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Energy Efficiency in Historic Buildings: a Strategy to Increase the Sustainability of the Built Environment

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ABSTRACT

The paper aims to define the most appropriate energy and environmental retrofit on historic buildings, to enhance the historical value of a building, to reduce energy consumption and to improve human comfort, health and safety. It allowed the evaluation of the conservation risks, energy consumption, and maintenance procedures and also led to a proposal on the most appropriate energy actions. It also defines the difficulties of integrating green practices with historic preservation, and offers recommendations for ways in which sustainable standards could be more accommodating for historic buildings. The approach was used in the National Hotel building located in Port Said, Egypt.

Keywords: Sustainability-Historic Preservation- Revitalizing-Energy Efficiency-High Performance-Urban Harmony.

1. Introduction

Before implementing any energy conservation measures, the existing energy-efficient characteristics of a historic building should be assessed. Buildings are more than the sum of their individual components. The design, materials, type of construction, size, shape, site orientation, surrounding landscape, and climate all play a role in how buildings perform. Historic building construction methods and materials often maximized natural sources of heat, light and ventilation to respond to local climatic conditions. The key to a successful rehabilitation project is to understand and identify the existing energy-efficient aspects of the historic building and how they function, as well as to understand and identify its character-defining features to ensure they are preserved. Whether rehabilitated for a new or continuing use, it is important to utilize the historic building’s inherent sustainable qualities as they were intended to ensure that they function effectively together with any new treatments added to further improve energy efficiency.

1.1. Energy Efficiency in Historic Building

Energy efficiency is a major topic in the world. The directive on energy performance requires minimum energy standards for new and existing buildings that undergo major renovation. Despite the directive admits a few exceptions for listed buildings, the international energy standards cannot be completely ignored or abandoned.

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Recent European policy officially introduces the concept of energy balance towards nearly zero-energy buildings and incentives the decreasing of 20% of environmental emissions and the increasing of 20% of renewable energy technologies within 2020. (1)

To achieve these goals, it is necessary to reduce user demand as well as to improve the efficiency of energy systems and to use renewable sources. Heritage must adapt to changes, physical and cultural, within its environment. The decision, inevitably, must be faced with the energy efficiency of existent buildings, independently by local bounds. Therefore we should develop techniques to maintain, refurbish and adapt the existing buildings to new requirements.

1.2. Sustainable Building Practices

Integrated design means thinking about how all aspects of a building are interrelated such as the structural components, heating, cooling systems, lighting, windows, walls, interior finishes, etc. By recognizing the connections between these systems, integrated design offers many benefits. For example, when operable windows are considered as part of a building’s ventilation system, expensive ductwork and air handlers can be made smaller and less expensive. Planning on the "thermal mass" of concrete structural members to slow down indoor temperature changes can also reduce the need for conventional air conditioning. These kinds of "passive" or low-energy design strategies can only be effective if the whole building’s energy performance is studied together. (2) These checklists are offered to encourage the use of sustainable building practices in remodels or renovations:

- Create a sustainable community.
- Respect the existing sites and reuse it.
- Avoiding additional energy consumption.

- Avoiding negative environmental impacts.
- Save water and reduce local water impacts.
- Save water and energy in plumbing systems.
- Reduce, reuse, and recycle systems.
- Using sustainable materials and support the market for recycled materials.
- Preserving architectural history.
- Reviving urban areas.
- Create healthy indoor environments.
- Save energy through passive design.
- Make a sustainable roof.
- Save energy in lighting.
- Save energy in equipment use.
- Replace fossil fuel use with alternatives.
- Use creativity and innovation to build more sustainable environments.

1.3. Environmental Performance to Achieve Sustainability Principles

Preservation-based sustainability is offered as a more comprehensive approach to development, as it takes into consideration environmental, economic, social, and cultural implications of buildings. These principles constitute the basis of the more important sustainable tools. These programs emphasize design, construction and operation for obtaining a "high green performance" building to reduce environmental impacts through energy efficiency, use of recycled materials, storm water management, and other innovations. In order to confirm that preservation promotes sustainable development versus the environment, it must be demonstrated that the reuse of buildings successfully reduces pollution and promotes the conservation of nature. This section looks at the energy savings associated with preservation, the avoidance of additional environmental impacts, the avoidance of generating waste through demolition, and the ability of preservation to curb sprawl.(3)

1.4. The Positive Benefits Of Sustainable Preservation

The positive benefits of sustainable preservation identified through following points: (4)

- Minimizing Consumption of Energy;
- Reusing Existing Materials;
- Avoiding negative environmental impacts;
- Reusing Existing Sites;
- Reducing Construction Waste;
- Accommodating Human Needs;
- Meeting Performance Requirements;
- Preserving Architectural History;
- Reviving Urban Areas;
- Creating Economic Advantage;
- Time Saving for New Construction;
- Maintaining Traditional Standards.

1.5. Barriers To Achieve Sustainable Preservation

There are also barriers to achieve sustainable preservation, which invariably concern costs. However, this is often a fake reason obscuring the real reason that it is easier under current development processes to produce a new building. Adaptation of existing buildings is frequently considered to be less creative than producing a new building and therefore attracts less fame. (5)

The range of barriers to adopting sustainable preservation for an historic and existing building identified during through following points:

- Only being viable where the costs and benefits are factored in over the life of the building.
- Building owners see no economic benefits in reuse.
- Older buildings may require extensive and costly refurbishment.
- Inability to match the performance of a new building.
- Ongoing maintenance costs may be higher than a new building.
- Older buildings may not be able to meet current sustainability standards.
- Availability and price of matching existing materials.
- Difficulty of maintaining the structural integrity of older buildings.

1.6. Sustainable Preservation Principles

High energy and environmental performances may lead the preservation of a building, but each action on historic and listed heritage gives attention to the matter of vulnerability, physical alteration, and decreasing of immaterial and material value. The most important principles for sustainable conservation regard:

- **Compatibility:** modern materials tend to be harder, less flexible, and less moisture permeable than traditional ones. For these reasons when are used in direct conjunction with historic fabric can greatly accelerate decay in the original work;
- **Aesthetic integration:** history and authenticity of historic building should be respected as essential to its significance;
- **Reversibility:** the unavoidable changes of the building should wherever possible be made to be fully reversible. Adopting this principle, the valuable historic fabric can be returned to its original state without damaging the building;
- **Emphasis on effective maintenance:** care, planned conservation, and management should include regular inspections so that defects can be discovered whilst still small and easily fixable. This permits to

preserve historic fabric, minimize cost and disruption to the building's owners and users.

The retention of older buildings or the re-using of components in-situ and allowing for their energy upgrading that can provide excellent results which are fully in accordance with the principles of building conservation and sustainability (Fig.1).

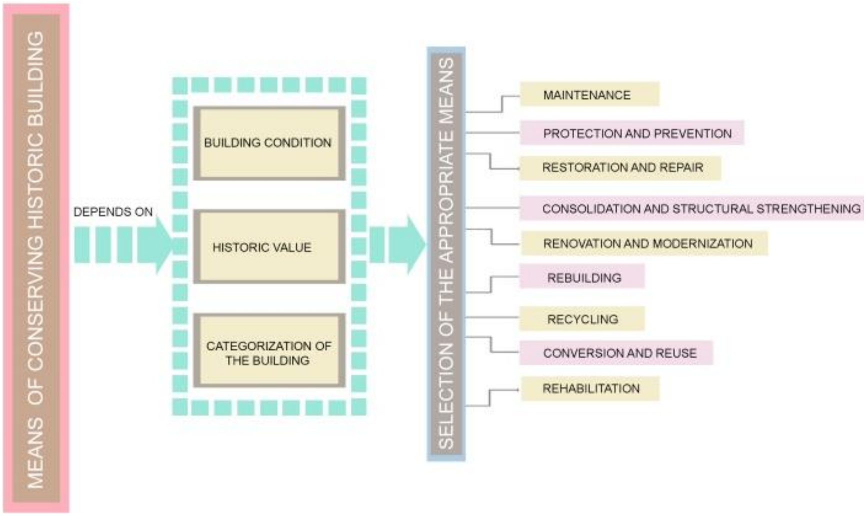


Figure 1: Means of Conserving Historic Building

1.7. Standards and Bases for Urban Harmony of Heritage Buildings and Areas

It is considered the baseline to direct and adjust urban development, conserve the unique urban heritage of cities, spread knowledge and awareness about the importance of heritage buildings and areas, guidance towards procedures for conserving architectural and urban heritage, and providing the scientific and technical mechanisms for the protection and continuity of urbanization as a principle base for developmental and community service programs. (6)

1.7.1. Supporting the Urban Character

The urban character is the product of the prevailing form characteristics that create groups of buildings, the urban fabric, the natural surroundings, and the prevalent uses in certain place. The urban character depends on a fully integrated matrix of references that is known as architectural character, urban space, urban fabric, activities and uses; which are all components of the urban language that defines the identity of the place. To achieve the goal of supporting the urban character, a full study should be presented and included the urban character elements as following:

- The Urban Fabric of the Area;
- Roads' Network and Pedestrian Paths;
- Advertisements and Signs;
- Vegetation and Greenery;
- Paving and Tiles;
- Lighting;
- Street and Open Space Furniture;
- New Buildings;
- Building Heights Inside and Around Heritage Areas.

1.7.2. Support of the Architectural Character

Architectural character is the product of the prevailing external composition characteristics in forming the building's facades at a certain place, which take it to uniqueness and excellence. To achieve the goal of supporting the architectural character, a full study should be presented and included the architectural character elements as following:

- Building Height;
- Building Facades and Type of Finishing;
- Projections (Towers-Balconies-Cornices);
- Architectural Style;
- Additions to Building;
- Architecture Elements and Treatments;
- Entrances of Buildings;
- Shops and Commercial Activities.

2. Methodology

Energy efficiency and environmental sustainable programs should be developed on the basis of a thorough knowledge of the property, blending technological and landscape requirements. This means understanding original construction, alterations, actual conditions, qualities, material and immaterial values, lacks, and retrofitting opportunities (Fig.2).The strategy aims to assess the following points:

- Historical analysis of city, urban site and heritage building;
- Analysis of functions, performance and needs of users;
- Building energy audit;

- Evaluation of environmental performance;
- Individualization of energy and environmental lacks;
- Definition of possible retrofitting actions.

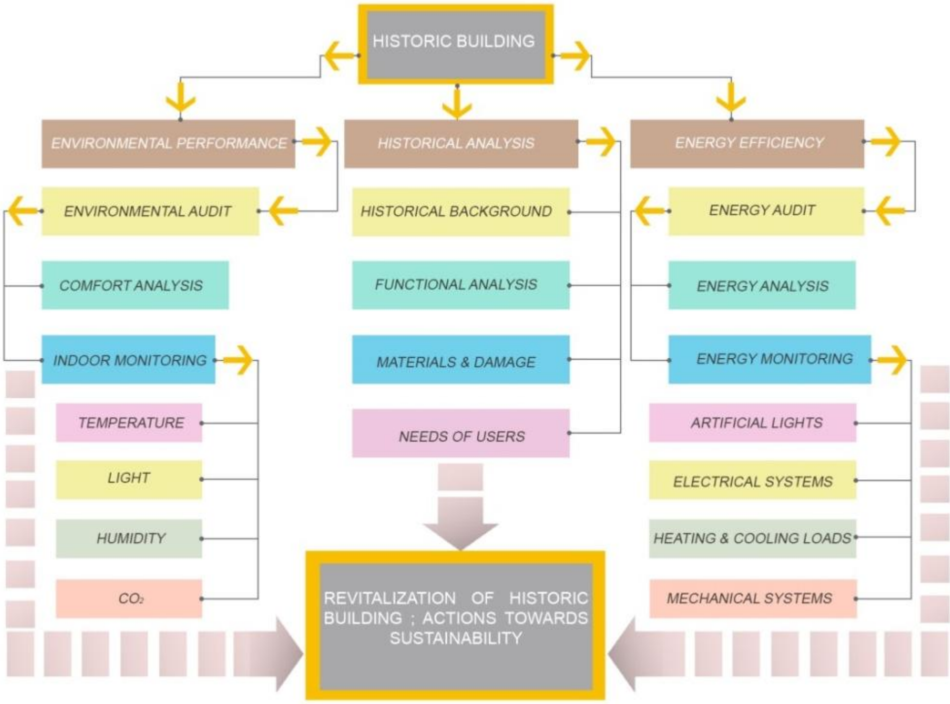


Figure 2: Method for Analyzing Energy and Environmental Performance of Historic Building.

3. The Case Study: National Hotel Building in Port Said, Egypt

The city of Port Said considered an international heritage value. The influences of culture and architecture of the city have given a unique architectural value to the city in the world. Port Said, located on the northeastern Mediterranean coast of Egypt, contains an architectural wealth, which will hopefully be saved by virtue of Cabinet Decree No l096 for 20ll. The decree has specified a list of 500 buildings classified as historic based on their singular architectural style and age. Port Said, Founded in l859 by the viceroy Said Pasha. During the digging of Suez Canal in 1859, a new cosmopolitan city formed for over a century. European memory and French in particular, linked to its construction by the Canal Company of Suez, still marks the appearance and atmosphere of the city (Fig.3).

Figure 3: Current Condition of National Hotel Building.

3.1. Historical Background

The Island of National Hotel is one of the oldest buildings in the city still visible. The hotel building was probably built in the 1880s on the island owned by Bazin Marseille Soap Company. That had obtained the concession docks of Port Said during construction the channel. The northern part of the island also contained cellars which were the imported goods stored. In 1866, to facilitate unloading cargo the company had drill a small canal that connected the island in the commercial basin. In 1877, a bridge was erected over the canal and ramps as it existed before an "impassable to cars" gateway. This new bridge was made by the famous company Gustave Eiffel. The island which enjoys a remarkable position along the ship canal has always maintained its commercial vocation. In the twentieth century, it has hosted a series of small hotels for transit customers as evidenced by the remains of Many brands such as "Hotel de France and Hotel Belle Vue" To celebrate its remarkable character, it is obviously noted wooden galleries, but also its singular form "U", or imported materials which have allowed its construction (maritime pine, bricks and tiles Marseille). Its location in the heart of the city, facing the pool with trade vis-à-vis the captaincy of the authority of the Suez Canal, is also very relevant to fact and provides maximum visibility to this catering company (Fig.4,5).

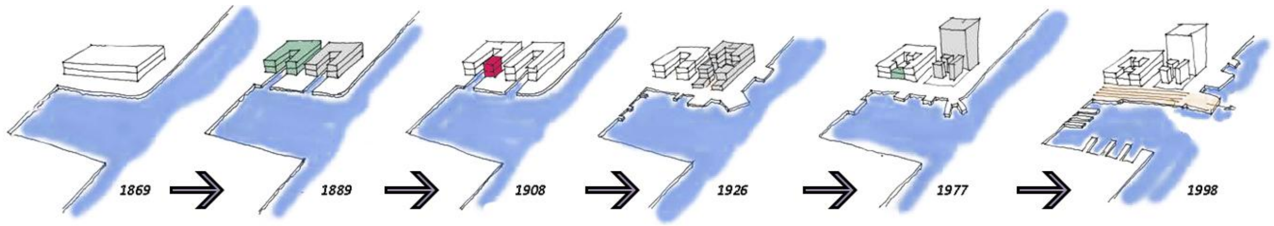


Figure 4: Conception Drawings Addresses the Development of the Site Since 1869.

Figure 5: Conceptual Perspective for the Original Case of National Hotel Island in 1877.

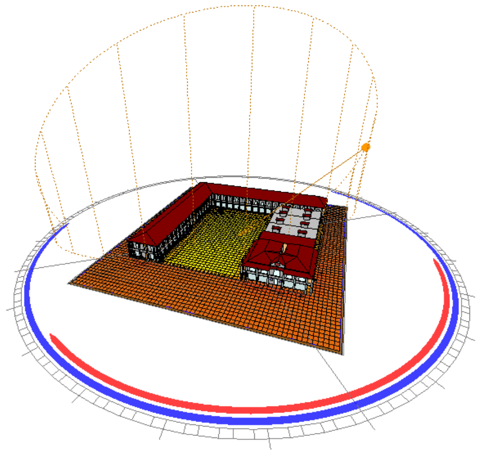


Figure 6: Modeling of the Building Using Autodesk Ecotect Analysis Program.

3.2. Evaluation of Energy Performance for the Building's Original Case

A software simulation with Autodesk Ecotect Analysis allowed verifying the energy performance for the building. (7) In this way, the proper interventions have been selected in order to improve energy and environmental efficiency of the building (Fig.6).

3.2.1.Results: Thermal Analysis

The following figures represent the thermal analysis on the building throughout the year, and are divided into monthly heating, cooling loads and discomfort degree hours analysis (Fig.7, 8).

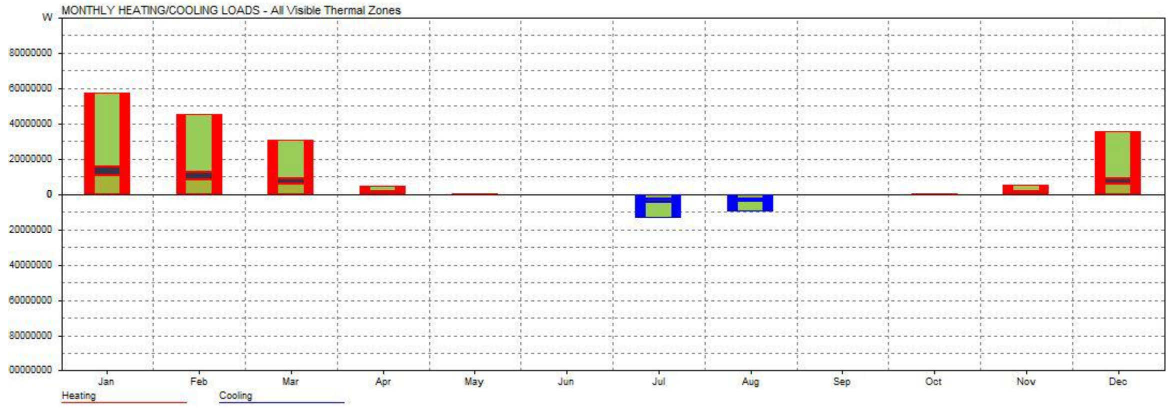


Figure 7: Heating and Cooling Loads in the Building.

- **<u>Cooling loads:</u>** represents in blue and reach to the maximum in July and is equal 1395 watts per square meter.
- **<u>Heating loads:</u>** represents in red and reach to the maximum in January and is equal 10336 watts per square meter.

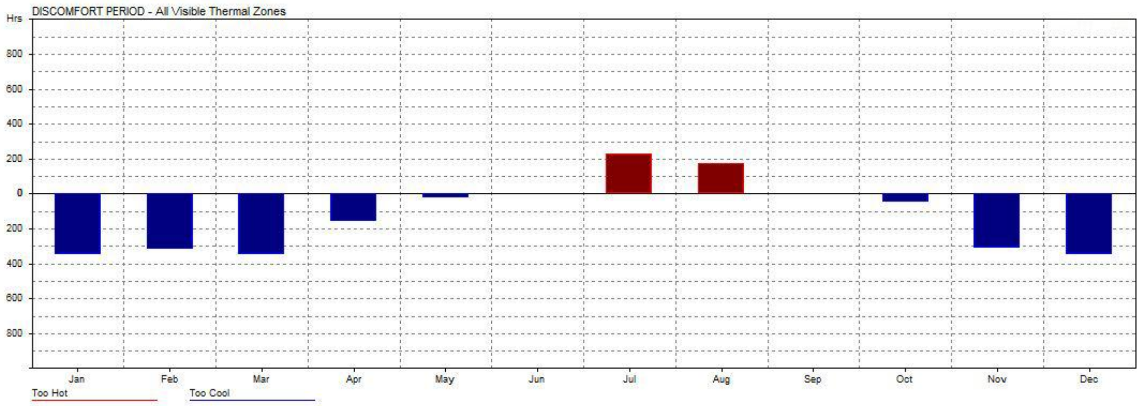


Figure 8: Discomfort Degree Hours in the Building.

- **Discomfort Degree Hours:** represents the total discomfort degree hours throughout the year and are equal 2298.5 Hour which represents 26% of the year.
- **Too Cool:** represents in blue and reach to the maximum in January and the total too cool hours equal 1891.8 Hour which represents 82% of these hours in winter.
- **Too Hot:** represents in red and reach to the maximum in July and the total too hot hours equal 406.8 Hour which represents 18% of these hours in summer.

3.2.2. Results: Energy Consumption Analysis

The following figure represents the daily energy use for the building divided into energy used for heating, cooling and electricity (Fig.9).

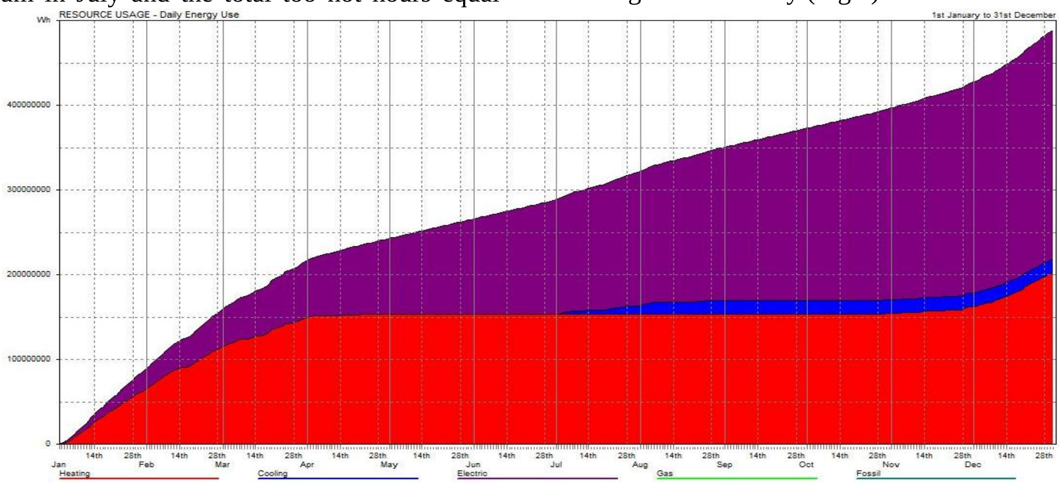


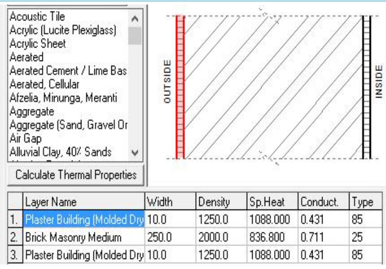
Figure 9: The Daily Energy Used By the Building.

- **Energy Used for Heating:** represents in red and shows the total energy used for heating the building throughout the year and is equal 204452 kilo watt.
- **Energy Used for Cooling:** represents in blue and shows the total energy used for cooling the building throughout the year and is equal 16342 kilo watt.
- **Energy Used for Electricity:** represents in purple and shows the total energy used for electricity in the building throughout the year and is equal 274495 kilo watt.

3.2.3. Analysis Of The Building Envelope Without Changing The Style Of The Building

The building envelope has to achieve thermal comfort through controlling the temperature inside the building by using materials which have efficiency of insulation.

Table 1: A Comparison between the Analysis Results and the Egyptian Code Rates for Overall Heat Transfer.

<table>
<tr><th colspan="3">BUILDING ENVELOPE ANALYSIS</th></tr>
<tr><td rowspan="2">Constituent Materials for the Building</td><td>Insulation Analysis Results</td><td>Insulation Egyptian Code</td></tr>
<tr><td>U-VALUE =KW/M^2</td><td>U-VALUE =KW/M^2</td></tr>
<tr><td>EXTERNAL WALLS:</td><td></td><td></td></tr>
<tr><td>
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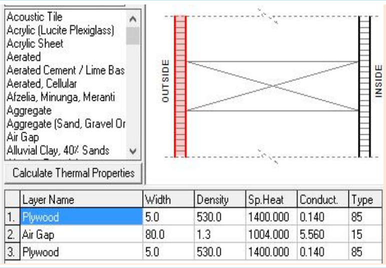
<tr><td>
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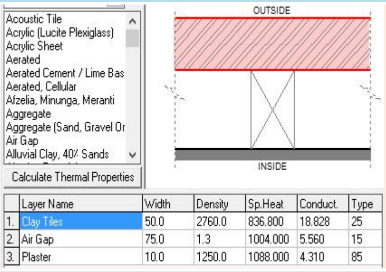
<tr><td>
</td><td>2.760</td><td>0.4</td></tr>
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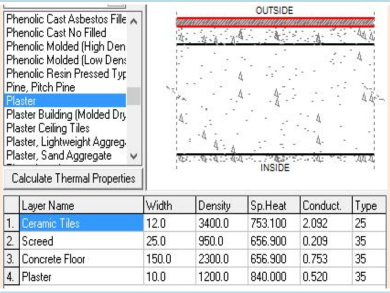
<tr><td>
</td><td>1.920</td><td>0.4</td></tr>
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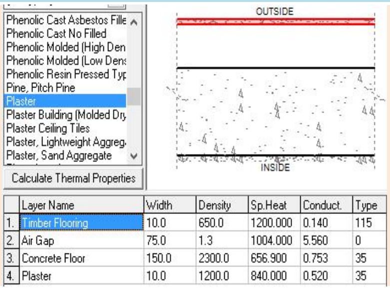
<tr><td>
</td><td>1.540</td><td>0.4</td></tr>
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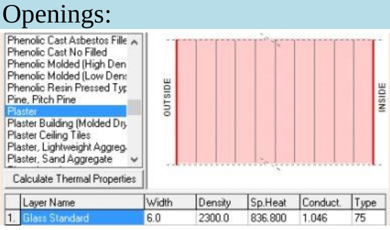
<tr><td>
</td><td>5.440</td><td>3.5</td></tr>
</table>

By calculating the overall heat transfer (u-value) and comparing these results with the Egyptian code, the results were higher than the code which means that the building envelope layers should be modified to achieve the heat transfer rates in the Egyptian code.

3.3. Revitalization Project Guidelines

First of all, it was necessary to understand how traditional buildings behave as environmental systems. The analytical study shows that the building envelope requires applying of insulation systems. It is possible to insulate with thermal plaster or internal rigid insulation in transpiring materials. The roof has high energy losses due to the missing of insulation. To insulate the lower insole preserving the original floor, it is possible to add rigid or sprayed foam insulation on the internal surface. To insulate the roof could be installed underside insulation or insulated ceiling characterized by mechanical, chemical and physical compatibility with the original roof. Transparent envelope has high thermal losses and air infiltrations. For this reason, it is necessary to evaluate the replacement of existent glasses and frames with new windows (low-e glasses and wooden frames) having better performances of thermal insulation, air permeability, water resistance and UV protection. For protecting the building from solar gain and discomfort glare can be installed internal shading devices and curtains, without adding radical and mechanical changes to the original facades. The absence of insulation, thermal distribution, climatic control and heat accounting systems, Furthermore, air-conditioning systems damages the artifacts and the buildings because the movement of air masses soils and dusts the walls, the frescoes, the inlays and the decorations. (8)

The intervention requires the evaluation of the insertion of radiant panels on existing floor (not characterized by particular historic value). Instead, it is necessary to insert thermostatic valves on existing radiators and heat accounting systems. The electric system not always is safety from risks. The lighting has discrete energy performances, guaranteed by the integration with daylight, halogen lamps and periodic maintenance on inefficient devices. To increase the level of light can be installed diffusers on existent glasses of the office and high efficiency sources. Solar energy technologies must be integrated within buildings and their surrounding landscapes, in order to obtain financial support and to increase their efficiency. The use of photovoltaic panels is recommended for decreasing the high electric consumption.

3.4. Possible Retrofit Actions For The Building Envelope

- Add rigid insulation under the pitched roofs;
- Apply sprayed foam insulation to the top of flat roofs;
- Install insulated ceiling;
- Install underside insulation;
- Insulate with thermal plaster or double wall;
- Install high-efficiency doors and windows;
- Install low-e glasses on existing frames;
- Transparent Insulating Materials;
- Install selective materials;

- Install weather-stripping on windows;
- Install internal shading devices;
- Install diffusers on existent glasses ;
- Install interior curtain.

3.5. Possible Retrofit Actions For Sustainable Technologies

- Install efficient air conditioning units and heat pumps;
- Install an exhaust air heat recovery system;
- Replace existing systems with efficient systems;
- Install thermostatic controls;
- Optimize the operating temperatures;
- Install the most efficient lamps and ballast;
- Install dimmers;
- Maintenance of lamps;
- Install photovoltaic panels;
- Install solar heating panels.

3.6. Evaluation of Energy Performance for the Building after Revitalization Project

Evaluating energy performance for the building after modifying the building envelope, according to the Egyptian Code for heat transfer (u-value)

3.6.1. Results: Thermal Analysis After Modification

The following figures represent the thermal analysis on the building after modification throughout the year, and are divided into monthly heating, cooling loads and discomfort degree hours analysis (Fig.10, 11).

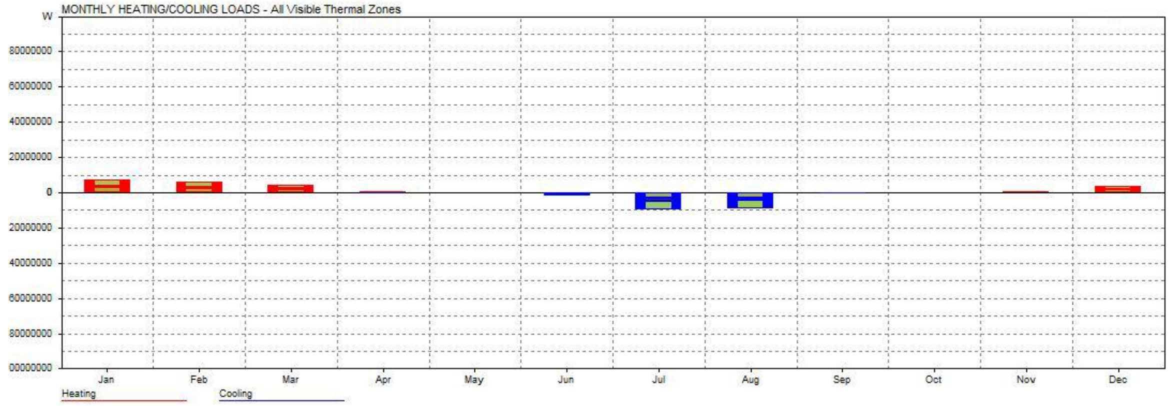


Figure 10: Heating and Cooling Loads in the Building after Modification.

- **<u>Cooling loads:</u>** represents in blue and reach to the maximum in July and is equal 1277 watts per square meter.
- **<u>Heating loads:</u>** represents in red and reach to the maximum in January and is equal 1270 watts per square meter.

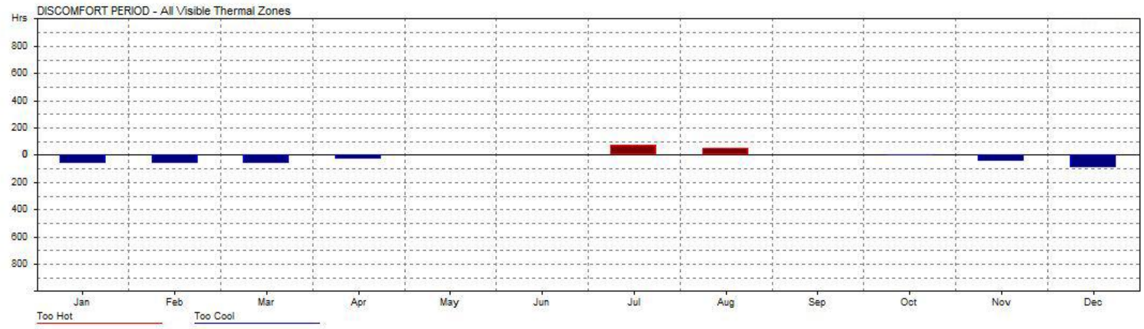


Figure 11: Discomfort Degree Hours in the Building after Modification.

- **<u>Discomfort Degree Hours:</u>** represents the total discomfort degree hours throughout the year and are equal 466 Hour which represents 5% of the year.
- **<u>Too Cool:</u>** represents in blue and reach to the maximum in January and the total too cool hours equal 342 Hour which represents 73% of these hours in winter.
- **<u>Too Hot:</u>** represents in red and reach to the maximum in July and the total too hot hours equal 124 Hour which represents 27% of these hours in summer.

3.6.2. Results: Energy Consumption Analysis

The following figure represents the daily energy use for the building divided into energy used for heating, cooling and electricity (Fig.12).

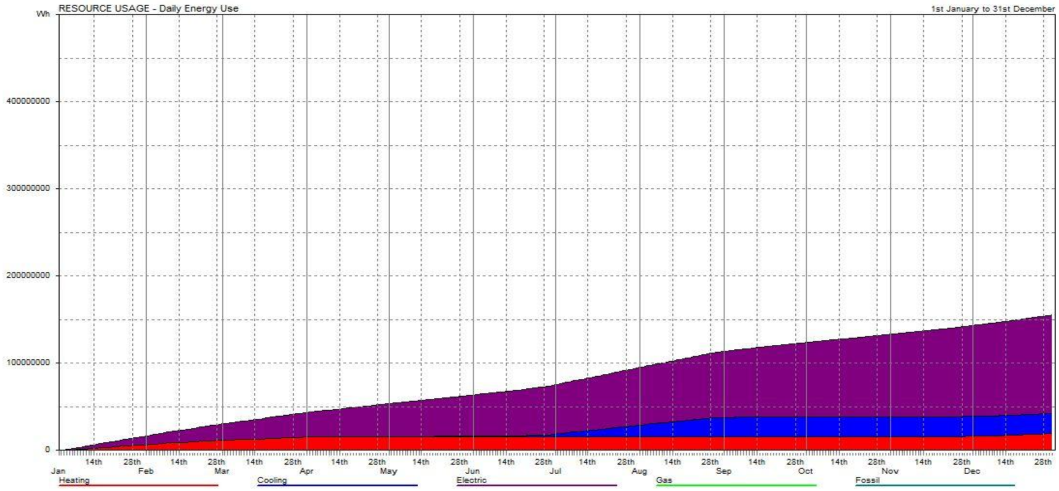


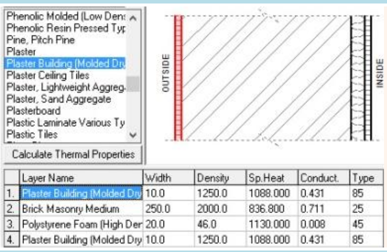
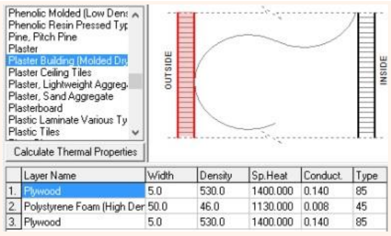
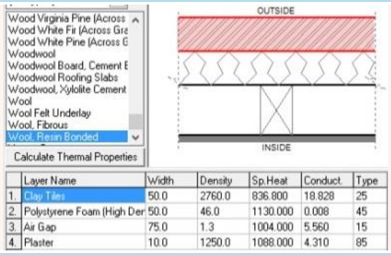
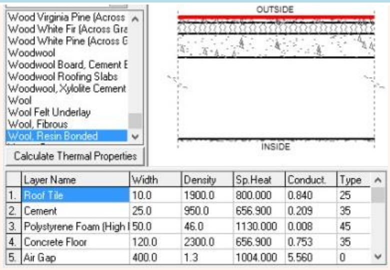
Figure 12: The Daily Energy Used By the Building after Modification.

- **<u>Energy Used for Heating:</u>** represents in red and shows the total energy used for heating the building throughout the year and is equal 21988 kilo watt.
- **<u>Energy Used for Cooling:</u>** represents in blue and shows the total energy used for cooling the building throughout the year and is equal 22101 kilo watt.
- **<u>Energy Used for Electricity:</u>** represents in purple and shows the total energy used for electricity in the building throughout the year and is equal 112427 kilo watt.

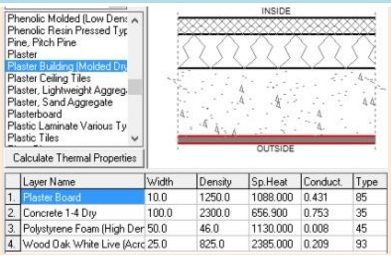
3.6.3. Analysis Of The Building Envelope After Modification

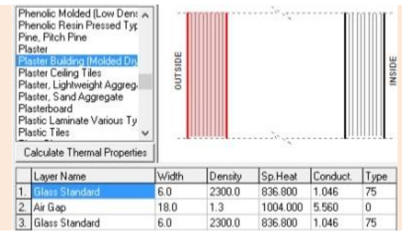
The building envelope has to achieve thermal comfort through controlling the temperature inside the building by using materials which have efficiency of insulation.

Table 2: A Comparison between the Analysis Results after Modification and the Egyptian Code Rates for Overall Heat Transfer.

BUILDING ENVELOPE ANALYSIS		
Constituent Materials for the Building	Insulation Analysis Results	Insulation Egyptian Code
	U-VALUE =KW/M²	U-VALUE =KW/M²
EXTERNAL WALLS:		
	0.340	0.9
INTERNAL WALLS:		
	0.160	0.9
PITCHED ROOF:		
	0.150	0.4
FLAT ROOF:		
	0.150	0.4

Continued Table 2

Floors:		
	0.150	0.4
Openings:		

	2.710	3.5

By calculating the overall heat transfer (u-value) and comparing these results with the Egyptian code after modification, the results were within the range stated in the code which means that the building envelope layers after modification have achieved the heat transfer rates in the Egyptian code.

4. Conclusion

The objective of studying energy efficiency and environmental quality in historic building can only be achieved by:

- Combining a full study of the building envelope condition and the energy efficiency of the building;
- Studying the thermal comfort inside the building;
- A proper actions and modifications can be applied to the building envelope without affecting the architectural style of the building or destroying the heritage of the building;
- Energy efficiency in historic building can be achieved by controlling the usage of energy inside the building and diversification of energy production from various renewable sources together with cutting greenhouse gas emissions;
- The goal may be obtained only by an integrate analysis of historic, dimensional, functional, energy and environmental matter;
- A deep knowledge of a real need permits to propose the most appropriate retrofit actions.
- The rehabilitation of existing structures is nearly always superior to new or replacement construction in terms of the various aspects of sustainability and sustainable development.
- Rehabilitated projects provide many advantages, including maintenance of historical and architectural integrity, revitalizing urban areas, and avoiding negative environmental impacts and unnecessary consumption of materials and energy.
- In planning a sustainable rehabilitation project, it is necessary to consider the surrounding context of the project, potential impacts to the human and natural environment, and economic viability compared to other alternatives.
- Sustainability as a decision includes all of these considerations, and can serve as a governing objective for all project decision makings which will help to ensure the survival of the earth and its inhabitants into the predictable future.
- Although there are many factors, the concept of revitalizing historic building has significant support as a positive strategy to make the built environment more sustainable.
- Revitalizing historic building enhances the longer term usefulness of building and is more sustainable than demolition or rebuilding.
- The positive benefits for revitalizing historic building identified during the research also support the tenets of sustainability and include:
  - Reducing resource consumption, energy use and emissions;
  - Extending the useful life of buildings;
  - Being more cost effective than demolition and rebuilding;
  - Reclaiming embodied energy over a greater time frame;
  - Creating valuable community resources from unproductive property;
  - Revitalizing existing neighborhoods;
  - Reducing land consumption and urban sprawl;
  - Enhancing the aesthetic appeal of the built environment;
  - Increasing the demand for retained existing buildings;
  - Retaining streetscapes that maintain sense of place;
  - Retaining visual amenity and cultural heritage.

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