5th International Conference on Environmental Design and Health, ICED2024

Narimene Cherienne
PHD student in Architecture and Environment
Department of Architecture, University of Salah Boubnider,
laboratoire Architecture Bioclimatique et Environnement (ABE)
Narimene.cherienne@univ-constantine3.dz

PARAMETRIC DESIGN AS A TOOL FOR MODELING ADAPTIVE ENVELOPES

Introduction :

As a result of current standardization practices, architecture is often detach from its surrounding environment, and conventional building envelopes are not able to adapt to external climatic conditions because of their static properties.
Due to these limitations, it has become imperative to adapt technologies to local conditions and design architecture that reflects our lifestyles while respecting the environment.
The city of BISKRA, located in South Algeria, experiences scorching temperatures and intense sunlight, making efficient window shading devices crucial to minimizing solar heat gain and creating a comfortable indoor climate.
With parametric design tools, we evaluated how much solar radiation was intercepted on the south façade of the architectural project, a renewable energy research center, before and after incorporating a dynamic skin.

Methodology :

1- parametric modeling:

An equilateral triangle mesh (Sierpinsky triangle12) is the basis of the dynamic facade.
Triangular units are divided into four equilateral triangles, with the first triangle in the center. On the remaining triangles are the vertical surfaces called the "wings," which control the amount of radiation received.

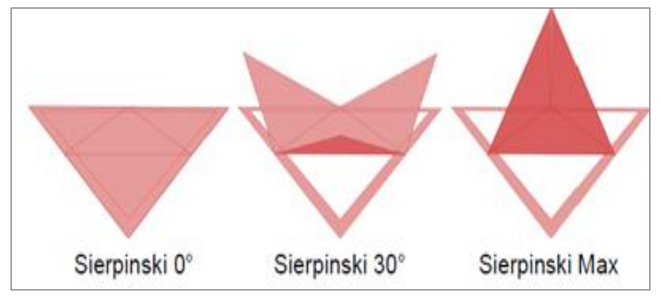

Figure 1. the basis module of the dynamic facade

Initial Steps:
1.3D Geometric Modeling: The initial phase involved the creation of a 3D geometric model of the building using Rhinoceros 5 software.
2.Weather Data Integration: Meteorological data for the city of Biskra was introduced into the simulation platform.
3.Weather Data File Generation: A ".wea" format "weather Data" file was generated for the Ladybug plugin in Grasshopper, serving as a foundation for analyzing direct solar radiation on the building.

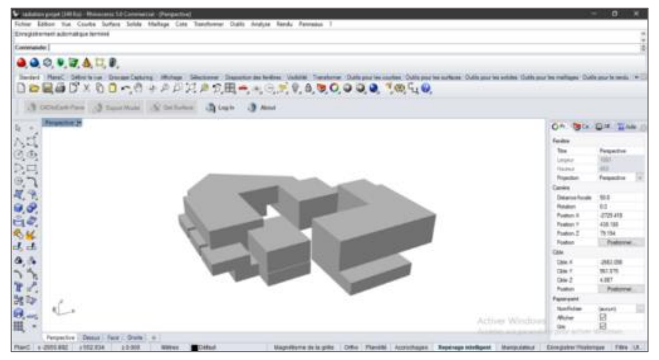

Figure 2 : geometric model of the building studied in the Rhino interface

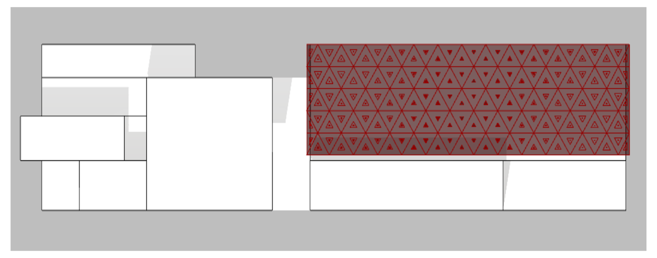

Figure 3. Dynamic Shading Device

2-building Simulation (without protection) :
Analysis of Solar Radiation Distribution on Building Surfaces
For a one-year period :

- The roof receives a significantly high amount of solar radiation, reaching a value of 1940.20 kWh/m².
- This is followed by the south façade, which receives an amount of solar radiation of 1358.14 kWh/m².
- The lowest quantity of solar radiation is recorded on the north façade, with a value of 388.04 kWh/m².

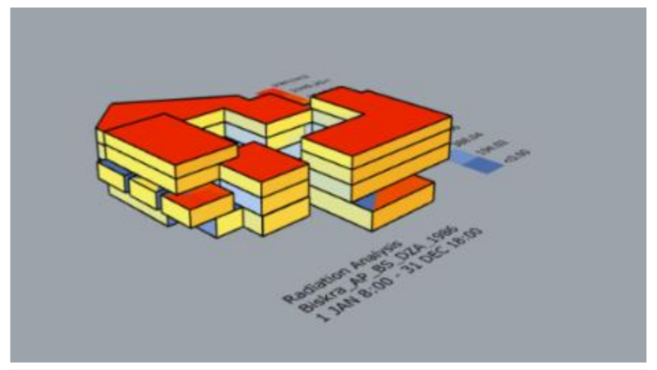

Figure 4 . Direct incident radiation during one year

During the overheating period :

- The roof receives an exceptionally high amount of incident solar radiation, reaching a value of 1382.79 kWh/m².
- Both the south and west facades receive a significant quantity of radiation, amounting to 691.40 kWh/m².
- The lowest amount of solar radiation is recorded on the north façade, with a value of 276.56 kWh/m².

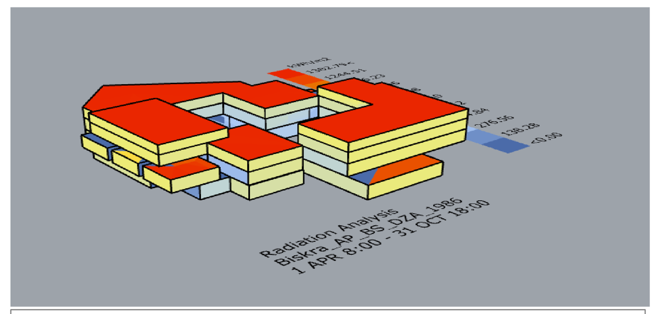

Figure 5 : Direct incident radiation During the overheating period

3. Building Simulation (with protection) :

The simulation results reveal a significant difference in solar radiation levels between the exposed and protected areas of the dynamic facade.

For a one-year period :

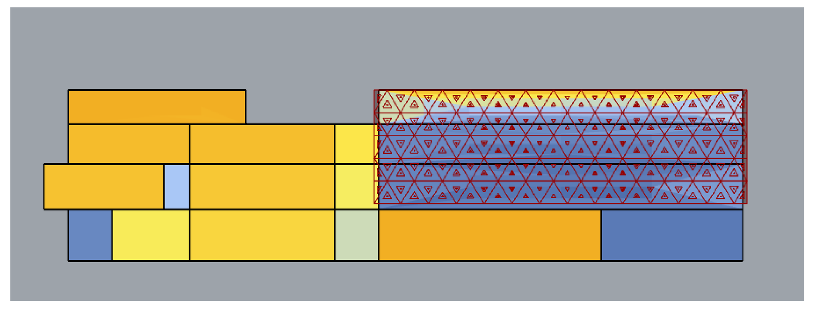

Figure 6. Total annual solar radiation incident on the south façade (fully closed)

The exposed portion of the dynamic facade receives a substantial amount of solar radiation, reaching a value of 1164.12 kWh/m². In contrast, the protected area experiences a remarkable reduction in solar radiation. The amount of radiation intercepted by the partially open panels decreases to 194.02 kWh/m². In areas where the panels are fully closed, the solar radiation reaches 0 kWh/m².

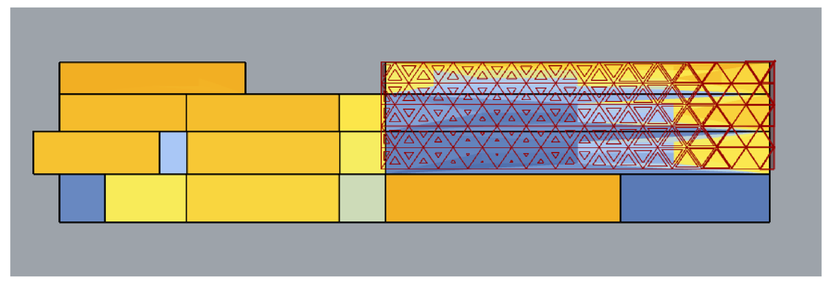

Figure 7. Total annual solar radiation incident on the south façade (partial opening)

The exposed portion of the dynamic facade receives a substantial amount of solar radiation, reaching a value of 1164.12 kWh/m². In contrast, the protected area experiences a remarkable reduction in solar radiation. The amount of radiation intercepted by the partially open panels decreases to 194.02 kWh/m². In areas where the panels are fully closed, the solar radiation reaches 0 kWh/m².

During the overheating period :

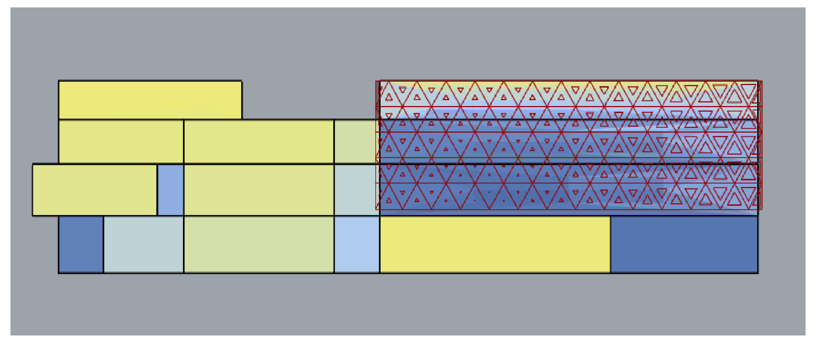

Figure 8. Total solar radiation incident during the overheating period on the south façade (fully closed)

- The exposed portion of the dynamic facade receives a substantial amount of solar radiation, reaching a value of 553.12 kWh/m². This indicates the intense solar heat gain that this area is subjected to.
- The protected area of the dynamic facade experiences a complete blockage of solar radiation. This means that the panels are fully closed, effectively preventing any solar radiation from reaching the protected area.

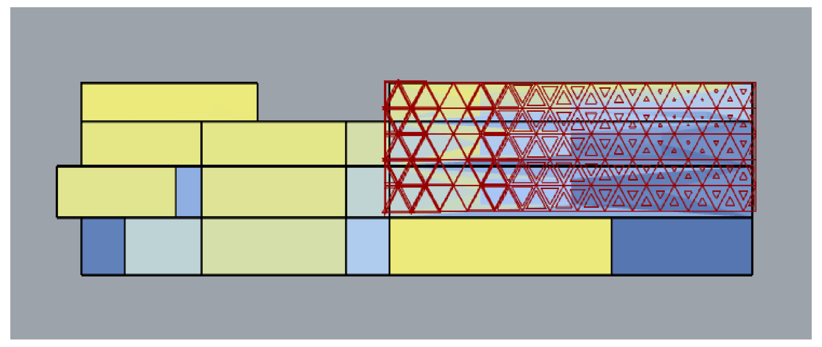

Figure 9. Total solar radiation incident during the overheating period intercepted by the south façade (partial opening)

- The exposed portions of the dynamic facade receive a significant amount of solar radiation, reaching a value of 553.12 kWh/m².
- The protected area of the dynamic facade experiences a dynamic variation in solar radiation levels, depending on the state of the panels.
- When the panels are fully open, the protected area receives solar radiation ranging between 414.84 kWh/m² and 553.12 kWh/m².

Results and discussion :

In arid and hot climates, solar radiation is considered to be the most important factor in architectural design.
Before applying the dynamic skin, the project simulation indicated that the roof and the three exposed facades (South, East and West) intercepted a high amount of solar radiation.
With the dynamic solar protection system integrated, we noticed a noticeable drop in incident solar radiation intercepted by part of the SOUTH facade. According to the simulation, dynamic facades can be considered as very effective passive cooling processes in arid regions thanks to the impressive results obtained by the simulation.

Conclusion :

The impressive reduction in radiation values following the integration of the second dynamic skin demonstrates how effectively this device reduces radiation and allows buildings to adjust to external environmental conditions. Thus, the architectural envelope plays a crucial role in creating optimal thermal comfort and in reducing energy consumption, particularly in arid climates. Nevertheless, it is still difficult to evaluate the performance of such facades, making design, use, and maintenance difficult. Therefore, the market introduction of adaptive facades is not utilizing its full potential, resulting in a loss of energy savings and user satisfaction.