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Thermal Simulation using BIM A Case Study: Tunisian Traditional Dwelling

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Abstract

Traditional architecture is adapted to the cultural and climatic environment. It was able to respond to the conditions of minimal comfort of its inhabitants. This architecture contains centuries of knowledge to encourage researchers to make out its secret and evaluate its energy efficiency. In Tunisian context, pioneering work analysis concerning traditional houses, have shown that comfort conditions were acceptable during the hot season and mediocre during the cold season. Other studies have shown that this kind of architecture was able to respond to winter and summer climate requirements, but especially in the summer period, in coherence with the lifestyle of residents. Several study models concerning the thermal behavior of buildings are found in the literature. These models use software for simulating stationary regime or transient. Each program has its own interface and its own modeling engine, calculation and analysis, as TRNSYS (Transient System Simulation Tool) and EnergyPlus. For the simulation, we opted for sustainable software that allows architects and engineers to collaborate and interoperate more efficiently based on workflow and project requirements. The use solution is the BIM (Building Information Modeling) of Autodesk Revit that allows coordination throughout the design project. Our paper examines the effectiveness of promising new technology BIM in the thermal simulation of traditional Tunisian architecture bioclimatic. Research has showed the importance of BIM technology in the workflow and is efficiency to determine the energy performance of buildings with passive design and to evaluate their energy consumption. Revit gives interesting results for the standard contemporary home. As far as it knows, there are no studies on the traditional bioclimatic house or vernacular character using BIM technology for simulate this type of habitat. In this paper, we propose to use Revit to study the thermal behavior of the Tunisian traditional home.

Keywords: *BIM, thermal simulation, Revit, bioclimatic traditional house.*

1. Introduction

The thermal quality indoors can be comfortable or uncomfortable to ensure a thermal comfortable environment; the occupant uses a system for heating and cooling. In Tunisia, the energy consumption in building sector is increasing rapidly; it becomes the second largest energy consumer after transport and it will be the first energy consumer in the 2020s [1]. This increase in energy consumption is the result of various social changes and architectural transformations. Among architectural changes, there is the brutal transformation without transition from traditional to contemporary house. For centuries, the traditional house was adapted in the climatic conditions, especially in summer, fully consistent with the lifestyle of its inhabitants. It contains centuries of knowledge and manners, is presented to us as a learn lesson. This architecture is adapted to its cultural environment that provides the minimum conditions of comfort of its occupants. This knowledge has prompted researchers to decipher the secret of this architecture and expose to thermal analysis in relation to the current architecture.

2. Literature Review

Studies nationally and internationally have been taken to determinate thermal efficiency of traditional house. The results of analysis in the Algerian [2] context show that the thermal comfort within a traditional house depends mainly on the skills of the residents, the characteristics of the building, integration into the site and mode of

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occupation the living space. On national analysis the study work of these types of houses have shown that comfort conditions were acceptable during the hot season. The software used for the dynamic thermal simulation like TRNSYS (Transient system simulation) [3]. According A.Ouartani [4] this type of architecture was able to respond the requirements of the climatic features, especially in the summer, fully consistent with the lifestyle of the inhabitants. By against the thermal quality of modern buildings tends to deteriorate due to short-term considerations.

This paper aims to simulate this bioclimatic and vernacular architecture using BIM technology in heating and cooling period. The purpose of this article is to assess Revit efficiency to simulate this kind of architecture that focused to simulate a standard building.

3. Study Model

Our study is limited in the context of littoral Tunisia. Our case study is located in Sousse traditional medina. In Sousse the period of heating and cooling concerning residential buildings are similar [5]. The traditional house in Tunisia is oriented South-East which represents its respect to climate, cultural, and religious. It spatial organization is around the patio as Fig. 1, that creates a microclimate. In winter, it protects against cold winds and provides light and ventilation. In summer, the patio walls create mutual shadow and an atmosphere of freshness. To protect from the bad weather, traditional home is protected by stone envelope, such the thickness is between 70cm to 80cm. This large heat capacity allows good recovery of solar gain during the cold season and restitution in the late afternoon. During the hot season, envelope with high thermal inertia can distribute the gain heat progressively to indoor. In patio the openings at low level associated with small holes near the ceiling create indoor air circulation from bottom to top of the room.

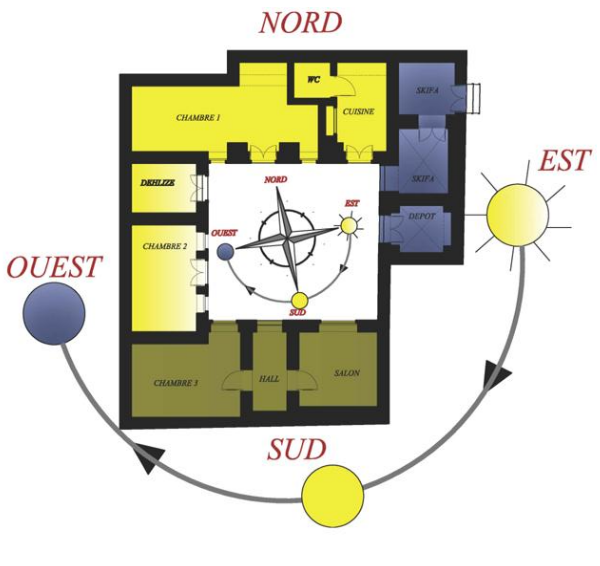


Fig.1 Traditional house plan with pieces orientation

In addition, in traditional house the spaces are no communicant. Such as each space is considered as a thermal zone which is independent of the rest. The envelope is known by the horizontal roof accompanied by a cross vault ceiling, Barrel vault or ceiling wooden square. It is painted of lime to protect from the humid Mediterranean climate and to minimize infiltration. The white color of lime wash reflects emitted light. As a result, we can deduce that envelope reflect its climate.

4. Methodology for Simulation

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 don't use the same solutions in the same sizes. 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, it used Autodesk Revit Version 2014 for simulation. It 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. But 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. So 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 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.

Method for Simulation

There are two kind of energy analysis tool: Conceptual energy analysis (CEA) and Heating and cooling tools.
In this paper, we use CEA to simulate a traditional model.
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 the draft phase. This tool consists of two modes: conceptual mass mode and building elements mode.

For simulation, we need to design a geometric model then to create an energetic model using energy setting after run energy simulation, in this step the model will be sent in the cloud to servers that will make the calculations when the calculations is made we are informed and we can reimport the result of this calculation. For calculation, Revit used RTS (Radiant Time Series) method.

The calculation method in Revit is the RTS 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. Assumptions:

-Design conditions are periodic regular and steady (climate, occupation).
- The conditions of heat gain are identical cyclically for 24 hours.

Thus, the heat gain for a particular component at a particular hour is the same as the 24 prior, which is the same as 48h prior, etc. This assumptions is the basis for the RTS derivation from the HB method

- For calculation of the cooling load, the RTS method takes into account the two delay time:
- Time delay by conduction for exterior surfaces.
- Time delay radiative load [6].

Modelization Traditional House

To perform conceptual energy analysis, we need design a model for simulation. There are two kinds to design Conceptual Mass Mode or Building Elements Mode.
For modeling, we create a model using a conceptual mass mode Fig. 2.

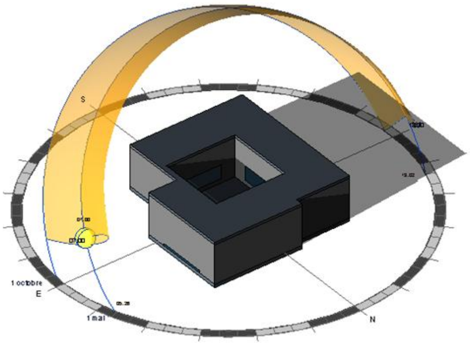
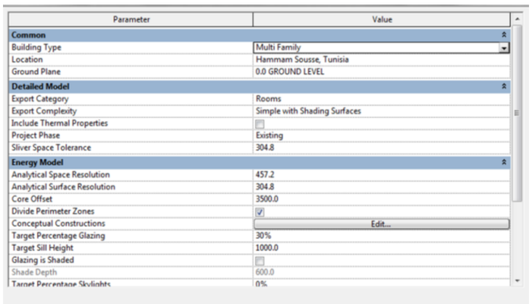


Fig.2 Modelization traditional house using a conceptual mode

Input Energy Setting of Study Model

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, energy model parameter and building services parameter Fig. 3.



Parameter	Value
Common	
Building Type	Multi Family
Location	Hammam Sousse, Tunisia
Ground Plane	0.0 GROUND LEVEL
Detailed Model	
Export Category	Rooms
Export Complexity	Simple with Shading Surfaces
Include Thermal Properties	☐
Project Phase	Existing
Sliver Space Tolerance	304.8
Energy Model	
Analytical Space Resolution	457.2
Analytical Surface Resolution	304.8
Core Offset	3500.0
Divide Perimeter Zones	☑
Conceptual Constructions	Edit...
Target Percentage Glazing	30%
Target Sill Height	1000.0
Glazing is Shaded	☐
Shade Depth	600.0
Target Percentage Skylights	0%

Fig.3 Energy setting workflow

1. Common Parameter

In this part, we need to specify a location and building type.

2. Energy Model

In this part, we divide a perimeter zone in 4 zones (conditioned and unconditioned).

To specify properties of different zones, we choose a ‘condition type’ dialogue box.

We set two separate heated zones and two unconditioned zones Fig.4. Because of, traditional home topology has independent areas. In this special construction, the residents have a special behavior during the heating period. In the evening, the occupant heats space that will be used. Thus, all family members will come together in the same space. This behavior is related to the topology of the traditional house and the Arab-Islamic culture.

Hence, we group transient spaces like ‘Skifa and entry as unconditioned zone. Thus, we consider rooms as heated zone.

Concerning, unconditioned zone no loads will be calculated in the specific zone. When set to Heated, only heating loads are calculated; when set to Cooled, only cooling loads are calculated. In addition, in parameter energy model, we customized glazing surface and ''target still height'' using "massing site" panel and setting by surface.

For a simulation, we divide year to 3 periods:

- Period of cooling from July to October.
- Period of heating from November to February.
- Period without conditioned system from Mars to June.

Concerning this part, we focused for winter, summer and spring period.

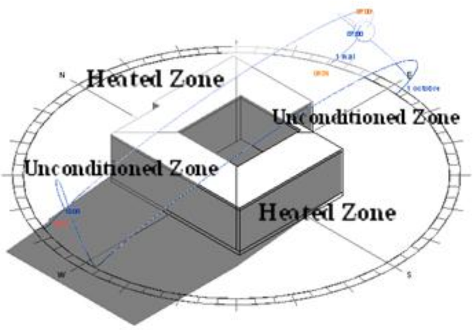


Fig.4 Unconditioned and heated zone for thermal simulation for heating period

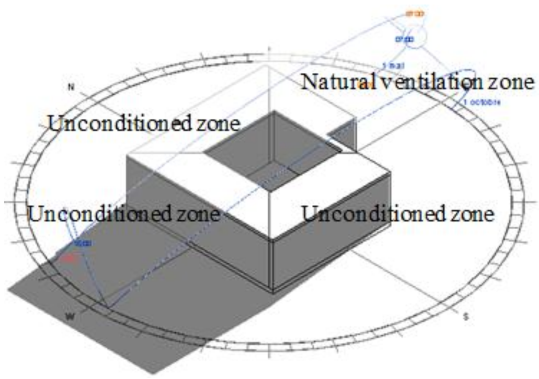


Fig.5 Unconditioned and natural ventilation zone for traditional house in cooled period

Wall of the Patio in North Side

- Target percentage glazing: 21%
- Target still height: 0,5m
- No target is shaded

Note: Glazing percentage composed of: door, window and high opening for ventilation.

Wall of the Patio in West Side

- Target percentage glazing: 20%
- Target still height: 0,5m
- No target is shaded

Note: Glazing percentage composed by surface of door, window and high opening for ventilation.

Wall of the Patio in South Side

- Target percentage glazing: 20%
- Target still height: 0,5m
- No target is shaded

Note: Glazing percentage composed by door surface and window.

Wall of the Patio in East Side

- Target percentage glazing: 13%
- Target still height: 0,5m
- No target is shaded

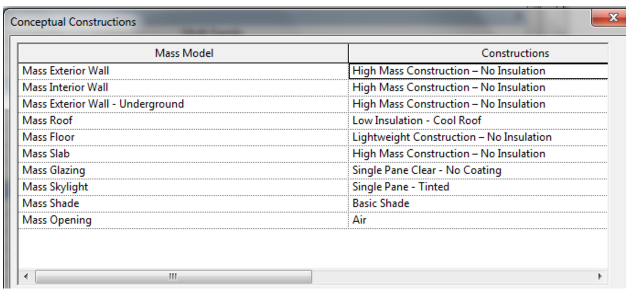
Note: Glazing percentage composed by door surface

Exterior wall

Exterior wall oriented to South, East, West composed by lime stone material

- Target percentage glazing: 20%
- Target still height: 0,5m
- No target is shaded

Concerning a material construction of building, it needs to set a parameter in a "Conceptual Construction" dialog box. We choose "High Mass Construction- No Insolation" for Mass exterior wall because of traditional envelope material is built by limestone. In "Conceptual Construction" dialog box, we assume "low Insulation Cool Roof" for Mass roof because of the traditional roof painted by white wash Fig.5.


Conceptual Constructions

Mass Model	Constructions
Mass Exterior Wall	High Mass Construction – No Insulation
Mass Interior Wall	High Mass Construction – No Insulation
Mass Exterior Wall - Underground	High Mass Construction – No Insulation
Mass Roof	Low Insulation - Cool Roof
Mass Floor	Lightweight Construction – No Insulation
Mass Slab	High Mass Construction – No Insulation
Mass Glazing	Single Pane Clear - No Coating
Mass Skylight	Single Pane - Tinted
Mass Shade	Basic Shade
Mass Opening	Air

Fig.5 Conceptual Constructions workflow

We note the parameter in "Conceptual Construction'' no taken into account: opening frame material, wall thickness and a ceiling.

3. Energy Model Building Services

Operation Schedule

We choose for a simulation in heating period a system that works for heated zones half a year (12/7).

Hvac System

We assume a system for heating, 11 EER Packaged VAV, 84.5% heating boiler.

Outdoor Information

The amount Outdoor air per area of study model is as following:

Table 1: Air exchange exterior flow and condition type in traditional house

Simulation period	Exterior flow of air exchange (l/m².s)	Condition Type
Winter	3	2Heated zone+ 2Unconditioned zone
Summer	16	1Natural Vented +3Unconditioned
Spring	3	1Natural Vented +3Unconditioned

6. Result for Simulation

Energy analysis results of three periods using Conceptual Mass Mode show that annual energy use in traditional house shown in as following:

Table 2: Results simulation based on intensity energy use in traditional house

Simulation Period	Exterior flow of air exchange (l/m².s)	Condition Type	Energy use intensity (MJ/m²/yr)
Winter	3	2H+ 2UN	752
Summer	16	1NV+3UN	539
Spring	3	1NV+3UN	489

Regarding literature review Ouartani [4] found that traditional Tunisian house is more beneficient in unconditioned period than heated period. For assess a thermal efficiency of bioclimatic Tunisian dwelling we opt for Revit. The prior table displays a maximal load energy need; it exhibits in winter period as 752 MJ/m²/yr. However, the lowest energy use intensity is exhibited for spring period.

In addition, it shows that energy use intensity is decrease in summer period. Because of, the dwelling is unconditioned and natural vented in spring and summer. A thermal result determine out that energy use intensity increase in winter because of the leakage of heat load through glazing rises in these periods. In further study, we will focuse to reduce the leakage of heat load through glazing. Therefore, we should improve a thermal quality of glazing. Then, we will take account of Solar Heat Gain Coefficient (SHGC), and Visible light transmittance (Tvis) value.

Conclusion

Results simulation using Revit show that traditional house in Tunisia is more efficient in spring and summer period than in heating period. Hence it needs in further research more improvement for a thermal quality of skylight. Revit is focused to simulate standard buildings, in addition, this study emphasizes that it is able to simulate a vernacular architecture.

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