DIAMOND SUN-SCREEN WALL

An investigation of different environmental solutions of diamond parametric pattern

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Abstract. Nowadays, Computer simulations have become part of the design process and affect the design decisions. This paper questions the possibility of generating different designs of curved sunscreen, their cladding systems and openings, taking into account environmental factors for evaluation. And that is by developing a computational evaluation method to test the formation of the screen with parametric modules to reduce radiation on it and by controlling the design of its component and opening units. First the study represent the background of diamond shape in nature and diamond pattern in fractal crystals.
Second the study suggests using diamond parametric patterns to generate these shapes. Each generated design follows an evaluation stage by comparing three different mathematical modules of diamond grids. Then the research will examine the different modules on curved screen wall and make different environmental studies using rhino ladybug environmental plugin and we stand on the advantages of each design and simulation of solar radiation to reach the best results. The results are used to feed back the generation process to contribute to the design decision. This study validates the method by adding some other environmental factors and applying studies on different forms of Solar screen wall. This study aims to test the susceptibility of diamond grid in reducing solar radiation gain as a driver and a source of concept to develop good designs of façades.
Keywords: Computational Design, Solar Screen wall, Diamond Parametric Pattern and Environmental Simulation Programs

1. Introduction

Diamond sun screen wall was the result of a Digital Design process. The goal of the study was to develop a diamond grid patterns be exploited in generating better environmental solutions.

The project was funded through a series of Departmental grants as well as supported by the Muncie Makes Lab, a local community organization. This paper will first outline the course structure and introduce the problematic associated with the designing of complex tensegrity structures. The paper will then explore a unique process, through the utilization and creation of new tools within Rhinoceros 3d, Grasshopper, Galapagos and Kangaroo through which students were able to design and fabricate a parametric system allowing for the design and aggregation of tensegrity modules which formed the pavilions structural envelope.

2. Background

2.1 Paramtericism versus differentiation

Diversity is important to conduct experiments on different factors affecting the design of facades, so we followed this approach by computing a mathematical module to form the components of the facade.

Correlation between differentiation and dataset; such as environmental factors – solar radiation study, The differentiation of the surface serves as a medium of articulating the design of the façade. This can be done by correlating with the geometric or functional aspects of the space the surface constructs.

2.2 Case Study :Solar Gate Sundial in Hull

Architect: Tonkin Liu, 2017

Solar Gate could be a timepiece that uses solar alignment to mark important times and dates in Hull. The super-light innovative two-shell structure is place-specific, responding to important historic events and to the cultural context of its location in Hull's Queens Gardens adjacent to the traditional site of Beverley Gate.

Figure 1. Solar Gate Sundial in Hull

The sculpture stands at Ten metres high, 4m wide and 1m deep (tapering to 100mm at the 2 open edges) however is formed from miraculously skinny 4mm plates. From these edges guests can see however the structure is formed. Two curving and corrugated surfaces join, while not the help of any extra supporting internal structures. All of the structural strength is inherent within the sculpture's shell form that uses Tonkin Liu's Shell Lace technique.

Solar Gate becomes an illuminated timepiece at night, with a controlled in-ground lighting system installed inside and outside the sculpture. Designed by Tonkin Liu, the lighting sequence has been programmed to alternate between outside and inside, changing the sculpture into near-transparency. Around the sculpture a ring of perimeter lighting turns on and off in a clockwise direction, to herald forthcoming events and festivals, including a Hull-wide art event stated because the "Golden Hour."

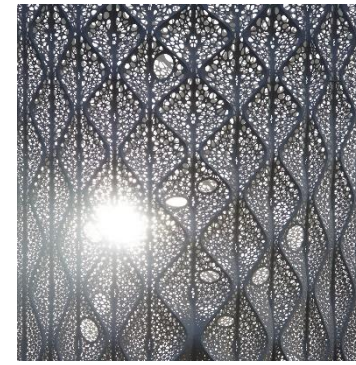


Figure 2. Solar Gate becomes timepiece

Solar Gate uses advanced digital tools to align actual sun angles from specific times and dates to pairs of huge apertures on its surfaces. Once a beam of Sunlight passes through an aligned pair of apertures, it lands on a corresponding disc on the ground, a disc that reveals a major event for the set of time and date. Sixteen reveal dates have been selected to celebrate Hull's history and world events.

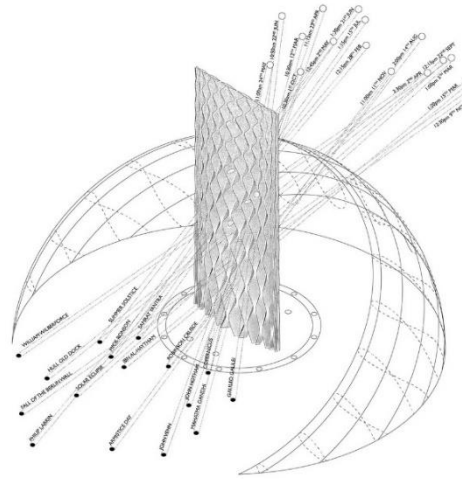


Figure 3. Solar Gate uses advanced digital tools to align actual sun angles

3. Diamond pattern in Nature and in Architecture:

Diamond Shape in nature is a unique crystal to inspire the paneling system we will use in the curved solar screen wall as one of parametric pattern examples in grasshopper computer program and study the different grids and its effect of the elevation also, studying the sun path diagram on and environmental study to see the relation of the façade form of paneling and the movement of the sun on winter summer and Rather than utilizing the traditional model based means of form finding, the study uses simu- lation tools within Rhino 3d and Grasshopper.

Figure 4. Diamond Crystals in Nature

3.1 Snow Flake Crystals Shapes in Nature:

Not all snowflakes look like six pointed stars. Many do, but there are also quite a few odd-looking crystals falling from the winter clouds. You will see them if you go out looking, but it helps if you know what to look for. On this page we examine a few examples from the snow crystal menagerie.

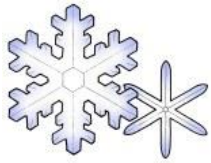
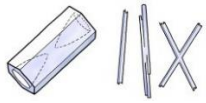
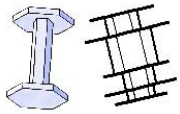
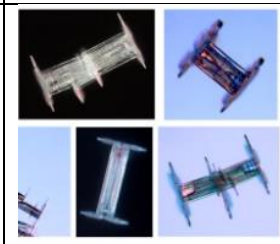
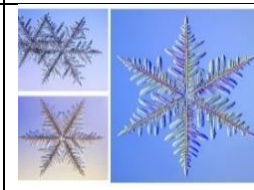
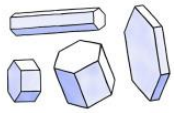
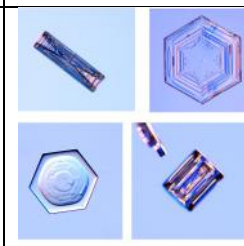
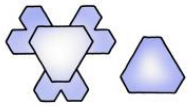
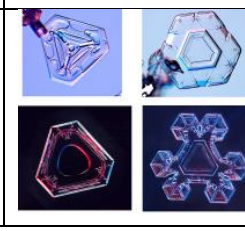
Name	**Description**	**Shape**
Stellar Dendrites 	Their name comes from their star-shaped appearance, along with their branches and side branches.	
Columns and Needles 	Columnar snow crystals appear when the temperature is around -6 C (21 F).	
Capped Columns 	A basic capped column is shaped like two wheels on an axle,	
Fernlike Stellar Dendrites 	These crystals are like Stellar (above), but larger and leafier, with many side branches that resemble the branches of a fern.	
Diamond Dust Crystals 	The basic ice crystal shape is that of a hexagonal prism.	
Triangular Crystals 	It appears that aerodynamical effects help produce these unusual snow crystals.	

Table 1. Diamond Crystals in Nature

4. Solar Screen Simulation Study

4.1 Diamond Shape the pattern of solar screen study:

In this analysis we will use simplify the snow flake pattern to produce the diamond pattern to apply on free form pavilion

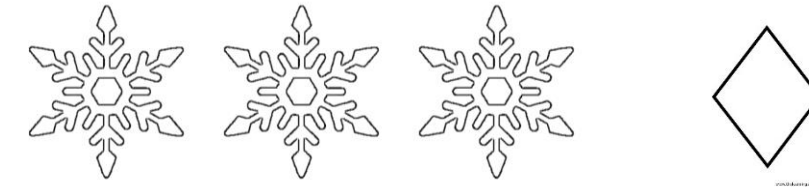


Figure 5. Simplified Diamond Crystals in Nature

4.2 Diamond Pattern Module Construction:

The paper will use Rhino Grasshopper program to produce three modules for diamond pattern to apply on the paneling system

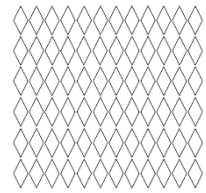
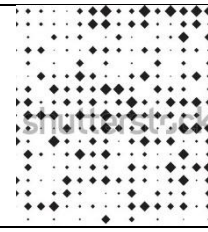
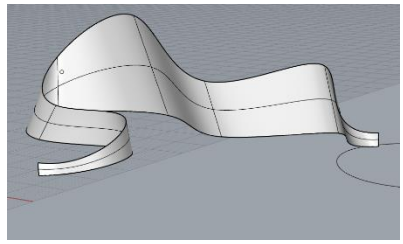
Diamond Grid	Graph	Grasshopper Code
Structure Diamond pattern		Diamond Grid in Lunch Box Plug-In
Random Diamond pattern		Random Hexagonal Based Pattern Generation
Interactive Diamond patter		Point Attractor

Table 2. Diamond Pattern Modules

5. Stages of the study of the Diamond curved Sunscreen Study

5.1 Form Generation

We produce the form of the 3D Model of the Curved SunScreen using Rhino Rhino Membrane, Grasshopper, and Ladybug were utilized for the project's simulation. Rhino membrane, a plug-in designed for Rhino 4.0 was used for initial module form finding, digital feedback and enclosure optimization. Lady bug plug in apply the environmental simulation study on the Sunscreen



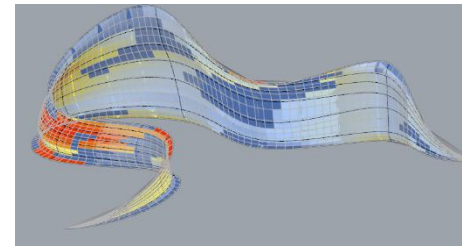


Figure 6. Solar Screen wall without diamond opening

5.2 Random Diamond Pattern Distribution Scenario 1 and Scenario 2

The first and second Scenario of the study we Apply the Diamond pattern in Two different scales of diamonds distribution and make the same studies on the solar wall to visualize the sun intensity on the surface.

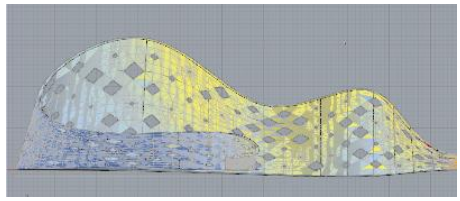


Figure 7. Solar Screen wall Scenario One (Small Diamond opening distribution)

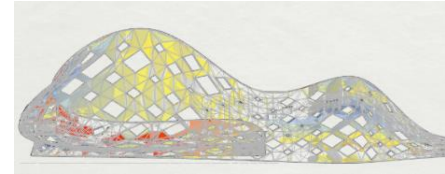


Figure 8. Solar Screen wall Scenario Two (Big Diamond pattern distribution)

6. Interactive Diamond Pattern Distribution Scenario 3

The third scenario we apply the interactive module to get another option of diamond distribution and make the same studies on the solar wall .

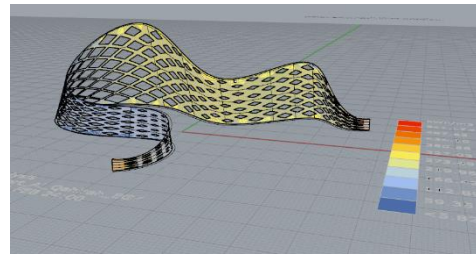


Figure 9. Solar Screen wall without diamond opening

7. Diamond Sunscreen Environmental Simulation Study Three Scenarios:

7.1 Scenario 1 Random Pattern Diamond SunScreen Wall:

7.1.1 Sun path Study:

In this study we use stereo graph diagram to visualize solar rays and solar fan simulation in summer and winter period on the screen wall

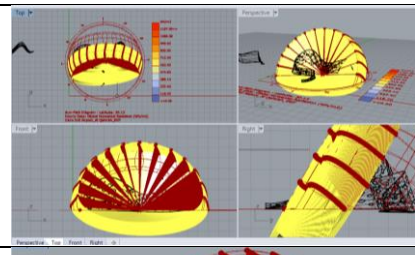
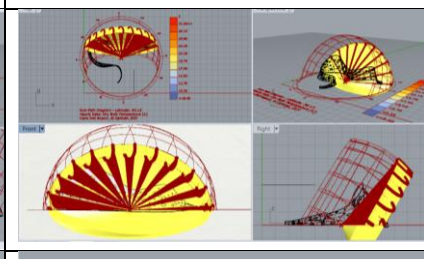
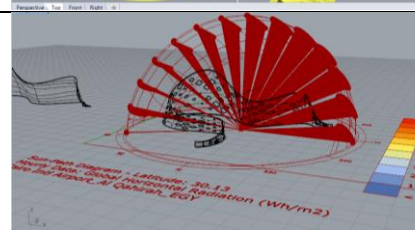
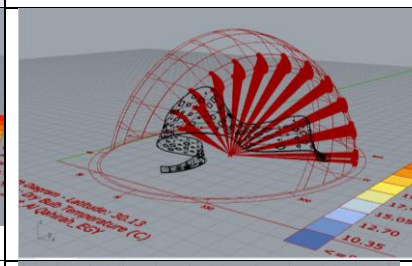
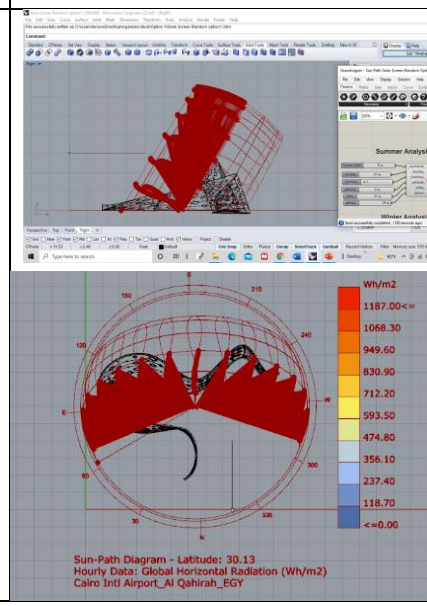
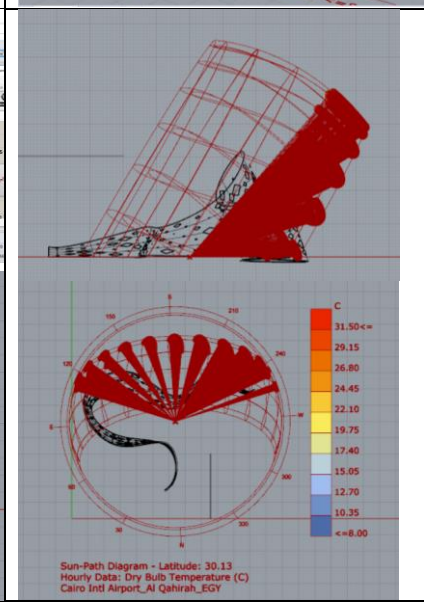
Sun path Study	Analysis period Summer Time	Analysis period Winter Time
Draw sun vectors and solar fan		
Draw Sun vectors		
		

Table 3. Sun Path and Solar Fan Study in Summer and Winter

7.1.2 Comparison Study of sun path with temp and sun path with wind speed Sun path Study:

The environmental simulation using Grasshopper lady bug plugin provide us with a visualization of comparison between **the sun path with temp and the sun path with wind speed** using the next equation

a) We add in the conditioning statement of the sun path commend the equation of Temperature (a) is between 0 and 35 and wind speed (b) between 3 and 18
Then the program give us the next graph to achieve the equation.

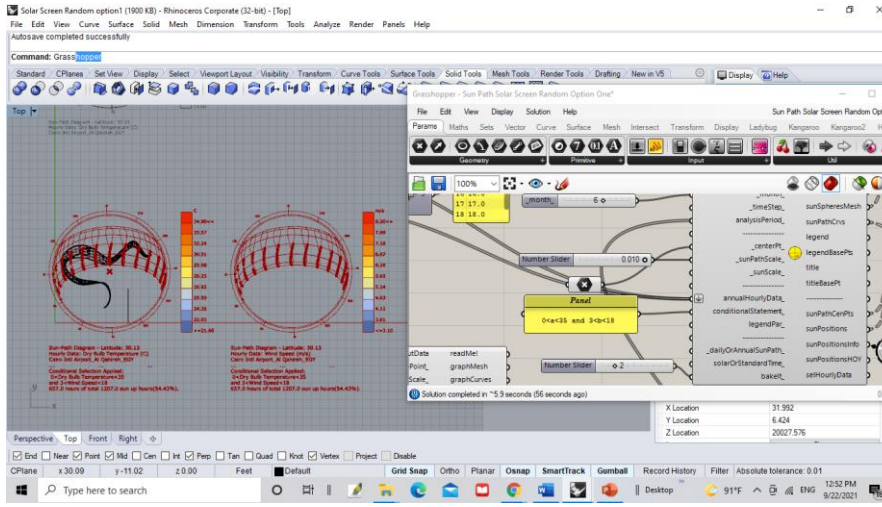


Figure 4. Equation of the graph comparison

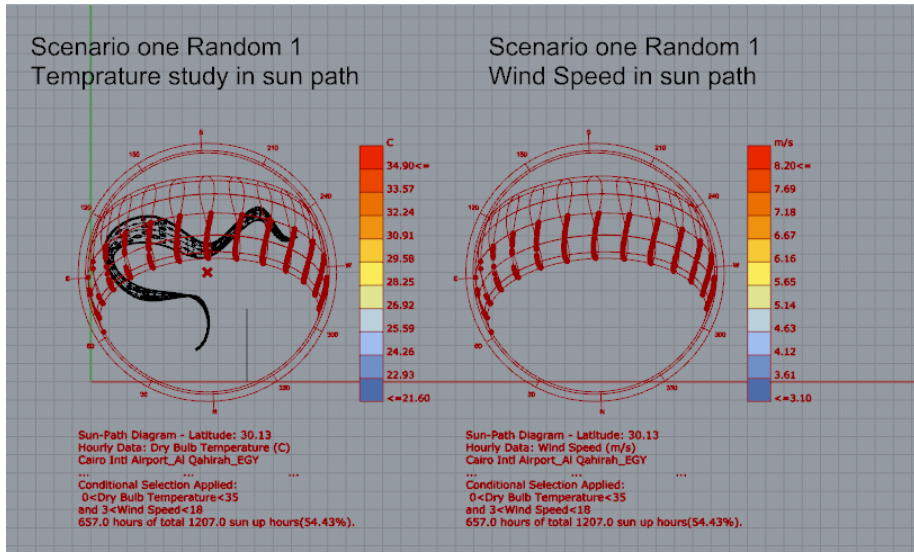


Figure 5. Comparison graph of the temperature and wind speed

7.1.3 Legend Radiation Analysis:

In this study we use the radiation rose commend to the graph of the direct and diffuse radiaton in Summer and Winter period.

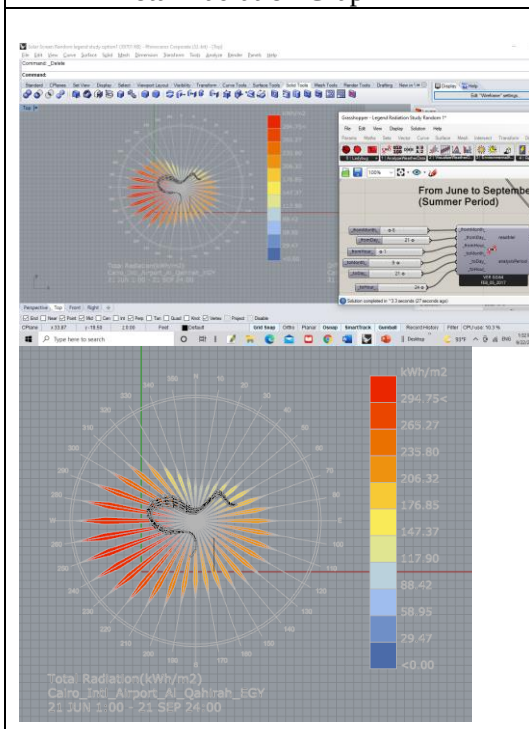
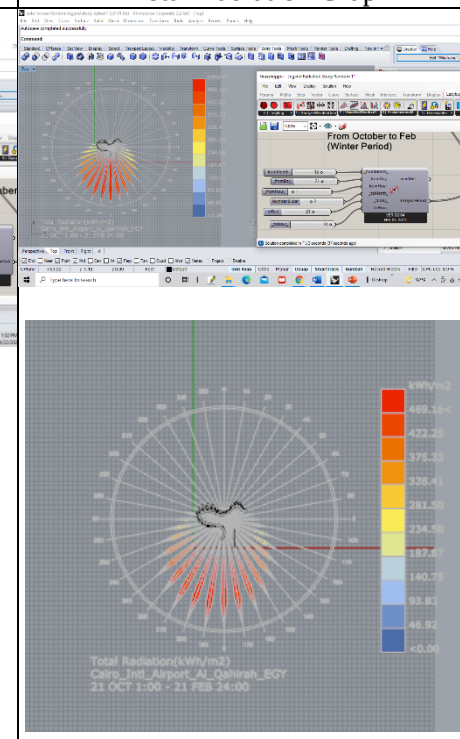
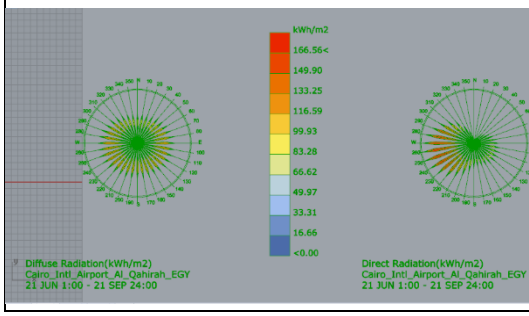
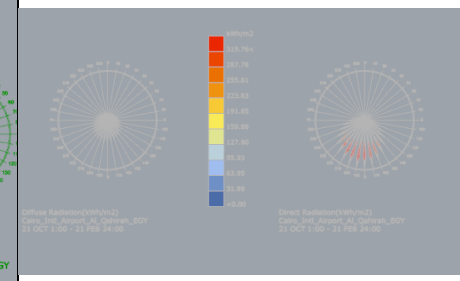
Radiation Analysis In Summer 21 June to 21 Sep	Radiation Analysis In Winter 21 Oct to 21 Feb
Total Radiation Graph	Total Radiation Graph
	
Diffuse Radiation and Direct Radiation Graph	Diffuse Radiation and Direct Radiation Graph
	

Table 4. Diffuse Radiation and Direct Radiation Study in Summer and Winter

7.1.4 Wind Rose Analysis:

In this study we visualize the wind rose in summer and winter on the solar diamond wall and get the minimum and maximum wind speed

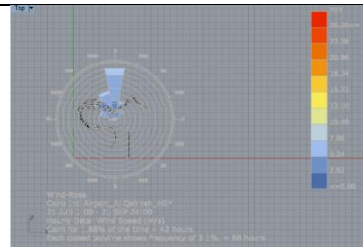
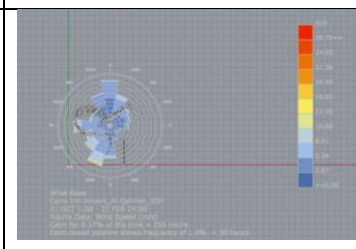
Wind Rose in Summer 21 June to 21 Sep	Wind Rose in Winter Winter 21 Oct to 21 Feb
	

Table 5 Wind Rose Analysis

7.1.5 Radiation Analysis:

In this study we visualize the radiation colors on sunscreen diamond wall in summer and winter and decide the opening sized of the random diamond pattern.

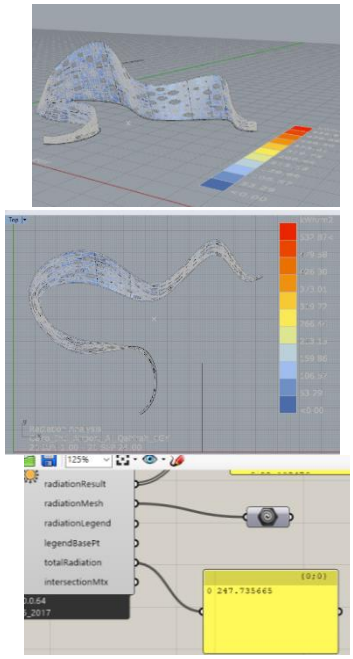
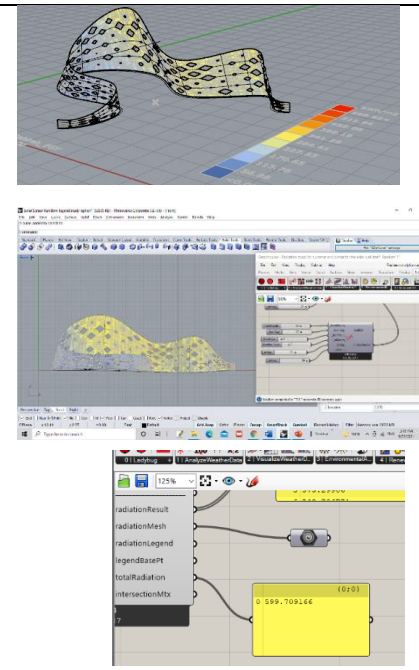
Radiation Analysis In Summer 21 June to 21 Sep	Radiation Analysis In Winter 21 Oct to 21 Feb
	
Total Radiation number in Summer 247.735	Total Radiation number in winter 599.709

Table 6. Diffuse Radiation and Direct Radiation Study in Summer and Winter

7.2 Random Diamond Pattern SunScreen Wall Scenario 2

7.2.1 Sun path Study:

In this Scenario we made a bigger random diamond opening and use solar rays and solar fan simulation in summer and winter period to visualize it on the screen wall

Sun path In Summer 21 June to 21 Sep

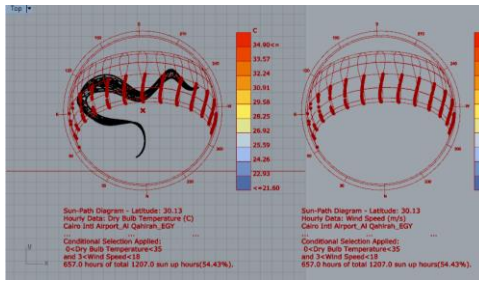
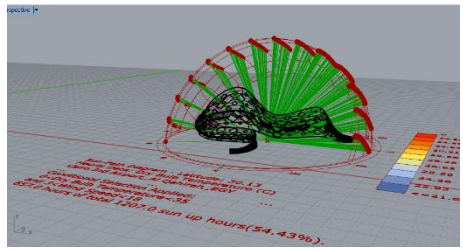
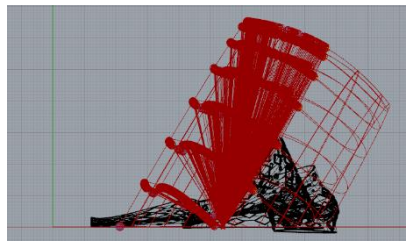
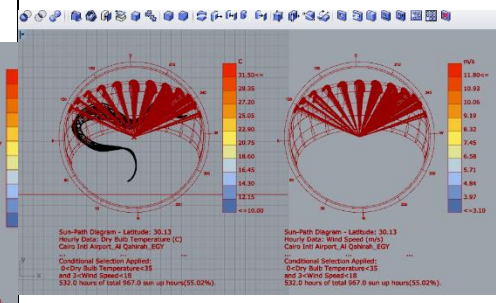
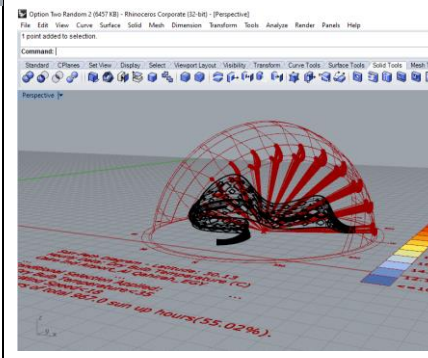
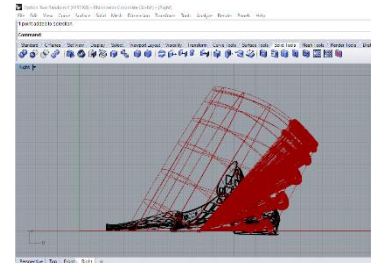
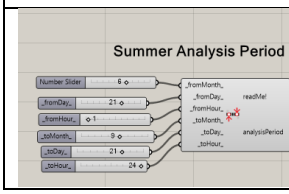
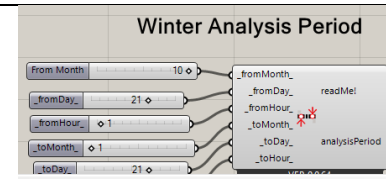
Scenario 2 Sun path In Summer 21 June to 21 Sep	Scenario 2 Sun path Analysis In Winter 21 June to 21 Sep
  	  
	

Table 7. Scenario 2 random Sunscreen sunpath Study in summer and winter

7.2.2 Legend Radiation Analysis:

In this study we use the radiation rose commend to the graph of the direct and diffuse radiaton in Summer and Winter period.

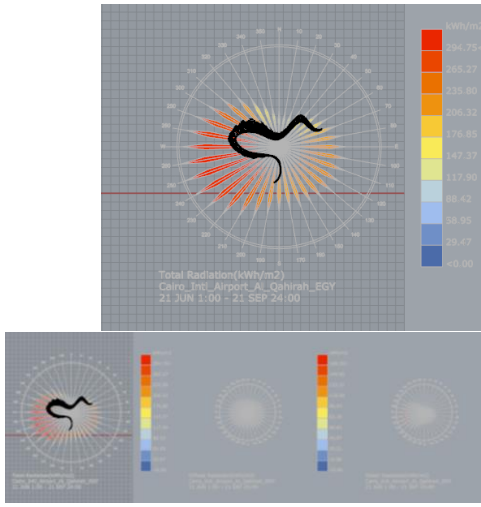
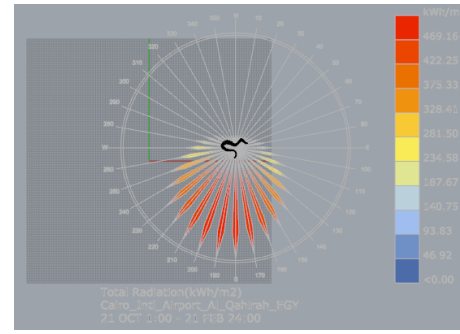
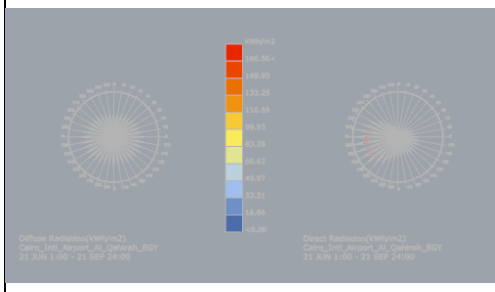
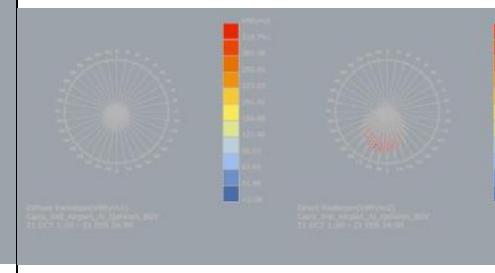
Radiation Analysis In Summer 21 June to 21 Sep	Radiation Analysis In Winter 21 Oct to 21 Feb
Total Radiation Graph	Total Radiation Graph
	
Diffuse Radiation and Direct Radiation Graph	Diffuse Radiation and Direct Radiation Graph
	

Table 8. Scenario 2 random Sunscreen Diffuse Radiation and Direct Radiation Study in summer and winter

7.2.3 Wind Rose Analysis:

In this study we visualize the wind rose in summer and winter on the solar diamond wall and get the minimum and maximum wind speed

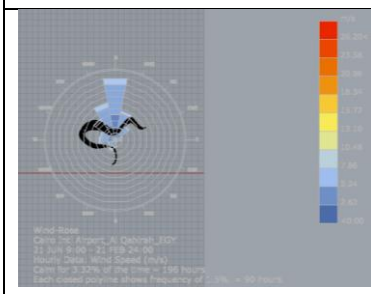
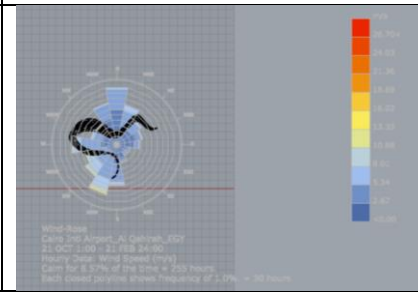
Wind Rose in Summer	Wind Rose in Winter
	

Table 9 . Scenario 2 random Sunscreen Wind Rose Analysis

7.2.4 Radiation Analysis Scenario 2:

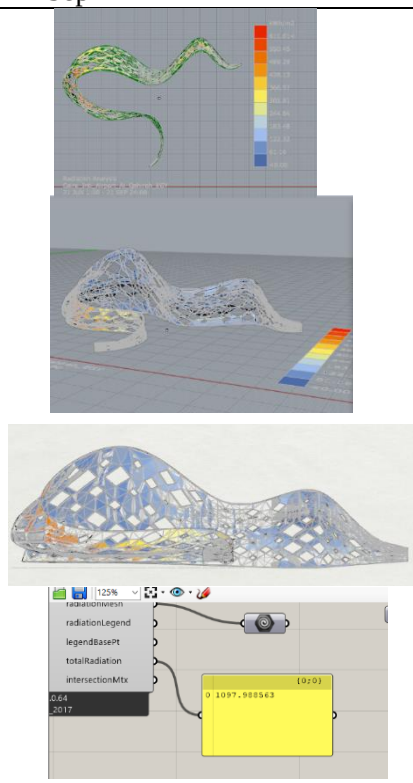
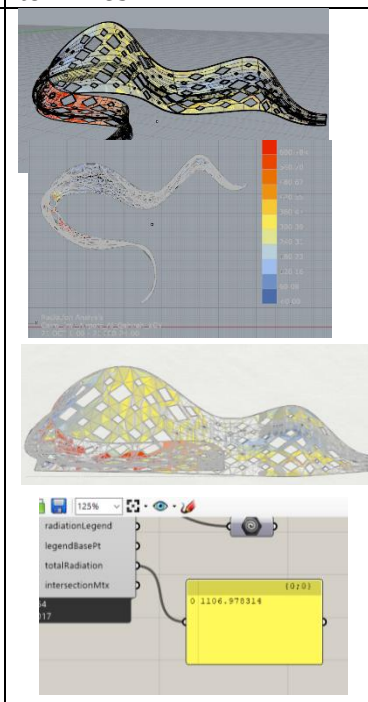
Radiation Analysis In Summer 21 June to 21 Sep	Radiation Analysis In Winter 21 Oct to 21 Feb
	
Total Radiation number in Summer 1097.98	Total Radiation number in winter 1106.97

Table 10. Scenario 2 random Sunscreen Diffuse Radiation and Direct Radiation Study

7.3 Third Scenario Interactive Diamond Solar Screen:

7.3.1 Sun path Study:

In this Scenario we made a interactive diamond opening uses point attractor on grasshopper and use solar rays and solar fan simulation in summer and winter period to visualize it on the screen wall

Sun path In Summer 21 June to 21 Sep

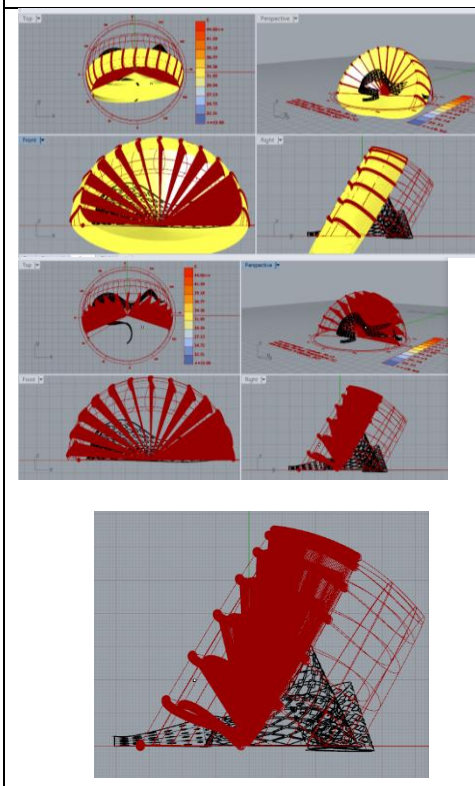
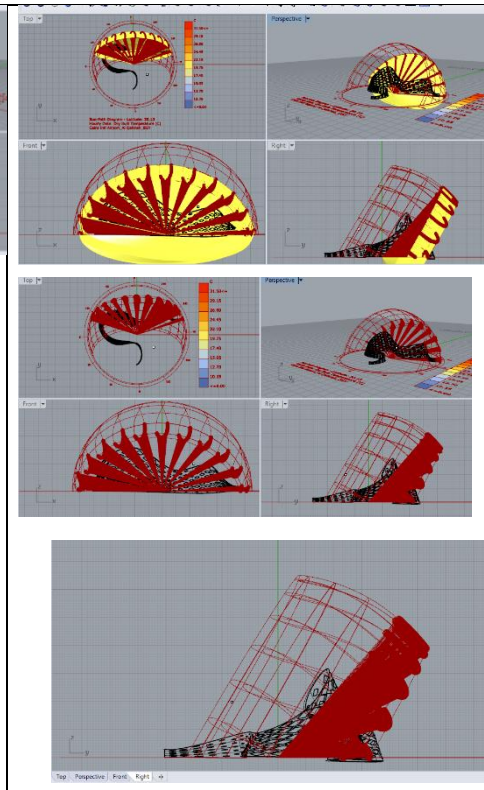
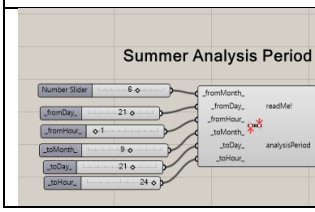
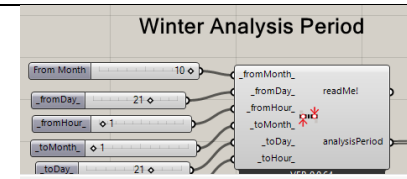
Scenario 3 Sun path In Summer 21 June to 21 Sep	Scenario 3 Sun path Analysis In Winter 21 June to 21 Sep
Draw sun vectors and solar fan	
	
	

Table 11. Scenario 3 interactive Sunscreen Sun Path and Solar Fan Study in Summer and Winter

7.3.2 Legend Radiation Analysis Scenario 3 :

In this study we use the radiation rose commend to the graph of the direct and diffuse radiaton in Summer and Winter period

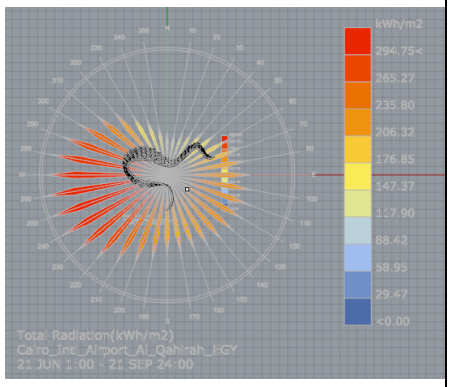
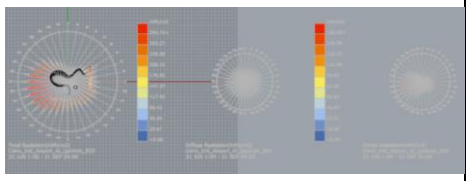
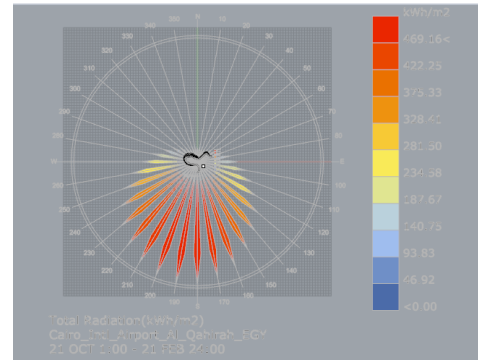
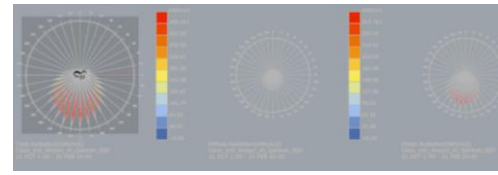
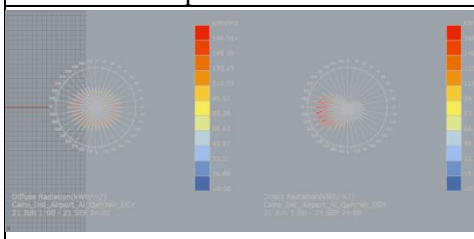
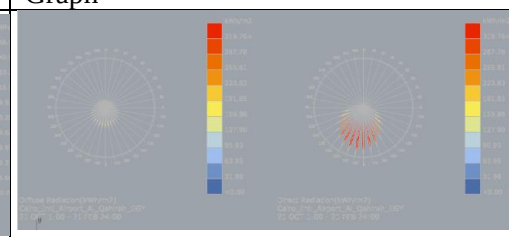
Radiation Analysis In Summer 21 June to 21 Sep	Radiation Analysis In Winter 21 Oct to 21 Feb
Total Radiation Graph	Total Radiation Graph
 	 
Diffuse Radiation and Direct Radiation Graph	Diffuse Radiation and Direct Radiation Graph
	

Table 11. Scenario 3 interactive Sunscreen Diffuse Radiation and Direct Radiation Study in Summer and Winter

7.3.3 Comparison Study of sun path with temp and sun path with wind speed Sun path Study:

Scenario 3 interactive Sunscreen a visualization of comparison between **the sun path with temp and the sun path with wind speed** using the equation

A comparison between **the sun path with temp and the sun path with wind speed**

Using the equation

Temperature (a) is between 0 and 35 and wind speed (b) between 3 and 18

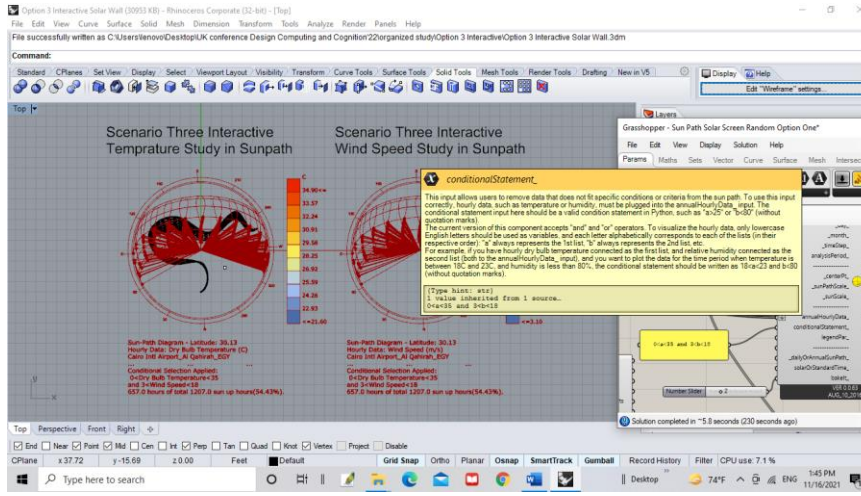


Figure 6. Scenario 3 interactive Sunscreen equation of the graph comparison

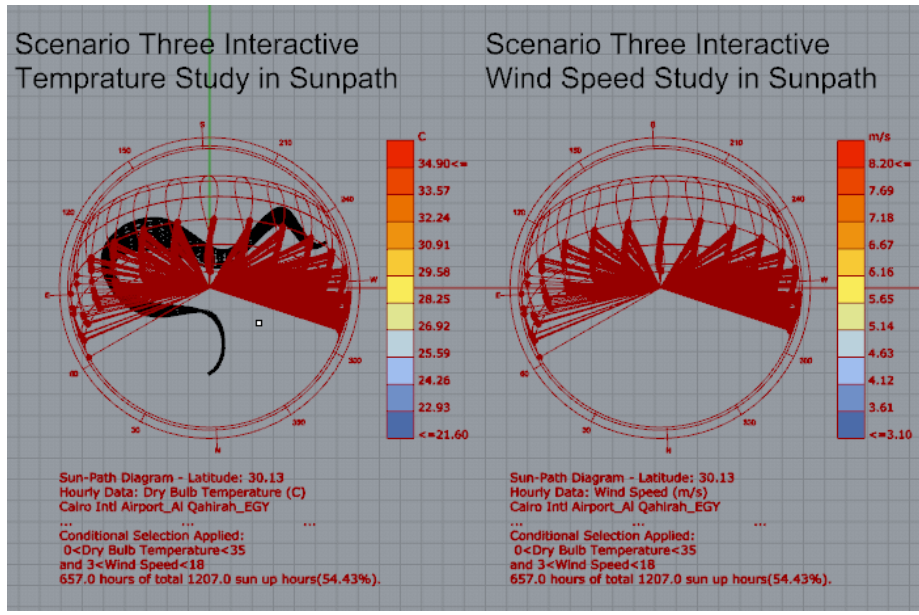


Figure 7. Scenario 3 interactive Sunscreen equation of the graph comparison

7.3.4 Wind Analysis Random Diamond Two:

Scenario 3 interactive Sunscreen In this study we visualize the wind rose in summer and winter on the solar diamond wall and get the minimum and maximum wind speed

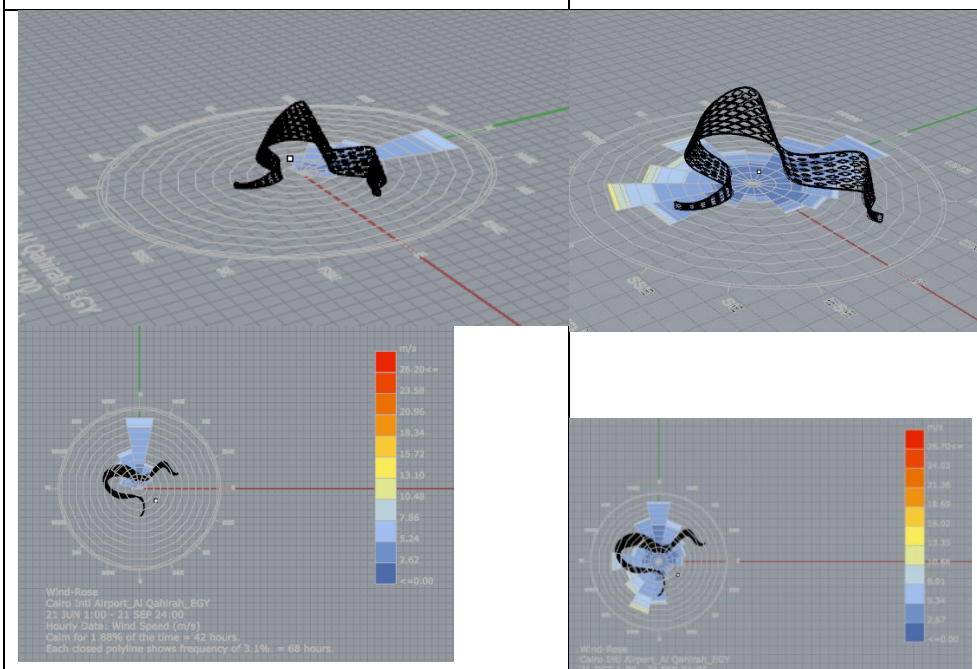
Wind Rose in Summer	Wind Rose in Winter
	

Table 12. Scenario 3 interactive Sunscreen Diffuse Radiation and Direct Radiation Study in Summer and Winter

7.3.5 Radiation Analysis Scenario 3:

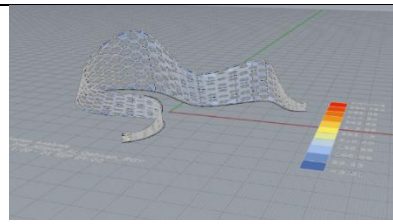
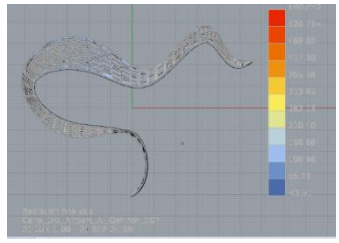
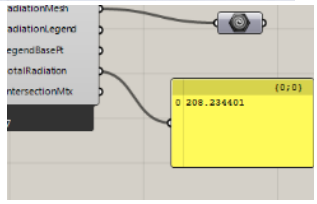
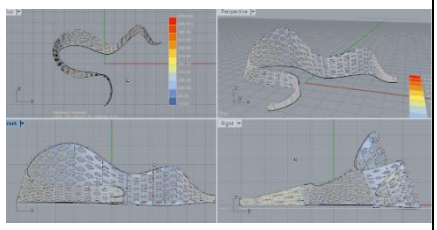
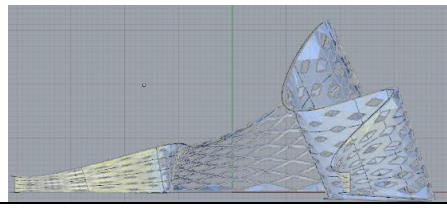
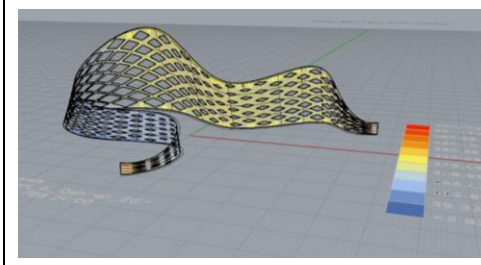
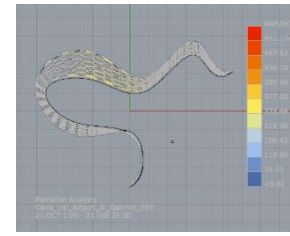
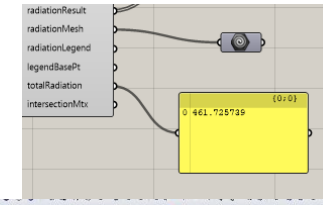
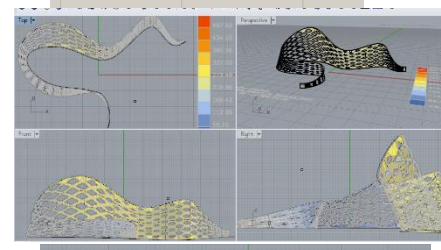
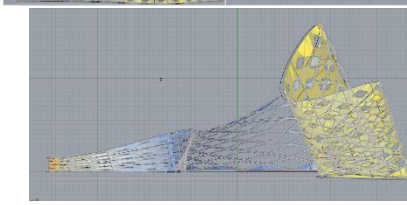
Radiation Analysis In Summer 21 June to 21 Sep	Radiation Analysis In Winter 21 Oct to 21 Feb
    	    
Total Radiation number in Summer 208.23	Total Radiation number in winter 461.72

Table 13. Scenario 3 interactive Sunscreen Diffuse Radiation and Direct Radiation Study in Summer and Winter

8. Final Results analysis for Radiation Study :

The Distribution of the diamond panelling depend on the colors of radiation so you put the bigger opening in the blue colour and the smaller diamond opening in the yellow and orange colour to reduce the total radiation inside the space

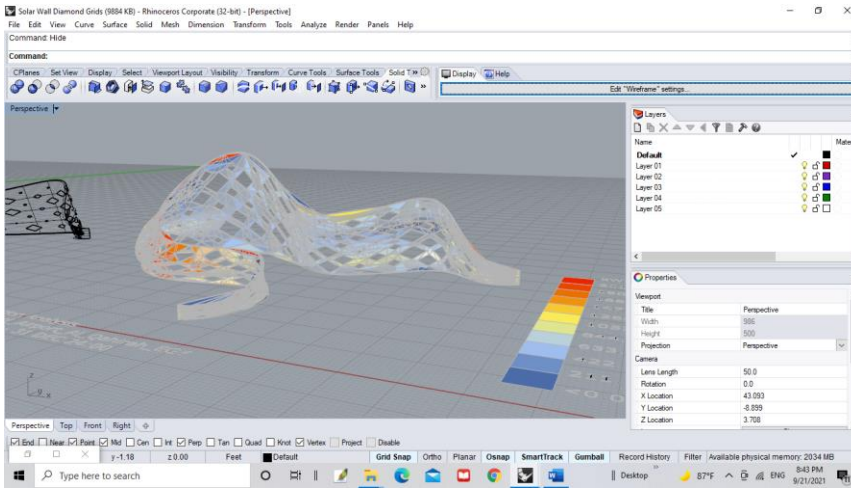


Figure 8. Scenario 2 Random Diamond Sunscreen Radiation Study in 3D

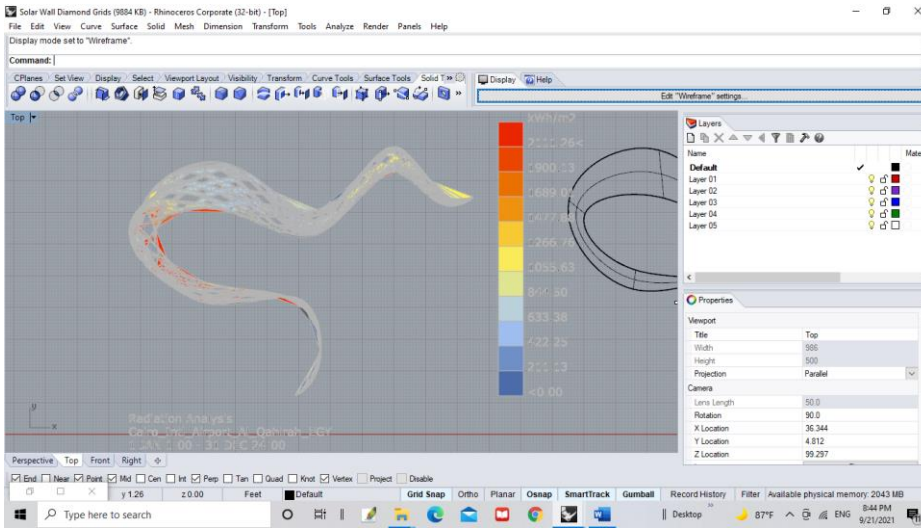


Figure 9. Scenario 2 Random Diamond Sunscreen Radiation Study in Plan

9. A comparision between the main sunscreen wall without diamond and the first scenario of the diamond panels

The paper made a comparison in the next table to visualize the difference between of the sunscreen wall without adding diamond pattern and one of the scenarios we add the diamond pattern on the wall visualized the sun vectors in summer and winter and radiation analysis and how it affect the value of of intensity of the radiation on sunscreen wall.

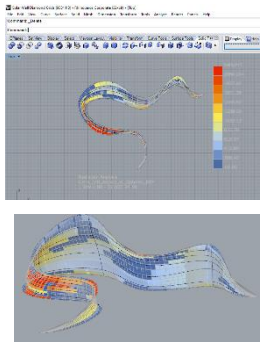
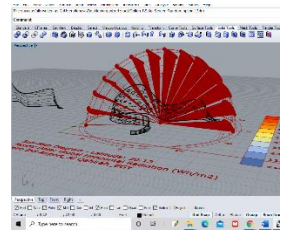
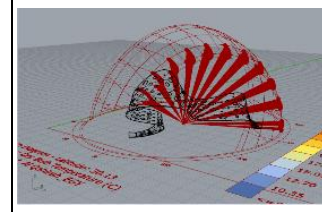
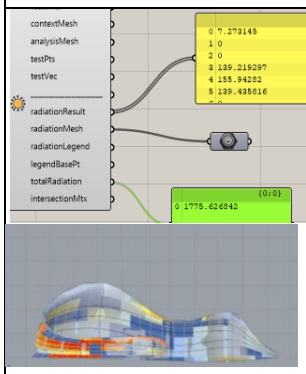
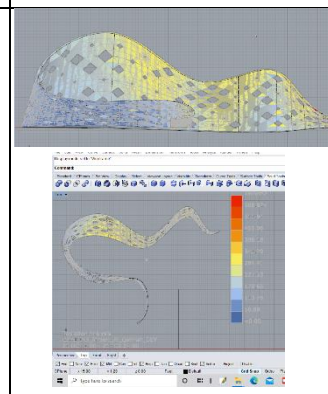
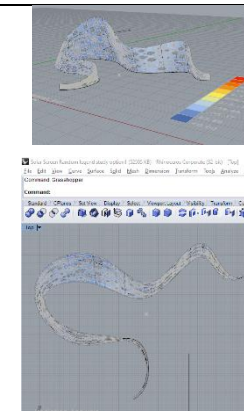
Sun screen wall before adding diamond openings	Sun Screen First Scenario Random Distribution In Winter	Sun Screen First Scenario Random Distribution in Summer
		
		
Total Radiation number in winter 1775.62	Total Radiation number in winter 599.709	Total Radiation number in Summer 247.735

Table 14. Diamond Sunscreen Radiation Analysis comparison study

9. Conclusion

The use of the diamond grid pattern gave us different and innovative solutions to deal with the Sunscreen wall and made us better control to study the strength of the sun's rays on the surface through the different distributions.

The use of environmental simulation programs in the parametric design made it a tool for the designer to see and study the different solutions for this solar screen. Through the research paper, we made different comparisons for the different distributions, studying the best solutions, visuluizing the different environmental factors and their impact on the shape of the innovative solar screen and choosing the best design according to the climate.

The use of a parametric Pattern had in the case of the curved sunscreen wall give us different solutions and designs and The findings from environmental simulation will allow for further prototypes to explore the possibility of more sunscreen designs which respond to new sets of parameters in the future.

Acknowledgements

David Rutten at Robert McNeel & Associates who created Grasshopper is a visual programming language and environment that runs within the Rhinoceros 3D computer-aided design (CAD) application. Ladybug Tools Mostapha Sadeghipour Roudsari. Admin · Chris Mackey. Admin · Abraham Yezioro. Member · Grasshope. Member · Theodoros Galanos. Member · Devang Chauhan, Faculty: Sherif ElFeky , Samir Sadek; The department or architecture for grants and facilities ,

References

Alberto Lastra, 2021, Parametric Geometry of Curves and Surfaces: Architectural Form-Finding, Springer Nature

Carlo Aiello, 2014, Digital and Parametric Architecture, New York

Kenneth George Libbrecht, 2006, Ken Libbrecht's Field Guide to Snowflakes, USA

Arturo Tedeschi, Le Penseur, 2011, Parametric Architecture with Grasshopper: Primer, Paris

https://tonkinliu.co.uk/solar-gate