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Technologies and Smart Solutions for Unconventional Adaptive Form Generation in Office Buildings; Al-Basrah, Iraq

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Executive summary

This research is related to the conference themes (Technologies and smart solutions: enhancing land management, land development and construction), (Efficient land use: tools and practices). Focused on Al-Basrah city in Iraq, investigates how to manage the land in a better way with the rules of the city and provides smart solutions by using the technology and the environment to generate an adaptive unconventional form with a responsive efficient shading system to reduce the impact of the radiation, and allowed daylight at the same time. Investigate how to see generative parametric design through the lens of the nature, as it provides great opportunities for architects and designers to contrive the design process more efficiently and can make a complex, creative forms easily and complete unity between the building, the users, and the environment.

Architects, and designers have always looked beyond the limits of their discipline, appropriating materials and methods. But many obstacles and difficulties that face architects through creating forms and shapes via unconventional methods and technologies. Some of these obstacles are the way to express their complex ideas, forms, and shapes, not complete the unity between the building, the users, and the environment. Not looking to the nature of the place which they designed the form in. While the innovative software and the new technologies with its advanced techniques in addition to computer simulation of evolutionary processes have been integrated into the architecture design realm around the world. So now it's necessary to generate new process to provide new opportunities for architects and designers to generate, manipulate and visualize non-standard and complex free form buildings throughout the design procedure simultaneously with the formal exploration of unprecedented complex forms, and generate geometries with by transcending the limitations of Euclidean geometry can deliver an aesthetic that appears more natural and organic but which can also achieve higher levels of performance.

In the introduction, there is a background of the parametric design and Biomimicry and their definitions also include: Problem definition of the study where the general character of the buildings in Al-Basrah city, especially office buildings characterized with typically and conventionally, creating forms in conventional ways, simple, and not looking to nature and environment of the place which the building's design in. Also, objective of the study where there is a requirement to develop new design strategies that match with contemporary architecture and develop a new methodology, and design thinking. So the main aim of the study is to develop an innovative way in which creates new design thinking and form generation through a combination of the biomimetic principles of design that relate to and inform the process of parametric design.

The methodology of the research includes generating the form, and analysis of the tall office building based on Biomimicry, mimicking the form and performance levels of Bottlebrush flower. The proposed process utilizes off-the-shelf one of the parametric design software, namely Rhino and its plug-ins named Grasshopper and ladybug in the generation of the form and analyzing the environmental studies.

Al-Basrah Case Study office envelope design. Where Al-Basrah location exactly and it is important for Iraq. And how Basrah has a hot desert climate. The study location area, and the building details like number of the floors, cross area, floor to floor height, the building total height according to Al-Basrah and Basrah Municipalities Management. The building form generation and how it is created from the Bottlebrush flower which its botanical name is (Callistemon viminalis), a shrub or small tree, high temperatures, moist soil, and full sunlight are the basic requirements for Bottlebrush shrubs to grow well. And the pattern shape, the mechanism, the colors and how its help to reduce the impact of the radiation.

Then showing the results, the process starts with making a simulation of the building by Using Grasshopper and ladybug plug-in to study and analyze the effect of the environment in the building in different stages and conditions, Sun path and radiation analysis according to Al- Basrah weather data. Firstly, analysis the effect of sun and radiation on the building before applying the envelope and compared it after applying the envelope with the same conditions and compare the results.

Considering the working hours in the building in the duration (from 8 a.m. to 5 p.m.), the temperature of Al-Basrah increases starts from spring to summer, which means from March to October, and that is the hottest period of all the year. The environmental studies included study and analysis of the sun path and radiation in duration (8 a.m.to 5 p.m.) on the day 15 March, July, and October. And then study and analyze the sun path and the radiation of the whole period from 15 March to 15 October.

-The first period: in day15 March at the time (8 a.m.to 5 p.m.)

-The second period: in day15 July at the time (8 a.m.to 5 p.m.)

-The third period: in day15 October at the time (8 a.m.to 5 p.m.)

-The fourth period: from day 15 March to 15 of October at the time (8 a.m.to 5 p.m.)

Then there is the discussion where discuss the results from the previous environmental studies of the sun path and the radiation, and see how there's a difference in distribution the radiation and the effect of the radiation during the different periods, and the effect on the building and the building's façade.

And finally there is the conclusion which is by using the technology it can provide a smart solutions through the parametric design in form generation by applying Biomimicry showing that nature has provided an unlimited source of design and can be effectively applied to form design process. Not only unconventional and adaptive building form, but also reducing the effect of the radiation on the office building.

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1. Introduction

The Parametric design based on the concept of parameters, it is understood as the process of developing a computer model or description of a design problem. This illustration is predicated on relationships between objects controlled by variables. Making changes to the variables leads to different models. The Selection of a solution is then based on some criteria that may be related to performance, easy construction budget requires user needs, aesthetics or a mix of these (Hudson, 2010). According to Starvic and Marina (Stavric and Marina, 2011) parametric design form is usually shaped by discipline form mathematic values of equations and parameters through design that are used to describe the relationships between the forms. While parametric design has been defined by Karle and Kelly (Karle and Kelly, 2011) as a series of questions to establish the variables of a design and a computational definition that can be utilized to facilitate a variety of outcomes or design alternatives in a dynamic process. Lee (Lee, 2015) states that Woodbury (2010) defines this style of design as a process based on algorithmic thinking that allows the expression of parameters and rules that, along the outline, codify and clarify the link between design intent and its restraint. Throughout history, architects have used nature for inspiration for their building form designs and many approaches. From this point the emulation method of nature has begun and has been developed in many disciplines and recently recognized as "BIOMIMICRY" (Alshami, Atwa, and others, 2015). There are three levels of Biomimicry, the organism level, behavioral level, and ecosystem level. Nature has enabled architects through Biomimicry to showcase their buildings with features that are characterized by nature, such as sustainability, survival, interaction, energy efficiency, and structures, as well as interaction with the environment. There is a lot of examples of buildings that used Biomimicry as a source in form generation by using parametric design, for example, Al-Bahr towers, The Abu Dhabi Investment

council new HQ in the UAE, and The Minister of Municipal Affairs and Agriculture (MMAA)in Qatar.

1.1. Problem definition of the study

The general character of the buildings in Al-Basrah city, especially office buildings characterized with typically and conventionally, creating forms in a conventional way, simple, and not looking to the nature and the environment of the place which the building's design in.

1.2. Objective of the study

There is a requirement to develop new design strategies that match with contemporary architecture and develop a new methodology and design thinking. So the main aim of the study is to develop an innovative way in which creates new design thinking and form generation through a combination of the biomimetic principles of design that relate to and inform the process of parametric design.

2. Methodology

The methodology of the research includes two main parts, the first one is about generating the form of a tall office building based on the Biomimicry, the form, and the performance levels by mimicking the form and performance of Bottlebrush flower by using the technology and provide smart solutions through the parametric design technique and its tools, and a software namely Rhino and its plug-in named Grasshopper. The second part is to analyze and test the building form under the effect of the environment (the sun path and the effect of the radiation) on this building by making a simulation of the generating building form in different environmental conditions and compare the results before and after. The proposed process utilizes off-the-shelf one of the parametric design software, namely Rhino and its plug-ins named Grasshopper and ladybug in the analyzing the environmental studies.

3. Section 1 / Al- Basrah Case Study: Office Envelope Design

AL- Basra or Al-Baṣrah is the Venice of the east as it was called by Sam Dagher (Dagher, 2007), the most southern province of Iraq, located in south-eastern Iraq, It has international borders with Saudi Arabia and Kuwait in the south, Iran from the east, and adjacent locally to Missan, Thi-Qar, and Muthanna provinces in the north and west. Lies within longitude (46o 60 to 48o 60 E) and from latitude (29o 13 to 31o 29 N) (Al-Muhyi, Bashar, & Kwyes, 2016). Its capital, Basrah, is located on the Shatt al-Arab river. The province consists of seven districts: Abu Al-Khaseeb, Al-Midaina, Al-Qurna, Al-Zubair, Basrah, Fao, and Shatt Al-Arab. Intersected by the Shatt Al-Arab waterway that is formed by the confluence of the Tigris and Euphrates rivers at Al-Qurnah and flows into the Arabian Gulf. It's Area (19,070 sq km) (JAU, 2013). Basrah's location at the Shatt Al-Arab

and its vast oil reserves make it one of the economically most important province of the country (NCCI, 2015).

Basrah has a hot desert climate (Al-musaed, 2004), like the rest of the surrounding region, though it gains slightly more precipitation than inland areas due to its location near the coast. During the summer months, of June through August, Basrah remains one of the hottest cities in the world, with temperatures regularly exceeding 50 °C (122 °F) in July and August, in Basra, the mercury soared to 129.0 degrees (53.9 Celsius) the highest temperature ever recorded in Iraq and one of the hottest temperatures ever recorded in the Eastern Hemisphere, based on weather underground meteorologist Jeff Masters and weather historian Christopher Burt (Samenow, 2016). The average evapotranspiration potential greater than 2,450 mm/year, but the average annual rainfall is below 100 mm/year (Jabbar, Zhou, 2011). In winter Basrah has mild weather and average high temperatures of about 20 °C (68 °F). On some winter nights, minimum temperatures are less than 0 °C (32 °F). High humidity – sometimes exceeding 90 per cent – is common due to the proximity to the marshy Arabian Gulf.

3.1. The study location

The study location area is 3600 square meters, located on a street intersection in Kut Al Hejaj Fig. (I) In the center of Basrah Dedicated for commercial use. On Main Street with 40 meters wide, a building with three floors in the west, and a residential area behind the location villas with two floor height. The cross- area of the floor in the building, according to building regulations within commercial areas in Basrah Municipalities Management (en.baladyatbasrah.gov.iq) should not exceed 65 per cent of the land area. The number of floors is equal to F.A.R divided by the construction area of the floor. F.A.R here is 22.75, so the number of the floors equal 35 floors, Floor to floor height is four meters.

Fig. (I) The location of the case study in Al-Basrah. (Source: googleearth.com)

3.2. Form generation

The form generation of the building here is coming from the environment and nature of the Geographic spot where the building designed, it came from mimicking a flower named

Bottlebrush its Botanical name is (Callistemon viminalis), a shrub or small tree, High temperatures, moist soil, and bright sunlight are the basic requirements for bottlebrush trees to grow well. It is native Australia, where it often occurs along watercourses, but it's also grown successfully in areas with a hot dry climate like Al-Basrah. Normal Weeping Bottlebrush grows up to eight meters tall and has drooping branches with green leaves. The bright red flower spikes occur between spring and summer (Gilman and Watson, 1993). The flower spikes of Bottlebrush form in spring and summer which are the hottest seasons in Basrah and are made up of a number of individual flowers. The flowers pollen forms on the tip of a long colored stem called a filament. It is these filaments that give the flower spike its color and distinctive Bottlebrush shape (www.anbg.gov.au/callistemon/callistemon.html).

Fig. (Ⅱ)(Left) The cylinder shape of the Bottlebrush flower capsules (Source: www.anbg.gov.au/callistemon)

Fig. (Ⅲ) (Right) Bottlebrush flower in the flowering season (Source: https://www.gettyimages.com/detail/video/bottlebrush-flower-blooming-extreme-macro-hd-stock-footage/125396802?adppopup=true)

The building form contains two parts, the first part is a cylinder and the second one is the envelope that covered it. The shape of the cylinder came from the cylinder form of the flower itself from gathering the individual flowers forming this shape Fig. (Ⅱ). The envelope form is a pattern forming from the overlap of the capsules and the flower spikes in bloom time Fig. (Ⅲ) As it is shown in Fig. (Ⅱ) Every capsule contains three petals and every petal took the shape of a triangle, the overlap of every three capsules form a hexagonal shape in the middle of it, and the flower filaments start to appear in the flowering season's spring and summer with full sun, it's responsive to the sun and changed with temperature. So the repetition of this module formed the pattern of the envelope as shown in Fig. (Ⅳ).

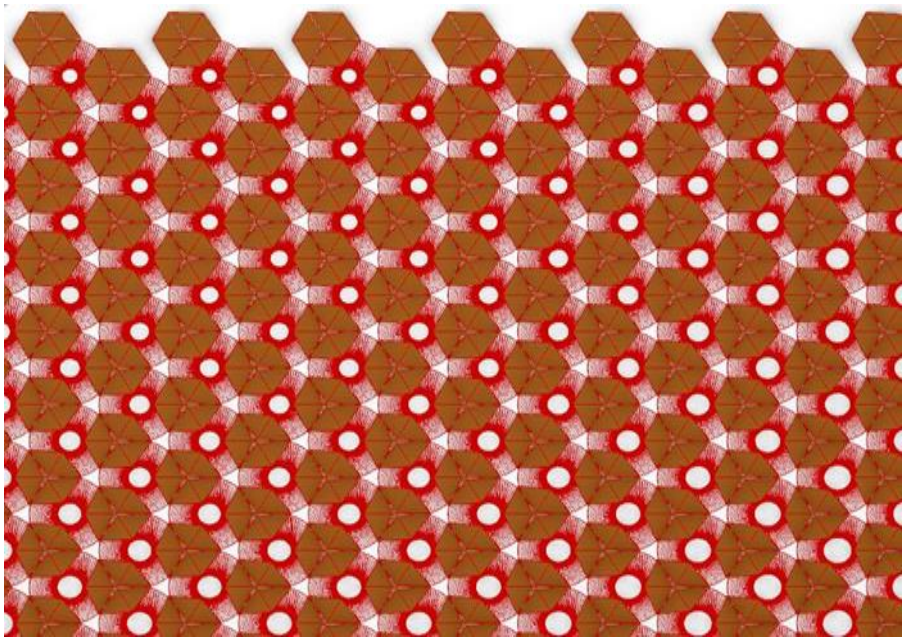


Fig. (Ⅳ) The envelope Pattern (Source: Researchers, 2021)

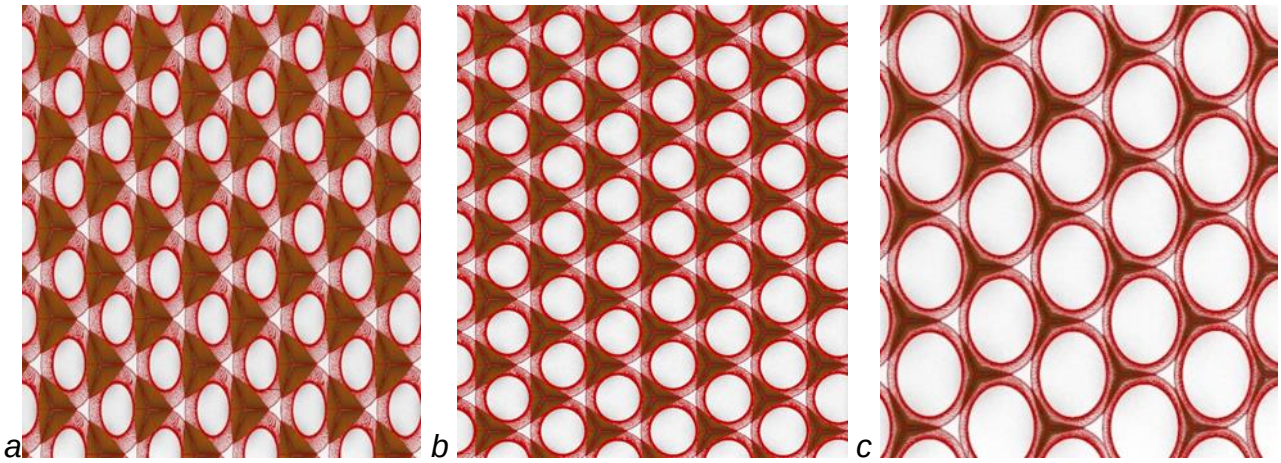


Fig. (Ⅴ a,b,c) Three different shapes of the pattern according to sun position (Source: Researchers, 2021)

3.3. The Mechanism

According to the performance of this flower, it starts flowering in the spring and summer seasons and needs full sun, this performance makes the pattern responsive to the sun, open and closed according to the sun position Fig (Ⅴ a, b, c). This mechanism makes the pattern changing in every day and on the same day after day and night, also changing along the seasons of the year.

3.4. The colors

The colors of the building are taken from the Bottlebrush flower through totally different growing stages, and these colors help to cut back the radiation, thus helps to reduce the temperature within The building too. As famed radiation is measured in wavelengths or frequency. A wavelength has outlined the distance from peak to peak and it's measured in nanometers (nm). Frequency is outlined as wavelength cycles per second and is expressed in hertz (Hz). Bands with shorter wavelengths get higher frequencies. Likewise,

the longer the wavelength, the longer it will catch to complete a cycle, which creates a lower frequency. The energy of the wavelength will increase with the frequency and reduced to the scale of the wavelength. In alternative words, shorter wavelengths are more energetic than longer ones. This symbolizes that ultraviolet radiation is more energetic than infrared radiation. Due to this additional energy, shorter wavelengths tend to cause a lot of damage than longer wavelengths. The more energy a wavelength has, the simpler it is to disrupt the molecule that absorbs it. Ultraviolet contains wavelengths between 100-400 nm. Visible light falls within the range of 400-700 nm, and infrared light contains wavelengths from 700 nm to over one millimeter (Fondriest Environmental, Inc., 2014). The used color here as it is shown in Fig. (Ⅵ) Having long wavelengths, the glass of the building with green color, the circles in the envelope with red color which is the flower color, and the hexagonal shape in the envelope with reddish-orange which is the color that the flower turns to in the fruiting time. Using these colors reduced the radiation on the building and so the inner temperature of the building.

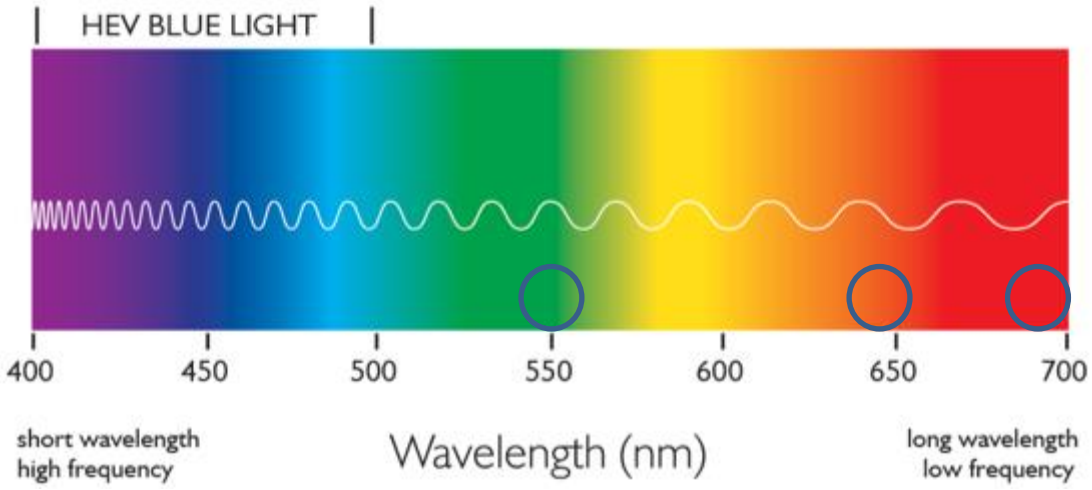


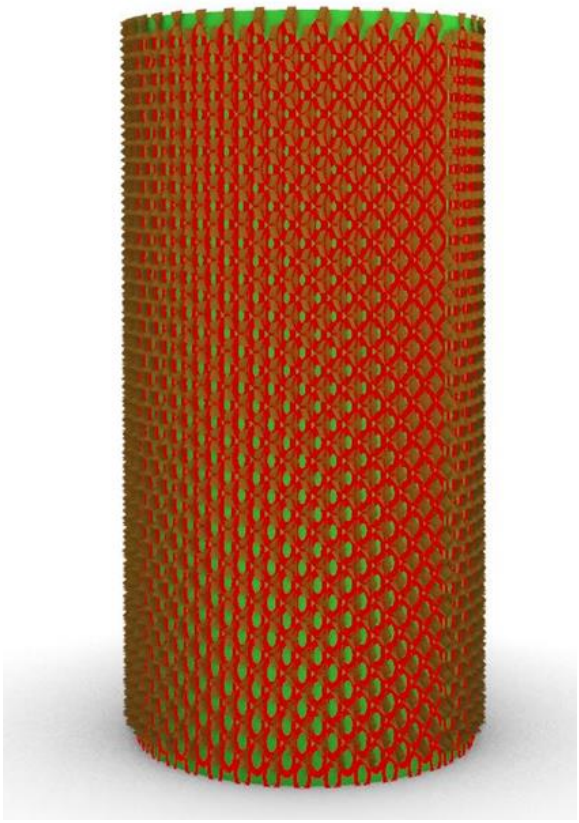
Fig. (Ⅵ) Showing the used color wavelengths.
(Source: https://caltechletters.org/science/color-in-nature)

3.5. The Building

Applying the building information in Grasshopper to get the final shape and form of the building Fig. (Ⅶ), (Ⅷ). The calculations and areas of the building showing in the following table (Ⅰ).

Land area	*3600 m2*
The cross area	*1962.5 m2*
Floor to floor height	*4 m*
Number of the floors	*35*
The total height	*140 m*

Table (Ⅰ): showing the building calculations (Source: Researchers, 2021)



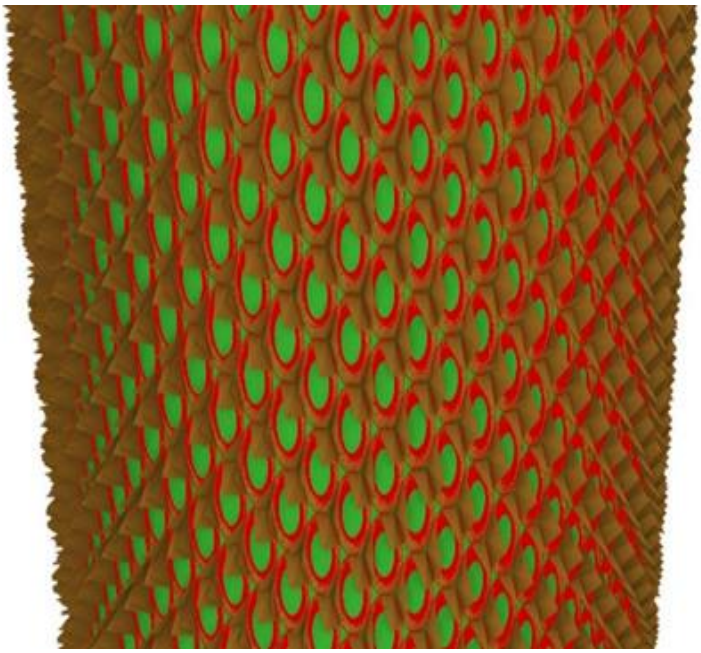


Fig. (VII)(Left) The final parametric biomimicry inspired office building. (Source: Researchers, 2021)
Fig. (VIII)(Right) Close shot from the building. (Source: Researchers, 2021)

3.6. Results

The process starts with making a simulation of the building by Using Grasshopper and ladybug plug-in to study and analyze the effect of the environment in the building in different stages and conditions, Sun path and the radiation analysis according to Al-Basrah weather data. A firstly, analyses the effect of the sun and the radiation on the building before applying the envelope and compared it after applying the envelope with the same conditions and compare the results.

Considering the working hours in the building in the duration (8 a.m. to 5 p.m.), the temperature of Al- Basrah increases starts from the spring to the summer, which means from March to October, and that is the hottest period of all the year. The environmental studies included study and analysis of the sun path and the radiation in duration (8 a.m.to 5 p.m.) on the day 15 of March, July, and October. And then study and analyze the sun path and the radiation of the whole time period from 15 March to 15 October.

-The first period: on day15 March at the time (8 a.m.to 5 p.m.) Fig. (IX, X, XVII)

-The second period: on day15 July at the time (8 a.m.to 5 p.m.) Fig. (XI, XII, XVIII)

-The third period: on day15 October at the time (8 a.m.to 5 p.m.) Fig. (XIII, XIV, XIX)

-The fourth period: from day 15 March to 15 October at the time (8 a.m.to 5 p.m.) Fig. (XV, XVI, XX)

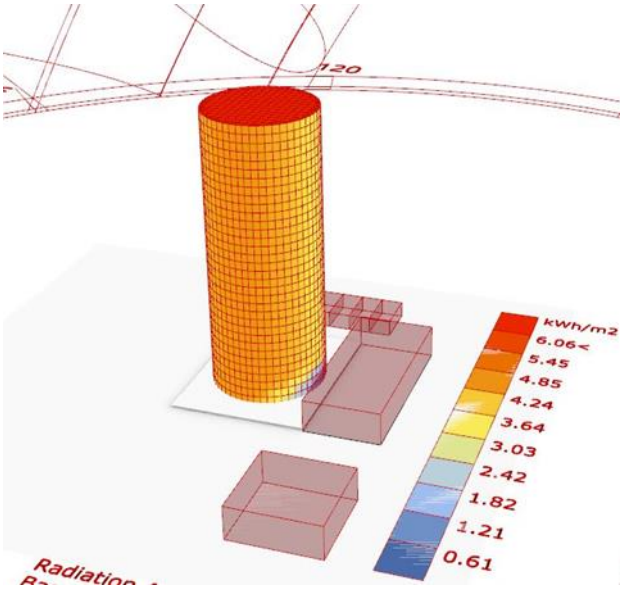


Fig. (IX) Rhino, Grasshopper & Ladybug radiation analysis for the building without an envelope on day 15 March at the time (8 a.m.to 5 p.m.), as shown the lowest value of the radiation on the building is 0.61 kWh/m2 and the highest is 6.06 kWh/m2.
(Source: Researchers, 2021)

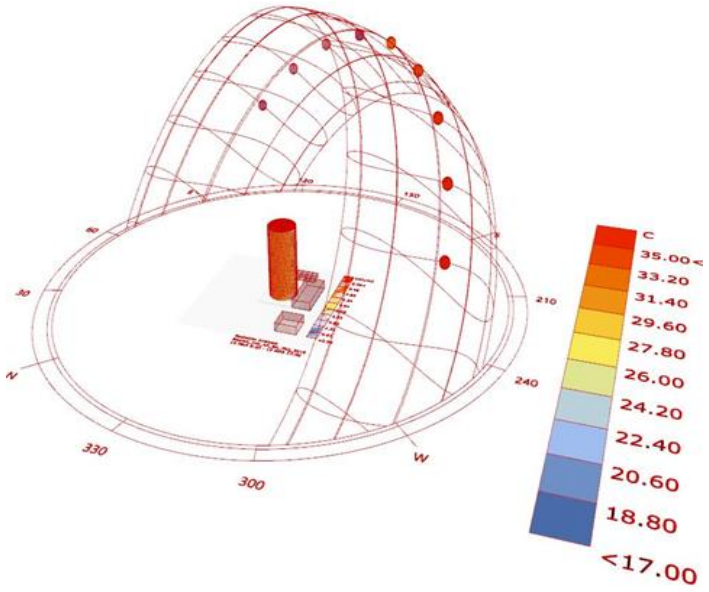


Fig. (X) Rhino, Grasshopper & Ladybug sun path analysis for the building without an envelope on day 15 March at the time (8 a.m.to 5 p.m.), as shown the lowest temperature is 18.80 Celsius degree and the highest is 35 Celsius degree.
(Source: Researchers, 2021)

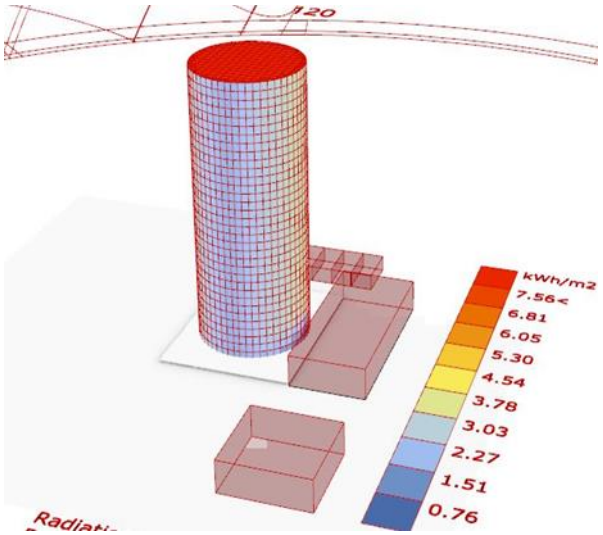


Fig. (XI) Rhino, Grasshopper & Ladybug radiation analysis for the building without an envelope on day 15 July at the time (8 a.m.to 5 p.m.), as shown the lowest value of the radiation on the building is 0.76 kWh/m2 and the highest is 7.56 kWh/m2. (Source: Researchers, 2021)

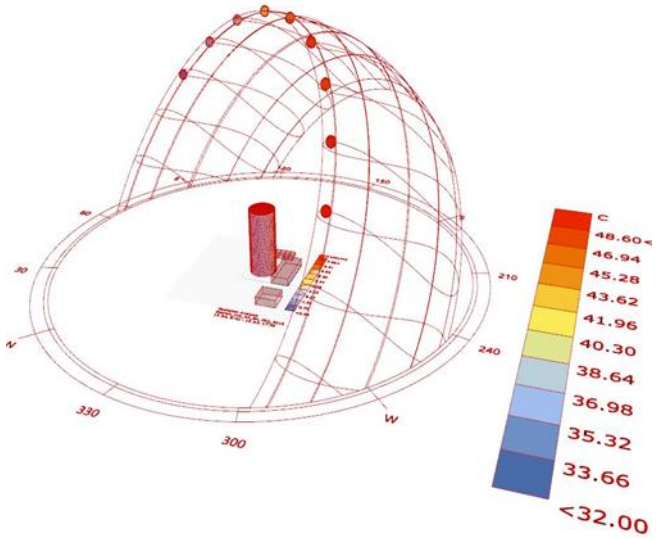


Fig. (XII) Rhino, Grasshopper & Ladybug sun path analysis for the building without an envelope on day 15 July at the time (8 a.m.to 5 p.m.), as shown the lowest temperature is 33.66 Celsius degree and the highest is 48.60 Celsius degree. (Source: Researchers, 2021)

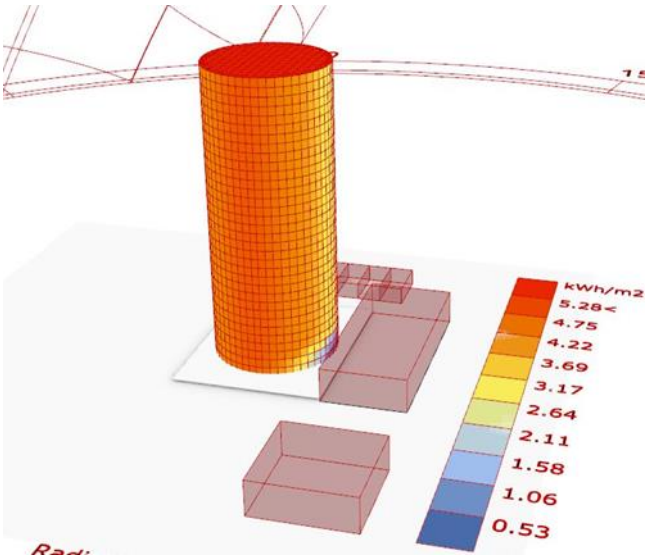


Fig. (XIII) Rhino, Grasshopper & Ladybug radiation analysis for the building without an envelope on day 15 October at the time (8 a.m.to 5 p.m.), as shown the lowest value of the radiation on the building is 0.53 kWh/m2 and the highest is 5.28 kWh/m2. (Source: Researchers, 2021)

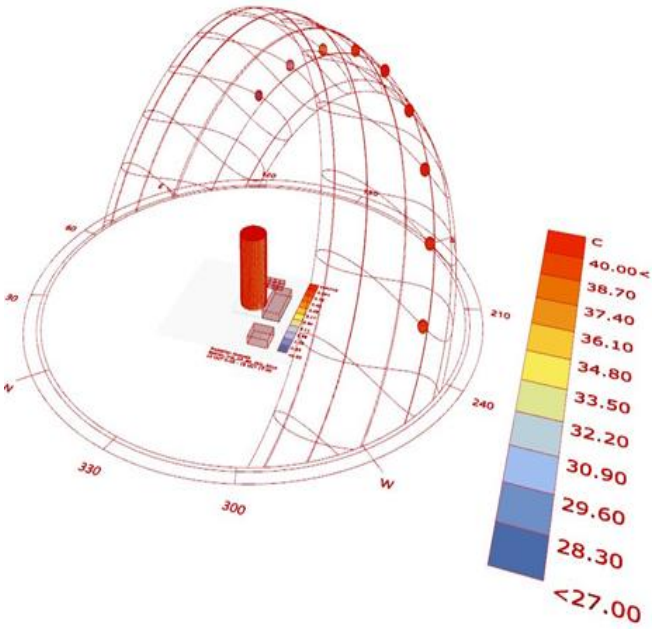


Fig. (XIV) Rhino, Grasshopper & Ladybug sun path analysis for the building without an envelope on day 15 October at the time (8 a.m.to 5 p.m.), as shown the lowest temperature is 28.30 Celsius degree and the highest is 40 Celsius degree. (Source: Researchers, 2021)

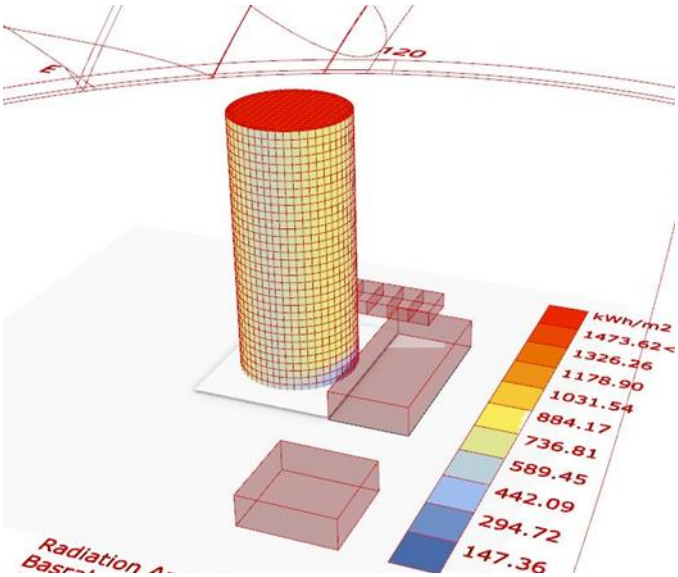


Fig. (XV) Rhino, Grasshopper & Ladybug radiation analysis for the building without an envelope from day 15 March to 15 October at the time (8 a.m.to 5 p.m.), as shown the lowest value of the radiation on the building is 147.36 kWh/m2 and the highest is 1473.62 kWh/m2. (Source: Researchers, 2021)

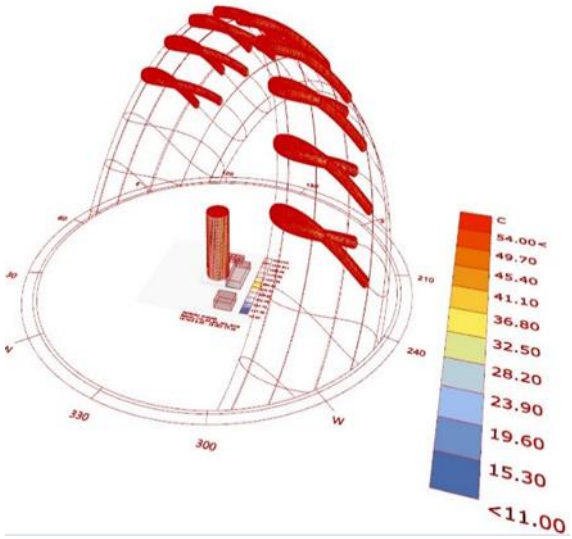


Fig. (XVI) Rhino, Grasshopper & Ladybug sun path analysis for the building without an envelope from day 15 March to 15 October at the time (8 a.m.to 5 p.m.), as shown the lowest temperature is 15.30 Celsius degree and the highest is 54 Celsius degree. (Source: Researchers, 2021)

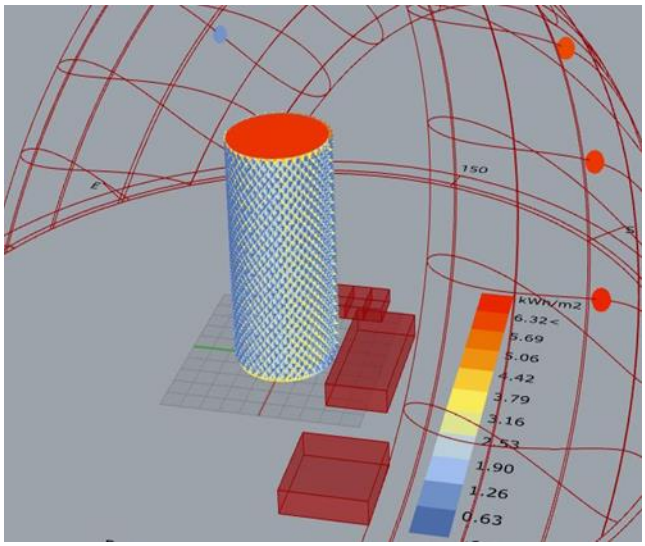


Fig. (XVII) Rhino, Grasshopper & Ladybug radiation analysis for the building with the envelope on day 15 March at the time (8 a.m.to 5 p.m.), as shown the lowest value of the radiation on the building is 0.63 kWh/m2 and the highest is 6.32 kWh/m2. (Source: Researchers, 2021)

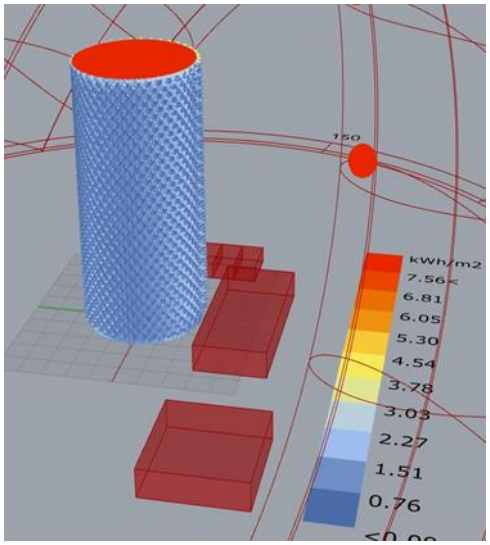


Fig. (XVIII) Rhino, Grasshopper & Ladybug radiation analysis for the building with the envelope on day 15 July at the time (8 a.m.to 5 p.m.), as shown the lowest value of the radiation on the building is 0.76 kWh/m2 and the highest is 7.56 kWh/m2. (Source: Researchers, 2021)

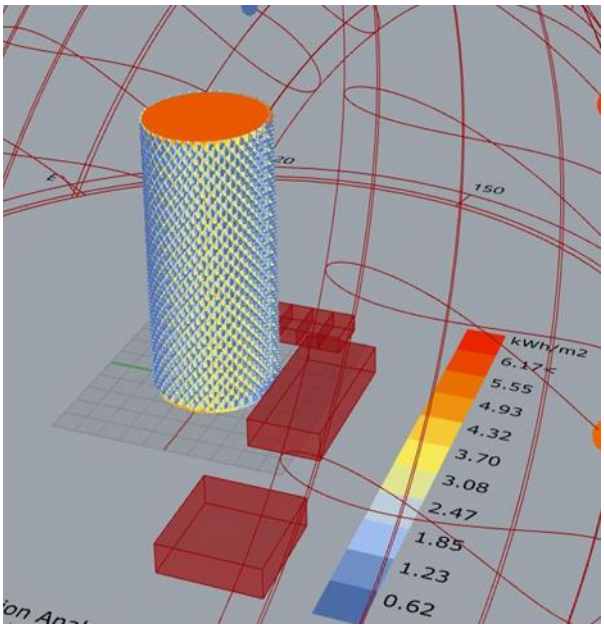


Fig. (XIX) Rhino, Grasshopper & Ladybug radiation analysis for the building with the envelope on day 15 October at the time (8 a.m.to 5 p.m.), as shown the lowest value of the radiation on the building is 0.62 kWh/m2 and the highest is 6.17 kWh/m2. (Source: Researchers, 2021)

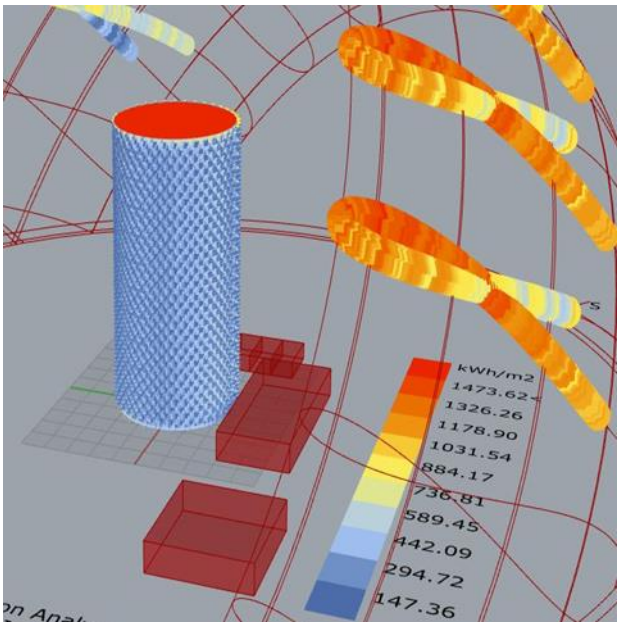


Fig. (XX) Rhino, Grasshopper & Ladybug radiation analysis for the building with the envelope from day 15 March to 15 October at the time (8 a.m.to 5 p.m.), as shown the lowest value of the radiation on the building is 147.36 kWh/m2 and the highest is 1473.62 kWh/m2. (Source: Researchers, 2021)

3.7. Discussion

As it was shown in the previous environmental studies of the sun path and radiation, there's a difference in distribution the radiation and the effect of radiation on the building's façade. As it is shown in the first period Fig. (IX) the radiation is between (3.03- 5.45 kWh/m2) and small area of the building gain radiation between(1.21- 1.82 kWh/m2) which is the lowest because of the shading from the side building, which is the part of the building that not need to be covered by the envelope because the radiation there is the lowest. While the effect of radiation on façade reduced after applying the envelope to the building as shown in Fig. (XVII) The radiation became between (1.26 – 3.79 kWh/m2). Also in the third period Fig. (XIII) The radiation on the building's façade between (2.64 - 5.28 kWh/m2), while it became between (1.23 -3.70 kWh/m2) after applying the envelope to the building Fig. (XIX). If see the radiation in the fourth time period Fig. (XV) Which is starting from March to October, the radiation between (147.36 – 884.17 kWh/m2), and after applying the envelope became between (147.36 – 589.45 kWh/m2) Fig. (XX). Besides that in the hot, humid climate the circular shape is the optimum geometric shape (receiving the lowest amounts of annual total radiation) among all high-rise building shapes according to a study in 2007 (Ling, Ahmad, and Ossen, 2007).

4. Conclusion

The management of the land can be in a better way with the rules and conditions of the city, and provide smart solutions by using the environment to generate an adaptive unconventional form by using the parametric design in form generation with applying Biomimicry, or (P.B.B.D) showing that nature has provided an unlimited source of design and can be effectively applied to form design. Parametric design can effectively enrich the content of form design. It is possible to take advantage of nature and the surrounding environment in obtaining forms and compositions limitless to the ability to apply in an engineering way in the buildings design process by parametric design, and at the same time take advantage not only of their form but also their performance to solve a particular problem in the building or reduce the impact of this problem by using Biomimicry, and may go beyond that not only in the work of simulation of form, composition or performance but also color. Take advantage of nature's solutions to solve building design problems. In this way we have used and provided an innovative and unconventional design method to design a renewable, variable building that is in keeping with future architectural development and can be implemented in an engineering way, and taken from the surrounding environment of the place which the building is designed, not only a shape, performance, and color, but also used to provide a treatment of a particular problem in this environment or place. Bottlebrush flower is one of many examples from the nature and environment of Al-Basrah city which proof that through generating unconventional renewable building form, and from its performance, providing a shading system to reduce the impact of the radiation on the building which helps to reduce the cooling loads. At the same time, this shading envelope, not completely solid but it allows daylight, which is helping to reduce the consumed lighting inside the building. Using the colors of the flower

which reduces the radiation. All that reduces the impact of the radiation on the building. In this way it is proved that the technologies can provide a smart solution to enhancing the field of land management and the land development and construction field.

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