Skylight as a passive design strategy in Tunisian dwelling using BIM technology

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Abstract
In Tunisia, energy saving in construction has become a necessity. Currently, it occupies third place of 27% of the final national consumption. Its will be the first in the head with a percentage of 33% in 2030. The decision-making of the climatic parameters at the preliminary design stage by the designer can reduce CO2 production and improve energy conservation. Therefore, the solar design must take advantage of solar radiation in an arid climate. A horizontal glass surface known as passive solar heating in the winter in which contributes to heating the space and reducing artificial lighting. This paper focuses to study skylight design using Revit architecture. The two conceptual mass modes with separated and grouped skylight are investigated. We based on Energy Use Intensity, Annual Energy Cost, and Life Cycle Energy Cost parameters to assess performance energetic and environmental of skylight system. The found results show that the skylight system improves the energy efficiency and life cycle of the building only if certain parameters of design are considered.

Keyword:
Revit; skylight; design; suistanable

I. Introduction
A solarium in a greenhouse attached to a building can provide many benefits, such as collecting solar energy, allowing the cultivation of plants and providing an enjoyable living space to its occupants [1]. It represents a passive heating system [2].

This system refers in this research on skylight. It is a reinterpretation of atrium design, already common in historical architecture of hot climates. Roofed atrium buildings first appeared in the 19th century as a result of the advancements in architectural technology in iron and glazing manufacturing [3]. The atrium has a popular form to allow penetration of daylight into a building and to act as focal points with a high sense of spaciousness [4]. The performance of daylighting has many aspects, including the comfort and health, visual function, use of energy and the economy, which are all high priority. As known daylight cannot be replaced by
artificial light completely during the day. Glazing transmits daylight and solar heat gains. During heating period these thermal gains are welcome, but during cooling periods they increase the cooling load and thus the temperature of the room. Therefore, windows need light (glare) controls and solar (thermal) control, especially for conditions sunny clear sky. These are defined in many directions by the reduction factors (%) of light transmission and solar heat many theoretical and experimental studies have focused on increase the efficiency of skylight system, it takes account parameters such as Daylight Factor, Daylight Autonomy, and Useful Daylight Index. This research show magnitude of stores in solarium and active users that close the blinds as soon as they perceive glare risk [4]. In addition, reach 3% improvement in energy efficiency thanks to the controls of daylighting [6]. This paper focuses on study Energy Use Intensity (EUI), Annual Energy Cost and Life Energy Cycle Cost of skylight system in Tunisian standard home using promising new technology BIM.

II. Study Model

Skylight, a bioclimatic technic is efficiency regarding climate parameters like amount of solar radiation and composition of the building. It influenced by their size, location, shape of glazing. Skylights in a horizontal orientation are the most efficient for daylighting because it is setting up in the face of full sky's hemisphere of 180°, receiving relatively high luminance from its zenith. The window area of a skylight need only be 20% of the floor area for a daylight factor of 5%, compared to 50-60% for vertical openings in roofs or walls [5]. The light transmittance of skylights like windows is influenced by the type of glazing and the area of casement frames. Although additional requirements like thermal insulation and solar control have also to be fulfilled by the glazing, a high light transmittance and true color rendering are indispensable for daylighting. Our study is limited in Sousse city of Tunisia. In Sousse the period of heating and cooling concerning residential buildings are similar [7]. My selection is made for an apartment setting up in second floor “Fig 1”.

II.1. Simulation Tool

There are several softwares that are used for thermal simulation and each of them has its own interface and its own engine for modeling, calculation and analysis. According, the features of each software, we can use it at different phases of the project. We use conceptual energy analysis tool in draft phase and then we use a dynamic thermal simulation in APD
phase and finally the thermal regulatory calculation to classify the building according its thermal efficiency. Indeed, many users and actors are involved and who have a problem information communicating. The users do not use the same solutions in the same workflow. Information will be re-entered several times and which imply lost time and risk of errors. What is the solution?

The solution is BIM (Building Information Modeling) technology. Concerning a simulation, I used Autodesk Revit Version 2016 for simulation. I opted for sustainable software that enables architects and engineers to collaborate and interact more effectively. This technology is based on workflow and building requirements. This process is able to coordinate throughout the design project from the preliminary design stage to the end of the project. Architects and engineers are responsible for the complete coordination of the project to minimize problems on site becoming very expensive for the owner. However, how the architect can work with other team members using Revit?

This collaboration is possible with available Revit tools, which belong to different disciplines in the same interface. Now, Revit it comes in four flavors, we have not just Revit architecture, Revit structure and Revit MEP. Therefore, we have all Revit versions in one interface and all the architecture tools, structure tools and system tools.

In fact, Revit proposes to import calculations results from model via GBXML [8] without any input by a simple import process. It retrieves all information that has calculated in third-party by specialized software. This is very important concerning the workflow and calculation process. In addition, Revit provides tools for comparing, emailing and exporting analysis results. Revit can compare analysis results within or between projects. It can email results and comparisons, or export them in common formats such as PDF. For a more detailed simulation the user can also export energy model information in Gbxml, DOE2 and Energy plus formats. Revit can export data charts as graphics presentation and it can create custom graphics. Finally, it can open GBS (Green building Studio) for more detail. Revit provides integrated calculation covering some needs tools. Using relives it can create spaces and it can be associated in area. In addition we can manage the heating load, and the cooling air flow of the zone. All this information can be found in the energy model. Revit uses analytical tools to
communicate decisions during the design process. Among these tools of analysis we find the energy analysis tool [9].

### I.1. Method for Simulation

For energy analysis, Revit use RTS (Radiant Time Series) for energy calculation [10]. This method used to calculate the heating and cooling needs month by month according to space and area. It is suitable for the maximum design load. In addition, it takes account to time delay: time delay by conduction and time delay by radiance. In Revit workflow, there are two kind of energy analysis tool that presents geometric model in a typical design tool [11]: Conceptual energy analysis (CEA) and Heating and cooling tools. In this paper, we use CEA to evaluate thermal performance of standard Tunisian dwelling.

CEA is a tool for overall conceptual analysis to compare several variants. He works in the cloud that enables her to analyze without disrupting the workflow. This thermal analysis is done from preliminary phase of conception. It enables to perform energy use and energetic analysis of natural resources. This tool consists of two modes: conceptual mass mode analysis and building elements mode analysis. The first tool is associated to mass model design and second it is related to building model by adding architectural elements. We opt for conceptual mass mode to simulate thermal efficiency of Skylight system because of we can adjust easily conditioned volume.

#### I.1.1. Modelization Skylight System

To perform conceptual energy analysis, we need to design a geometric model. To add skylight system, we would skylight area (A) as following:

$$\text{(H x 1.5)} \times \text{SRR} = \text{A}$$

(1)

Such as H is a height from floor to ceiling and SRR represents the skylight-to-roof ratio. For calculation we choose 5% SRR, modify this value depending on climate and building use. Our conceptual model has 204 m² ceiling and 3.5m height and we show 5% SRR. Then, the correct size for a skylight is approximately \((3.5 \times 1.5)^2 \times 5\% = 1.37 \text{ m}^2\).
Therefore, the project should use 1.17m x 1.17m skylights. For simulation, we used three tests, the first determine out energetic performance without skylight “Fig 2” and the second test base to assess energy use intensity with separated skylight such the width and length of one skylight corresponds to 1.17m x 1.17m “Fig 3”. Therefore, third test corresponds to evaluate intensity of energy use with grouped skylight “Fig 4”.

**Fig. 1.** Plan of standard apartment in Tunisia

**II.1.1. Input Energy Setting**

After create geometric model, we need to create an energetic model then we set “energy setting” workflow that specify different parameter like: common, detailed model parameter. We have the same Common and Energy Building Services parameters for two systems. By against, we have not the same parameters for Detailed Model and Energy Model setting.

**Fig. 2.** House model using a conceptual mass mode without skylight.
Concerning common part of energy setting dialog box, we need to specify a location and building type (residential) [12] “Fig. 5”. Figure 5 shows the interface of “Common Part” features.

**II.1.1.2. Energy model Building Services**

Energy model Building Services dialog box divides to different parts as: operation schedules, HVAC system, outdoor information.

**II.1.1.2.1. Operation Schedules**

For our house model, we choose a system that works half a year (12/7) for period heating.

**II.1.1.2.2. HVAC System**

We assume a system for heating, 11 EER Packaged VAV, 84.5% heating boiler
II.1.2.3. **Outdoor Air Information**

According Roulet [13] air renewal rate is sum of ventilation and infiltration. This rate is considered steady in heating period that corresponds to 2.25 vol /h. According Quartani [7] air renewal rate is varying in summer. During the daytime, she considered previous winter value but at night, she adds 10vol/h because, in cooling period occupant opens window at night to aerate his dwelling. Thus in summer air renewal rate is 12.25 vol /h.

Concerning outdoor air information dialog box, we choose amount value of the number of times per hour that the air volume of all occupied spaces in the zone is replaced. Therefore, the amount Outdoor air per area of a model is 2.18 l/s.m² in winter and spring. Meanwhile, in summer the outdoor we opt for 12 l/s.m² air exchange per area TABLE II.

II.1.3. **Detailed Model**

Like shown above to simulate skylight system, we need conceptual mass mode for energy analysis then, we export rooms for energy analysis.

![Fig. 5. Energy setting, common parameters workflow](image)

**II.1.4. Energy Model**

Concerning, skylight system, we divide a model to 4 zones and affect 3.5m to Core Offset of the model. In addition, in parameter energy model, we specify 30% percentage glazing and 1m “target still height”. Moreover that we used “massing site” panel and setting by surface for condition type. In addition, we select 5% percentage skylight and 1.17 m width and depth.

In “Conceptual Construction” dialog box, we choose a Lightweight Mass Construction Low Insulation for Mass Exterior Wall “Fig 6” for three tests. A thermal quality of glazing is expressed by Solar Heat Gain Coefficient (SHGC) [14], and Visible light transmittance (Tvis). SHGC coefficient depends on the climate, the building type, and the amount of glass [6]. Tvis value performs amount of daylight. Concerning skylight model (Table II and Table III), we choose Double Pane clear- Low Emissivity, Low SHGC, we divide the year in 3 periods according TABLE I.
• Period of cooling (summer) from July to October
• Period of heating (winter) from November to February.
• Period without conditioned system (springer) from Mars to June.

<table>
<thead>
<tr>
<th>Simulation period</th>
<th>Condition Type</th>
<th>Outdoor air flow (l/m².s)</th>
<th>Annual EUI (MJ/m²/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>winter</td>
<td>4H</td>
<td>2.18</td>
<td>977</td>
</tr>
<tr>
<td>Summer</td>
<td>4C</td>
<td>12</td>
<td>887</td>
</tr>
<tr>
<td>Spring</td>
<td>1NV+3UN</td>
<td>2.18</td>
<td>395</td>
</tr>
</tbody>
</table>

**TABLE II.**
**ANNUAL INTENSITY OF ENERGY USE USING CONCEPTUAL MASS MODE IN WINTER, SUMMER AND SPRING PERIOD OF STUDY MODEL**

**III.2. Test 2**

<table>
<thead>
<tr>
<th>Period of simulation</th>
<th>Annual EUI using dispersed skylights (MJ/m²/yr)</th>
<th>(EC)($)</th>
<th>LCEC ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>1018</td>
<td>3634</td>
<td>49498</td>
</tr>
<tr>
<td>Summer</td>
<td>930</td>
<td>4573</td>
<td>62285</td>
</tr>
<tr>
<td>Spring</td>
<td>401</td>
<td>1474</td>
<td>20070</td>
</tr>
</tbody>
</table>
### Test 3

#### TABLE IV.
**ANNUAL INTENSITY OF ENERGY USE USING GROUPED SKYLIGHTS OF STUDY MODEL**

<table>
<thead>
<tr>
<th>Period of simulation</th>
<th>Annual EUI using grouped skylight (MJ/m²/yr)</th>
<th>(EC) ($)</th>
<th>LCEC ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>1009</td>
<td>3601</td>
<td>49039</td>
</tr>
<tr>
<td>Summer</td>
<td>902</td>
<td>4421</td>
<td>60219</td>
</tr>
<tr>
<td>Spring</td>
<td>394</td>
<td>1444</td>
<td>19668</td>
</tr>
</tbody>
</table>

#### Difference results between Test 2 and Test 3

#### TABLE V.
**DIFFERENCE ANNUAL INTENSITY OF ENERGY BETWEEN MODEL WITHOUT SKYLIGHT AND USING GROUPED SKYLIGHTS OF STUDY MODEL**

<table>
<thead>
<tr>
<th>Period of simulation</th>
<th>Annual EUI without skylight (MJ/m²/yr)</th>
<th>Annual EUI grouped skylight (MJ/m²/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>977</td>
<td>1009</td>
</tr>
<tr>
<td>Summer</td>
<td>887</td>
<td>902</td>
</tr>
<tr>
<td>Spring</td>
<td>395</td>
<td>394</td>
</tr>
</tbody>
</table>

Table II and Table III show that in winter period a model without a skylight system is need lower energy than a model with a skylight system. Thus, dispersed skylight increases thermal heat leakage through glazing. In addition, test 1 displays maximal load energy need, it exhibits in winter period. Moreover, to compare test 2 and test 3, we found that Energy Use Intensity of grouped skylight design is better than dispersed skylights model. Indeed, Table V emphasizes on the difference of EUI between model without skylight and model with grouped skylight. It determines out that this difference decreases in winter and summer because of the leakage of heat load through skylight rises in these periods. Meanwhile, model with grouped skylight system is more efficient than a model without skylight in spring period. It is able to reduce EUI of skylight model in unconditioned period. However, EUI of our model without skylight remains lower than model with grouped skylight in heating and cooling period. Hence to improve this gap, we need to reduce the leakage of heat load through roof glazing. Therefore, we should improve a thermal quality of skylight system. In addition, roof skylight supplies high luminance levels [15]. It is more efficient in heating period than cooling period. It is able to create uncomfortable solar glare if glare value is too high and the glass area is large. If the value is too low and the glass area is too small, we do not get the benefit of natural daylight [6]. Obaidi [15] indicated that the skylights with reflectors have the best overall daylight and thermal performance among all the systems. Figure 7 displays that...
skylight system can deliver both good daylight illumination and an effect of depth in the interior space.

Figure 7: Skylight system in the roof of the Carthage hall, Bardo Museum

Revit workflow possesses selective coatings allow high Tvis and low SHGC as following:

**III.4. Test 4**

<table>
<thead>
<tr>
<th>Conceptual Construction</th>
<th>U/(m² • °K)</th>
<th>SHGC</th>
<th>Tvis</th>
<th>EUI (MJ/m²/yr)</th>
<th>(EC) ($)</th>
<th>LCEC ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Pane Clear – LowE (Emissivity), Hot Climate, Low SHGC</td>
<td>1.68</td>
<td>0.44</td>
<td>0.70</td>
<td>989</td>
<td>3521</td>
<td>47962</td>
</tr>
<tr>
<td>Double Pane Clear - High Performance, LowE, High Tvis, Low SHGC</td>
<td>1.63</td>
<td>0.27</td>
<td>0.64</td>
<td>982</td>
<td>3487</td>
<td>47490</td>
</tr>
<tr>
<td>Double Pane - Reflective</td>
<td>2.40</td>
<td>0.19</td>
<td>0.10</td>
<td>985</td>
<td>3496</td>
<td>47610</td>
</tr>
<tr>
<td>Triple Pane Clear - LowE Hot</td>
<td>0.22</td>
<td>0.47</td>
<td>0.64</td>
<td>990</td>
<td>3529</td>
<td>48063</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conceptual Construction</th>
<th>U/(m² • °K)</th>
<th>SHGC</th>
<th>Tvis</th>
<th>EUI (MJ/m²/yr) in winter</th>
<th>EC ($)</th>
<th>LCEC ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Pane Clear – LowE (Emissivity), Hot Climate, Low SHGC</td>
<td>1.68</td>
<td>0.44</td>
<td>0.70</td>
<td>894</td>
<td>4377</td>
<td>59617</td>
</tr>
<tr>
<td>Double Pane Clear - High Performance, LowE, High Tvis, Low SHGC</td>
<td>1.63</td>
<td>0.27</td>
<td>0.64</td>
<td>890</td>
<td>4356</td>
<td>59334</td>
</tr>
<tr>
<td>Double Pane - Reflective</td>
<td>2.40</td>
<td>0.19</td>
<td>0.10</td>
<td>890</td>
<td>4359</td>
<td>59370</td>
</tr>
<tr>
<td>Triple Pane Clear - LowE Hot</td>
<td>0.22</td>
<td>0.47</td>
<td>0.64</td>
<td>895</td>
<td>4383</td>
<td>59694</td>
</tr>
</tbody>
</table>
III.5. Test 5

TABLE VIII
BEST IMPROVEMENT USING MASS GLAZING AND WALL EXTERIOR OF DWELLING USING SKYLIGHT MODEL BASED ON EUI, AEC, LCEC IN COOLING PERIOD

<table>
<thead>
<tr>
<th>Description of conceptual construction parameters</th>
<th>Period of simulation</th>
<th>EUI (MJ/m²/yr)</th>
<th>(EC) ($)</th>
<th>LCEC ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightweight Construction with low insulation + Double Pane Clear - High Performance, LowE, High Tvis, Low SHGC + Roof mass construction with low insulation</td>
<td>winter</td>
<td>701</td>
<td>2605</td>
<td>35484</td>
</tr>
<tr>
<td></td>
<td>Summer</td>
<td>784</td>
<td>3784</td>
<td>51540</td>
</tr>
</tbody>
</table>

Furthermore according Table VI, we identify that each glazing provides energy rating [16]. For heating period the best improvement EUI is shown for Double Pane Clear - High Performance, LowE, High Tvis, and Low SHGC. This Conceptual Construction has 0.27 as SHGC and 0.64 as Tvis. Moreover, this glazing provides 3487$ as Annual Energy Cost (EC) and 47490$ as Life Cycle Energy Cost (LCEC). LCEC value corresponds to Fuel amount of our analyzed model may use during 30 years period. Regarding Table VI, AEC and LCEC previous values present the lowest values in heating period. In order to find the best possible solution in cooling period using skylight, a similar variety of glazing used previously have to be generated, which are then reduced by assessment. Findings results in Table VII show that “Double Pane - Reflective” and “Double Pane Clear - High Performance, LowE, High Tvis, and Low SHGC” reduce EUI in cooling period. Meanwhile, glazing that named a last one; it assigns lowest LECC and AEC value. Despite prior improvements energy use intensity rest low during cooling and heating period. Therefore, we need to mix different strategies in order to improve energy saving EUI, EC, and LCEC using skylight system. Then, we opt firstly to Double Pane Clear High Performance Low E High Tvis, low SHGC that provides a compromise between Tvis and SHGC value then lightweight mass exterior wall with low insulation and finally low mass roof insulation. The findings results in test 5 shows that combined improvement able to reduce EUI, EC and LCEC of skylight system in cooling and heating period. Moreover, all prior tests show that annual EC and LCEC for 30 years are higher in cooling period than heating period.
IV. CONCLUSION

This paper aims to assess Energy Use Intensity, Annual Energy Cost and Life Cycle Energy Cost of skylight system in Tunisian standard home using Revit simulation in heating and cooling period. Test 2 and 3 show that grouped skylight is more efficient than dispersed skylight system. Findings results for Test 4 determine out that glazing kind, “Double Pane Clear - High Performance, LowE, High Tvis, and Low SHGC” presents a compromise value between SHGC coefficient as Tvis value. Despite prior improvements EUI, EC, LCEC remain higher than energy needed of our dwelling model without skylight system. Meanwhile, we combined vary strategies like lightweight roof insulation and we take account SHGC, Tvis glazing value. Therefore, we identify that last strategies enable to reduce EUI, EC, LCEC. As a result, mixed strategies allow 10% EUI save in cooled period and 28% in heated period. Further that, Revit shows that natural daylighting based on skylight system promotes energy saving. Thus, it increases building susitanability in Tunisian climate condition only with a compromise between Tvis value and SHGC value and with roof insulation, it enables to carried out environment sustanaibility in heating and cooling period only with accurate improvements.In future research work, I propose to study the thermal efficiency of the skylight of the Bardo Museum using Revit to expand the investigatievecompaign.

References


