An Ultra Energy Efficient Building in Palestine

Case Study: BMIP Bethlehem Multi-Disciplinary Industrial Zone

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ABSTRACT

This paper illustrates building architectural design including building sitting, building envelope performance, solar chimneys heating and cooling performance, natural ventilation and forced ventilation by solar chimneys and effective use of building façade for shading. Mathematical modeling and computer simulation of this building incorporating actual weather data of Bethlehem have shown that all measures used will reduce energy demand in winter by more than 70% and heating load will be less than 6KWhr/m2. Solar chimney, natural ventilation and dynamic shading of all glazing area will result in reduction of temperature by 6-12ºC. This makes the need for cooling system operation in summer is limited for few days every year.

Background

On June 24th 2008, President Nicolas Sarkozy and President Mahmoud Abbas signed a memorandum of understanding for the construction of an industrial zone in Bethlehem aimed at the development of Palestinian small to middle-sized light industry enterprises and develop an environmentally friendly project.

Figure 1: Project site pictures and site map

Site Description

The site is located in Bethlehem Southern outskirts. The environment is currently slightly urbanized, with housing in the North, a village along the road on the east side of the site and another village a kilometer to the South. With a total area of 223.m2.

CLIMATE:

Palestine is a historic region located on the eastern shore of the Mediterranean Sea. Palestine is characterized by a Mediterranean type with warm to hot summers and cool, slightly wet winters.

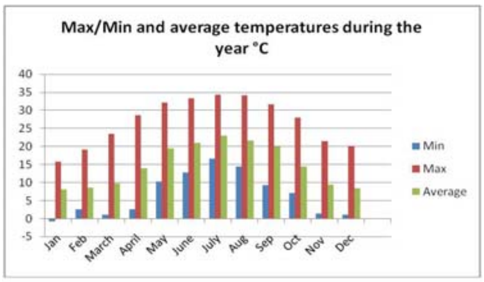

Figure 2. Minimum and maximum Temperatures in Bethlehem area.

According to data collected between 1990 and 2005 the average solar radiation per year is roughly 1970 kW/m2year in Jerusalem.

ENVIRONMENTAL QUALITY OBJECTIVES – DISCUSSIONS

OBJECTIVES

To create an environmental project, architectural and technical choices are guided by environmental concerns; design team leader should pay particular attention to the environmental components of the site.

The client's principle objective of creating a model in terms of environmental quality will have these special requirements:

- The building design should lead to lower costs for energy and water consumption, heating and cooling, and for conservation and maintenance.

- The building design should lead to the construction of a building that is comfortable for its occupants, notably in terms of thermal, visual and acoustic comfort.
- To achieve these various objectives, the building should be implemented and constructed from local materials that are carefully chosen to go with the building's other objectives and choices of materials and techniques.

The objective is to create pilot project where energy efficiency and the use of renewable prevail. It is of utmost importance for the BMIP.

The example should be able to "be read" from the building's facade .

In addition to energy consumption, several other criteria should be taken in consideration:

- Cost optimization
- Architectural quality, comfort and the building's integration with the environment
- Integration of energy systems in the building
- Environmental impact of materials and construction processes
- Flexibility

SPECIAL DESIGN CONSIDERATIONS

Building Setting and Implementation:

The idea of implementing, setting the building is particularly important when the goal is to lower energy consumption. It's also important because of the administrative building's strategic position in its urban environment, because of its exemplary role and because of the environmental components of the site.

The integration of the building's architectural and urban aspects is particularly important. The quality of its facades, layout, volumes and materials give structure to the space, contribute to its value as an exemplary space, and directly contribute to its energy-saving attributes.

Beyond the basic elements of urban development and architectural recommendations, the lead architect and designers should also pay attention to the urban environment, existing buildings and the climate in terms of rain, wind and sun.

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Building Envelope

The building envelope should be considered a priority in the process of thinking about energy efficiency for the entire structure.

Constructive measures that can be taken to keep the building comfortable in hot weather:

- Favor southern window exposures with exterior sun shades
- Do not use skylights on the roof
- Reduce daytime internal airflows, with ventilation at night
- Or, reduce daytime internal airflows, and use geothermal heat pumps
- Choose low transmission, heat-reflective materials
- Exterior insulation is also worth considering.

Visual and Thermal Comfort & Acoustic *Comfort*

The concept of "visual comfort" relates to lighting and the delicate relationship between natural and artificial light. The architect design team leader should favor natural light in meeting rooms and waiting areas, as well as in offices, workspaces and common traffic areas, as much as possible. The risk of glare and light limitation should also be taken into consideration.

At the same time, "thermal comfort" should be considered: The risk of overheating through glass windows should be taken into account as part of the design, as overheating can make workspaces very uncomfortable.

The Project

Master Plan of Bethlehem industrial zone

Figure 3. Master plan & Site plan

Specific Environmental Aspects of the BMIP administration Building

1.0 Introduction

The design of the building has been done in a way that provides natural comfort with minimal need for HVAC systems. The main criteria for the design were:

- Maximize heat gain in winter via passive solar system and proper insulation.
- Minimize heat gain in summer via proper shadowing, Proper insulation and adequate ventilation.

These criteria could be achieved in the design of Administration Building of Bethlehem Industrial Zone using the following parameters:

- High insulation of all external walls, slabs and basement floor
- Proper shading of sunshine in summer that will allow sunshine to penetrate glazing areas in winter
- Proper natural ventilation for summer
- Moderate thermal mass of the building
- Use of Passive and Active solar system for heating the building in winter and increasing air ventilation in summer.

2. Insulation

All external walls and slab were insulated near the inner sides of the envelope. The reason for that was to minimize the thermal mass of the building. This building is constructed mainly from concrete and stone with very huge thermal capacity, which is beyond the needs for thermal storage. If we take into consideration that this building will be used at daytime only, then the need for thermal storage for night time is eliminated. That does not mean in any way that the remaining mass is not large, as it consists of internal walls, slabs, columns, furniture and other building materials. This thermal mass; which was insulated from external atmosphere to minimize thermal losses will prevent fluctuations in temperature at daytime when there is sudden appearance or disappearance of sunshine.

The following table (Table 1.) indicates the calculated values of the thermal conductance of different components of the external envelope of the building.

Location Bethlehem – Palestine Latitude 32° North	
Component of external envelope	Thermal conductance (U factor)
Walls	0.43 W/(m^2.K)
Floor	0.52 W/(m^2.K)
Flat roof	0.41 W/(m^2.K)
Windows	1.3 W/(m^2.K)

Table 1. Thermal conductance's of envelope elements

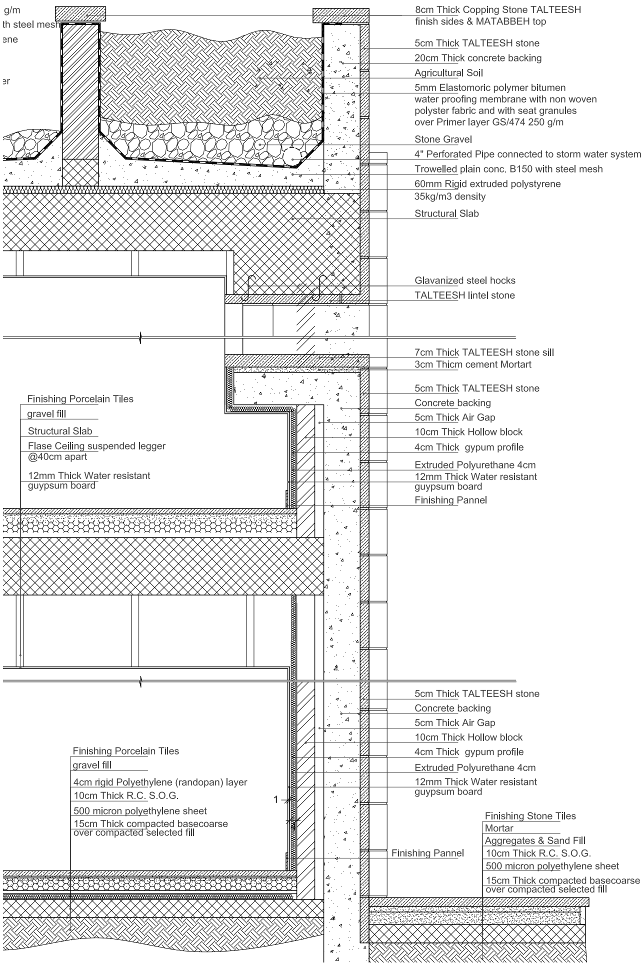

Figure 4. Thermal insulation near the internal surface of external walls and slabs

According to the climate conditions of Bethlehem, the heating load of the building is expected to range between 50-70 W/m2.

3. Solar Systems

This building has been designed with different passive solar systems. However, two types of systems are used heavily:

Solar chimneys on south-eastern wall and south western wall. These chimneys will provide space heating in winter for nearby offices in winter. In summer, these chimneys will generate forced ventilation in the building where air is drawn to the outside due to thermal siphonage.

Solar water collectors which will provide hot water for space heating and for domestic purposes. Evacuated pipes collectors are suggested here for the fact that their efficiency is high and almost constant regardless of the difference in temperature between water inside them and ambient temperature. Also, these collectors can absorb sun radiation from different directions.

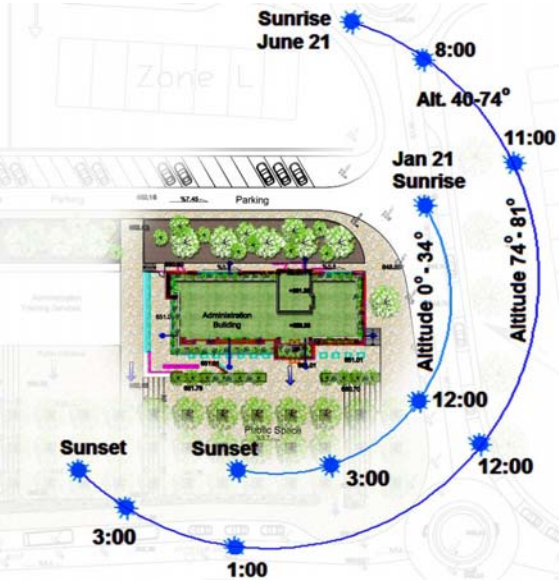

Figure 5. Sun path in summer and winter as related to the building

Solar chimneys

The solar chimney is a good example of a passive system that can be used for heating in winter and cooling (via ventilation) in summer. The cost of constructing solar chimneys is very low compared to their thermal impacts in both seasons. A well designed and constructed chimney can achieve an efficiency that exceeds 50% in winter when used for space heating.

For south-eastern wall of the building, each m² (glazing) is expected to gain around 2.9 KWhr/day in sunny days in January, and around 1.2 KWhr/day for an average cloudy day regardless of outside temperature. With six chimneys on the south-eastern wall with an area of 5.6 m² each, then it is expected to achieve thermal gain around 40 KWhr/day in an average cloudy day in January. This may exceed 95 KWhr/day for sunny days.

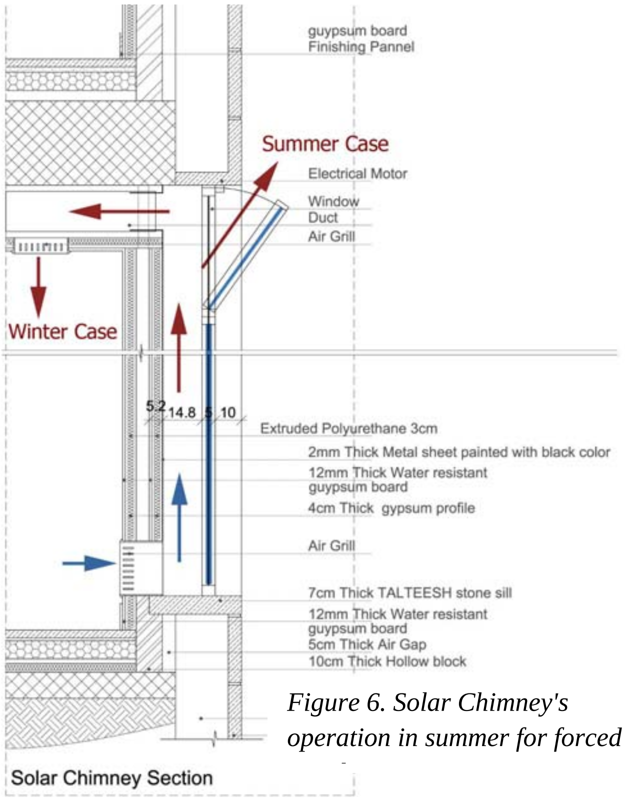

Figure 6. Solar Chimney's operation in summer for forced

In summer, when the upper opening of the chimney is opened to the outside, air stream will be generated in the adjacent rooms as hot air is drawn upward due to thermal siphonage. For a height difference between upper and lower opening around 3m, air velocity in the chimney will be around 2.5 m/sec. In such case, air movement and air steams in these rooms will create feeling of comfort for people in the rooms.

4. Shadowing for summer

Most of the glazing areas in the north-eastern and south-western walls will be provided with effective shadowing to reduce heat gain in summer, to prevent direct sunlight to penetrate into the building when it is not needed. As shown in figure 7, the north-eastern glazing area is equipped with rotatable wooden shutters. These shutters can be directed to allow sunshine to reach the glazing area in winter only. In addition to their thermal benefits, the shutters will help reducing glare effects of direct light on the residents of the building. Additional elements which give extra shading is vegetation around the building, Seasonal high trees are planted on the western and eastern sides of the building and evergreen low shrubs are planted around the building and over and around the parapet of the building. The aim of seasonal trees is

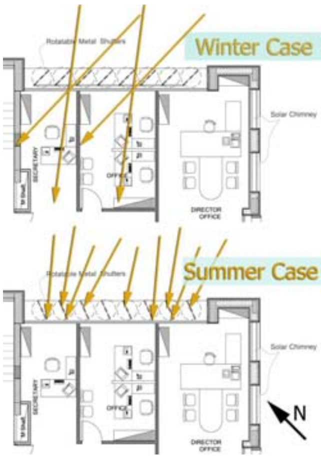

Figure 7. Rotatable metallic shutters

Figure 8. Shutters orientation for summer and winter at north-eastern wall

to give shade in summer and to allow the sun to penetrate to the building in the winter, on the other hand the vegetation areas which are around one third of the total area used for use of the administration building and surroundings are to give humid atmosphere and reduce and temperature in summer

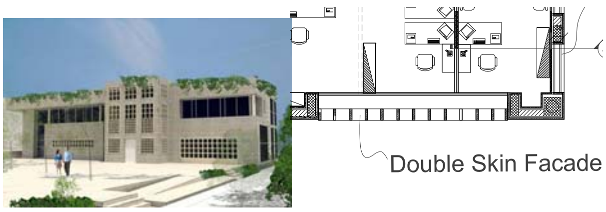

Figure 9. Double skin façade on the south-western wall for shade and ventilation aspects

The third factor used for making the thermal environment in this building more comfortable naturally is ventilation. Natural ventilation is guaranteed through the orientation of openings of windows in the building, which were made according to wind direction in summer. In addition to that the solar chimneys on the south-eastern wall will generate forced circulation of air, as the generated ***thermal siphonage*** will draw out air from the rooms to the outside.
Figure 8 illustrates the operation of the rotatable metallic shutters on the south-eastern glazing areas. Figure 9 shows a different technique has been used on the south-western wall. Double skin façade is used for shade and ventilation aspects. As the building is not in use at late afternoons, then there is no need for rotatable shutters.

5. Ventilation

Natural ventilation is guaranteed by the all directed opening of the building such as windows and doors. In Bethlehem area, most wind comes from West, North or North western direction. As it is clear in the design, summer wind can penetrate the building easily from the north western wall openings and leave it from south-eastern ones. This will help in reducing temperature in summer and will help in removing excess heat that may exist in the building.

Figure 10. Wind Direction

6. Thermal Mass

The thermal mass of the building is reduced through the use of insulation near the internal sides of all external walls and slab. The main reason for that is the fact that the building is used at daytime only. In such case, reducing the thermal mass will make it easy to warm the building rapidly in winter and reduce the heating load. The remaining thermal mass of this reinforced concrete building; which includes internal walls, floors, columns and furniture is relatively huge, and this is needed to eliminate thermal fluctuations and store heat for many hours.

Conclusions

Reference to the report of Dynamic Thermal Simulation of the Administration Building – Bethlehem Multi-Disciplinary Industrial Park, and reference to the report results of the study, done in France by (Engineer Michel Raoust French Consultant Engineer for Environment) engineer appointed by the French Government:

- The temperature in the building during the summer months can reach over 35°C with the standard design of a building.
- The solar chimneys reduce the temperature by 3 to 5°C of the building during the summer.
- Natural night time ventilation can reduce the temperature by approximately 3°C at the hottest time of the year.
- Systematic shading of all windows can reduce the temperature by 3 to 4°C at the hottest time of the year.
- The comfort of the occupants can be improved

by using effective natural ventilation and shading. However, the temperatures in some rooms in the building get high during the hottest weeks of the year.

- An active cooling system with a capacity of 37.5kW can be put in place to improve the comfort of the occupants during the hottest weeks of the year. A split system air conditioner can be used with a coefficient of performance of 3.5 to minimize the consumption. A consumption of 2,7kWh/m2 of electricity is then obtained using this type of system (while maintaining the use of natural ventilation and shading).

The heating needs of the building with the solar chimneys in place are 6kWh/m2. Taking away the solar chimneys increases the heating needs of the building. Therefore, the solar chimneys reduce the heating needs of the building.

The heating needs of the building can be reduced by increasing the insulation**.** The current choice of 40mm PU panels insulation is satisfying.

The insulation of the ground floor with 5cm of insulation would also reduce the heating needs of the building. Effective natural ventilation and shading on all facades reduces the overheating in the summer. An active cooling system with a consumption of 2.7kWh/m2/year can be used to further optimize the comfort of the occupants in the summer. The kindergarten and the classes do not necessarily need to have an active cooling system if solar shading and natural ventilation are provided or occupants can use it to the minimum as long as their understanding of the passive cooling means has been assured.

Abbreviations:
KwHr/M2 = Kilo watt (Total of Hours) / m2
HVAC = Heating, Ventilation & air conditioning.
W = watt
KwHr/day = kilo watt (Total of hours)/day.

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