibility. Nowadays, advances in information technology make what was once considered unrealistic or futuristic a very real possibility. In our real-world computing, sensors and computer chips would be built not only "everywhere," but "everything." James Law Cybertecture International Delivers High-Tech Solutions for Large Span Structures Through Innovative Designs for Smart Living. The office building incorporates a passive solar design and an elevated garden that moderates temperate. will use solar photovoltaic panels and rooftop wind turbines to generate onsite electricity.

CONCLUSION

Free-Form geometry in architecture refers to shapes and designs that deviate from traditional, straight-lined, and regular forms. It can be either conventional or non-conventional. Conventional free-form geometry incorporates curves and shapes that are mathematically defined, while non-conventional free-form geometry involves more organic, irregular shapes that are often created through digital means.

In conclusion, free-form geometry allows architects to break free from traditional forms and incorporate more creative and imaginative designs in their work. This type of geometry can create unique and visually striking buildings, but it also presents challenges in terms of construction and engineering. However, with the advancements in technology, these challenges can be overcome, allowing for greater freedom and expression in architectural design.

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