Energy rehabilitation of modern office building in the region of Xanthi

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ABSTRACT

This paper presents an energy status study of a modern office building in the region of Xanthi. The results of the study are analyzed and evaluated with the use of appropriate software. Finally solutions are proposed for building’s energy rehabilitation.

1. INTRODUCTION

During the last few years an effort has become for reducing the energy consumption in non made environment. A part of this, with high energy demands, is the modern building environment. Especially the modern commercial and office buildings are units with special structure and high energy consumption. The reasons that the energy design of this kind of building should be very careful are (Papadopoulos, 2003): they, usually, are buildings with high financial value and the cost of the region where they are built is high. Their design and construction are not rational because they are, usually, considered as prestige symbols of the enterprise they are owned by. They also must meet the different demands of the people that work in these. They are frequently and intensively, sometimes, reconstructed and they are occupied periodically during the day and during the week.

2. CHARACTERISTICS OF THE BUILDING

The building that has been studied is next to the national road of Xanthi- Kavala, next to the Industrial Area of Xanthi. The building was selected because of its recent construction, its isolation and its internal structure and particularities which are analyzed below.

The building is in a fenced area and its ground plan’s area is 893 m^2. The orientation of the building (Fig. 1) is with the longitudinal axis in North- South orientation with a 45^o deviation to west towards North.

The frame of the building is reinforced concrete. The walls are internally coated with plasterboards and the ceilings with furred ceiling. The building, externally, is coated with aluminum sheets, which are colored open grey. The transparent surfaces of the building do not open at any place of the building and they consist of double pane with alum frame. The roof is flat without a protection or a cover, so it could be protected from the environmental conditions.

The building has basement (883 m^2), ground floor, 1st and 2nd floor each covering 893 m^2. The total heat area is 2680 m^2 and the total area of the building is 3560 m^2.

The internal structure of the building (Fig. 1) consists of 3 parts. The ground floor and the 1st and 2nd floor have the same structure, in contrast to the basement which is a compound, non thermal area, and contains the main electrological and mechanical equipment of the building. The parts 1 and 3 are compound occupation rooms and they are identical, except part 3 on 2nd floor, where there are the office of the executive manager and other executive employees. The part 2 is the middle area of the building, where there are luncheonettes, the stairs, WCs, elevators and room with auxiliary electronic equipment.

The individual characteristic in the internal structure of the building is an opening on 1st and 2nd floor in the central part of the building (fig. 2). These openings are identical and cover 44.75

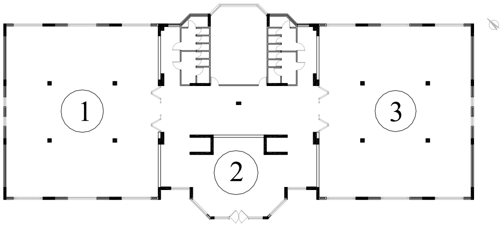

Figure 1: Ground floor plan

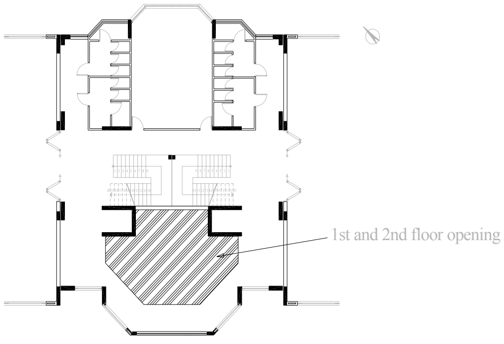

Figure 2: Central part plan

m^2 area each of them. They are very important because of the influence they have on the circulation of the air inside the building and on the distribution of the temperatures. The other characteristic that supports the importance of these openings are that the whole west face of the middle part consists of glass and the duration of this side’s insolation is longer than the other sides.

3. ENERGY STATUS OF THE BUILDING

The building consumes electric power, for covering the most of its energy demands. The electric power is mainly consumed by the PCs, the HVAC system and the lightening of the building. The heating system, in cold period of the year, consumes liquid gas as fuel and in the hot season the cooling system consumes only electric power.

The HVAC system covers all the area of the building except the middle part and the basement. The system is in every floor controlled by thermostats which are in the northern room of the floor. The luncheonettes have their own thermostats.

4. ENERGY LOSS EVALUATION

The evaluation of the energy loss of the building through its shell was done with an infrared camera and a thermoygrometer. The objective was to locate places of the shell with no or damaged insulation and places where detected thermo bridges (Grizanto & al., 1998).

The measurements have covered the entire building and have been accomplished during the day when there were employees in the building. The results have shown that thermo bridges are detected at the transparent surfaces and especially at the alum frames of the windows. Places where there is no or damaged insulation have not been detected. The figures 1-4 present temperature ranges of specific points of the building for the hot and cold period.

The Figures 3-6, present the temperature ranges of the three elements (wall, aluminum, glass), which constitute the shell of the building. The wall is taken as one material, because its overall properties that were observed were a result of its individual materials that constitute it. In Figures 3-6 are also presented the temperature differences of the three elements.

As we can see, during the hot season, the temperatures of the elements are generally high

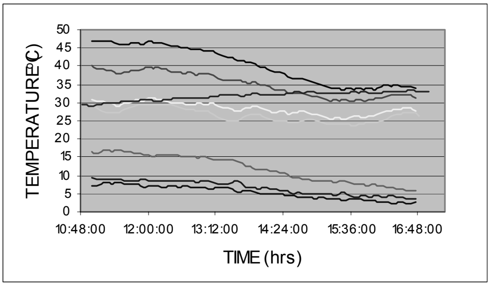

Figure 3: Temperature range of a point on southern face, internal, 19/7/2004.

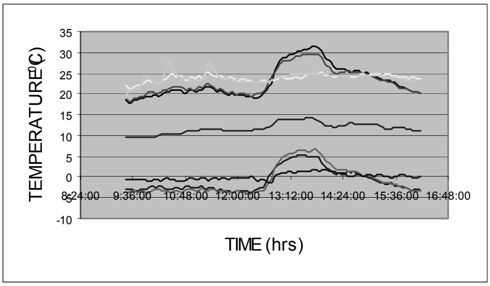

Figure 4: Temperature range of a point on Southern face internal, 24/11/2004.

and temperature of the aluminum approaches the 50 ^{o}C. The hottest element with the highest temperature range is aluminum, followed by the glass and the wall. As a result, the temperature differences are always positive, which means that the wall is always cooler than the other two elements.

In the cold season the conditions are reversed, the temperatures of the elements are lower than they are in hot season as well as the temperature ranges. Generally in cold season the element with the highest temperatures is the wall, but in days with sunlight the conditions, at least during the day, approximate the hot season’s conditions even thought the temperatures are lower. This happens only for the time of insolation, when aluminum and glass get hotter than wall. The rest of the time the wall is warmer than the other two elements, so the most of the time temperature differences of the elements are negative.

The conclusion regarding the temperatures of the building’s shell materials is that the main factor, that influences them, is the insolation time. For the wall, the conditions are a slightly different because the main factor is the internal temperature of the building.

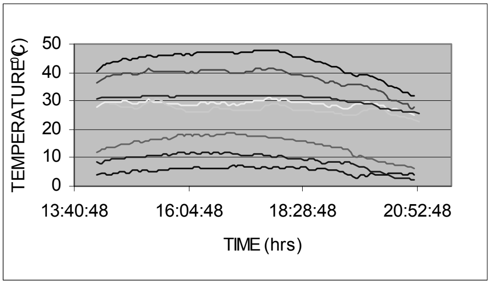

Figure 5: Temperature range of a point on western face, internal, 5/7/2004.

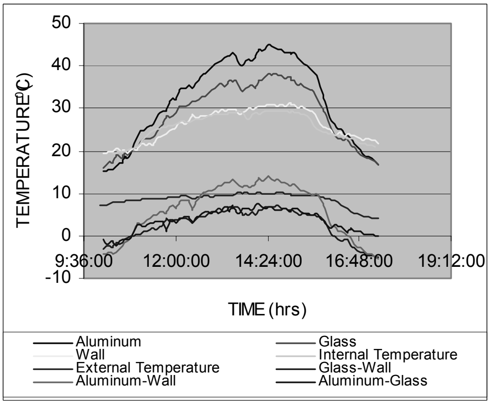

Figure 6: Temperature range of a point on western face, internal, 22/11/2004.

5. THERMAL COMFORT RESEARCH

In order to estimate the thermal comfort of the employees, during the hot season, and how they perceive the internal environmental conditions of the room they work, a questionnaire was distributed to them. The distribution based on the employees’ occupation room, in order to record the environmental conditions of the room.

The Figures 7-10 present the results that came up after the elaboration of the questionnaires to the question: “How do you perceive the temperature conditions at your working space”? These results concern the north room of the 1st floor and the south room of the ground floor. Figures 11-12 present the temperature range of the occupational rooms during the days of the questionnaire’s distribution.

The main conclusion that comes up is that there is a very serious problem of lack of steady temperatures in the occupancy rooms, during

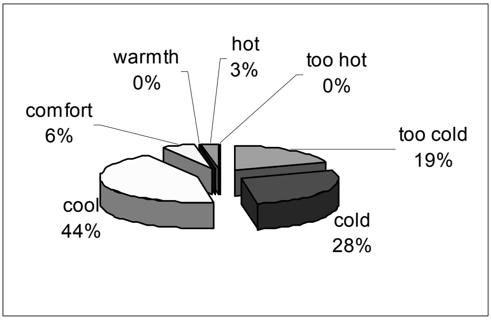

Figure 7: Questionnaire’s results for the southern ground floor’s room, HVAC operation, 22/7/2004.

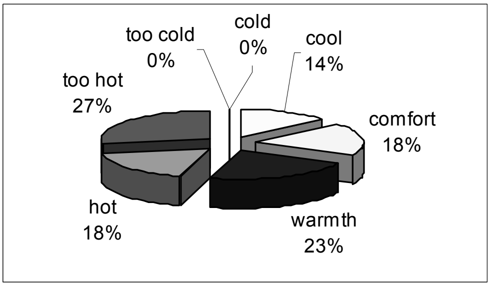

Figure 8: Questionnaire’s results for the southern ground floor’s room, no HVAC operation, 22/7/2004.

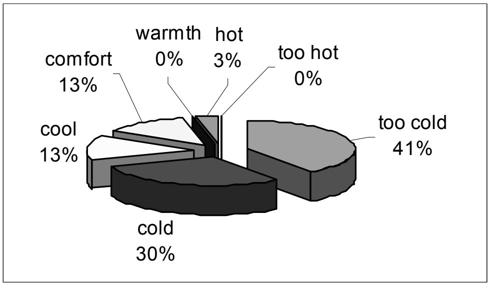

Figure 9: Questionnaire's result for the northern 1st floor's room, HVAC operation, 21/7/2004.

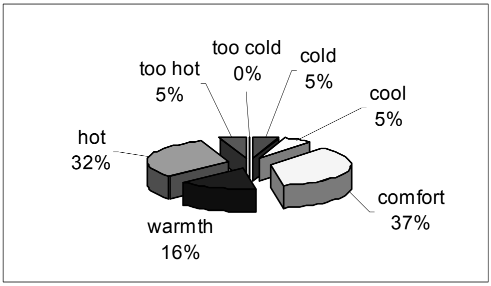

Figure 10: Questionnaire's result for the northern 1st floor's room, no HVAC operation, 21/7/2004.

the summer season. The problem of no equable distribution of the temperatures comes as a result of the way that the HVAC's system openings are located and how they spread the air into the space. It is also important the place points of the employees, if they are near or far from the window, because there is no protection from the incoming solar radiation. Another parameter, which adds to the problem, is the high fluctuation of the temperature as a result of the HVAC operation. The analysis of the questionnaires has shown that when the HVAC operates, there is a very quick fall of the temperature in the rooms until the temperature reaches the thermostat's selected temperature. When the HVAC stops, there is a very quick rise of temperature. This temperature's fluctuation in such a small period of time is unpleasant for the employees, because cold and warm conditions change very quickly, so it is difficult for them to adjust.

Figures 7-10 present how the employees perceive the thermal conditions of their occupancy room when HVAC operates and when not. For the northern room on the first floor, during HVAC operation, the percentage of the people who feel cold is 84 %, those who feel comfortable is 13 % and those who feel hot is only 3 %.

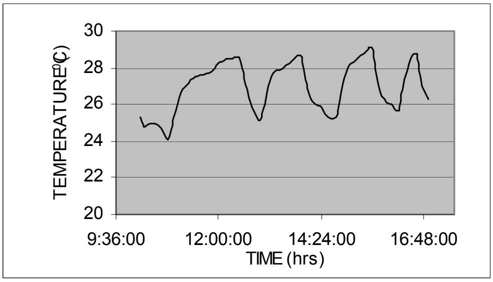

Figure 11: Temperature range, northern 1st floor's room, 21/7/2004.

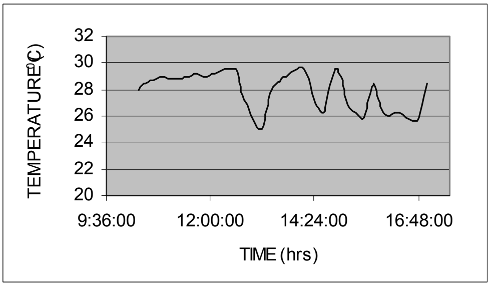

Figure 12: Temperature range, southern ground floor's room, 22/7/2004.

On the contrary, when there is no HVAC operation, the percentage of people who feel cold is 10 %, those who feel comfortable is 37 % and those who feel hot is 53 %. For the south room on the ground floor the percentages, during HVAC operation, respectively are 91 %, 6 % and 3 %, and when HVAC is not operating the percentages are 14 %, 18 % and 68 %.

The general conclusion after the elaboration of the questionnaires is that the internal environmental conditions of the building cannot satisfy the employees' thermal demands. The internal environment, during HVAC operation, is generally cold and when HVAC is not operating is warm. The percentage of thermal comfort is generally very low. Especially during HVAC operation the thermal comfort percentages are only 6 % and 13 %. When HVAC is not operating the percentages are increased to 18 % and 37 % respectively.

6. ENERGY REHABILITATION

The goal of this effort is to formulate suggestions in order to reduce the total energy consumption of the building, especially the heating and cooling loads. The goal was achieved with the creation of several scenarios and the estimation of their efficiency with the use of simulation software. The results are presented in Figure 17.

6.1 Present condition

The systems of the building that consume energy are the HVAC system and the other electrical and mechanical equipment, including lightening and applications like PCs. The highest energy consumption is during the cold season because of the high heating demands. During the hot season the energy consumption is much lower. The present energy consumption of the HVAC system is presented in Figure 13.

6.2 Case 1

The first scenario predicts the placement of double shading devices, all over the windows with west and south orientation, at the top and at the middle of their height. The width of the panels is 1 m, the length is as the length of the opening and they have 45^o gradient. The material is colored glass with 0.1 transparency coefficient. The results are presented in Figure 14. With this interface we achieved reduction of the energy consumption during the hot season without making extensive modifications to the building shell.

6.3 Case 2

The second scenario predicts the use of the same type of shading devices as the previous, additional with a more efficient control of the HVAC operation. The temperature range when the HVAC operates is 21^oC to 25^oC and the thermostats are only in the north room on every floor. The change in HVAC system is a thermostat placement in every room in order to control the temperature in every room separately. So it is easier to adjust the right temperature range in every single room according to its particular thermal needs. The adjustment of the new temperature ranges in every room is based on its present thermal loads. The new temperature adjustment was achieved by increasing or reducing 1 or 2 degrees of the previous adjustment (Fig. 15).

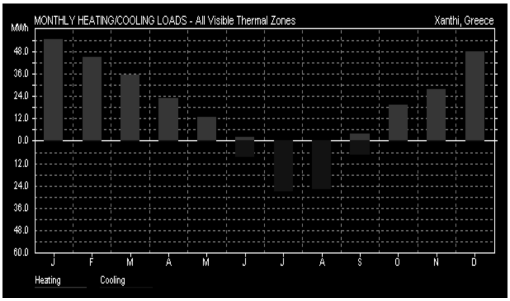

Figure 13: Present state of building’s heating and cooling loads.

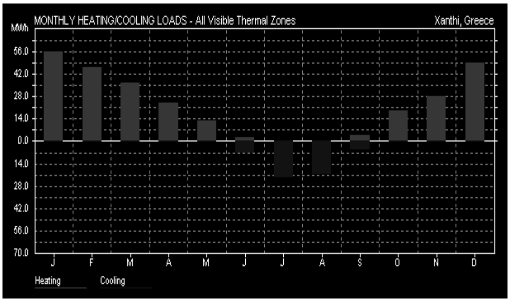

Figure 14: Case 1, building’s heating and cooling loads.

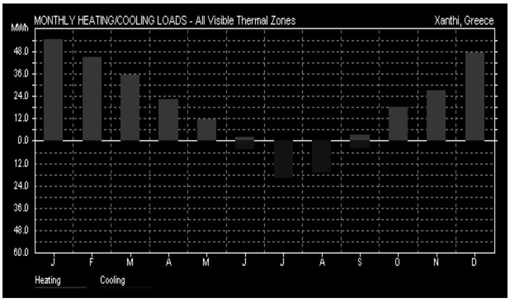

Figure 15: Case 2, building’s heating and cooling loads.

6.4 Case 3

The third scenario has not external modifications. Here is we have the change of the HVAC system as in case 2 and also the reinforcement of the existing insulation. The reinforcement of the insulation is done at the internal face of the building’s shell walls, with 0.15 m thick foamed polyurethane. This scenario has the highest reduction in building’s energy consumption. This result is due to the reduction of both heating and cooling loads (Fig. 14).

7. CONCLUSIONS

1. The temperature conditions of the building are not satisfactory for the employees because of their instability and their large changes.
2. Thermal comfort is of a low level because of

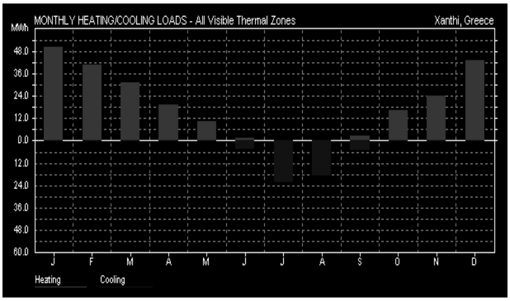

Figure 16: Case 3 building's heating and cooling loads.

	Energy consumption reducing percent (%).	Economical profit per year. (Euros)
Case 1	3	540
Case 2	10.6	1922
Case 3	14.8	3530

Figure 17: Energy and economical profits from the each case.

the internal environmental conditions of the building.

3. The places of the building shell that thermo bridges are detected are the transparent surfaces and their frames.
4. The major percentage of building's energy consumption is for heating.
5. The solution of shading devices is not satisfactory because of the small decrease of the total energy consumption.
6. The optimal solution from energy view is the *Case 3* because of the reduction of the total energy consumption (approximately 15 %).
7. Case 3, is also the optimal economic solution because of the amount of money, so the saved investment will be redumpted in a small period of time.

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