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Thermal building simulation of research building of Damascus university

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ABSTRACT

The Thermal Building Simulation is a very suitable way for optimizing the thermal performance of buildings. In this paper the thermal behavior of a public building including the heat demand, heat loads as well as the indoor temperatures during summer is simulated using the TRNSYS (Transient System Simulation Program) program package. For the start of the thermal building simulation, input parameters concerning the climate data, the building geometry and the use of the building were defined. The influence of the movable shading devices, night ventilation, roof insulation and internal gains were investigated. The results of the simulation showed the possible procedures to arrive at an optimized situation of the building: no window shading devices, shading devices only on the south façade, night ventilation with an air change rate of 6.0[h^{-1}], Roof insulation of 5[cm] and reduction of the electrical power consumption of the PCs to 80[W/PC]. This study will be used as a starting point for a possible refurbishment of this building to reduce the heating loads and to reduce the overheating problem in summer.

KEYWORDS

Thermal building simulation;
TRNSYS program package;
Thermal performance.

INTRODUCTION

TRNSYS (Transient System Simulation Program) is a program package simulates the performance of thermal systems over time. TRNSYS has originally been developed for the detailed analysis of solar thermal plants and buildings to optimize their performance[1].

While the building (a building of the renewable energy laboratory at Damascus University in Syria) has a considerable overheating problem during the summer months with maximum indoor temperatures of 40°C, the thermal performance of the building was intend to simulate to reach the optimized building. Thus, this research can be described as a future way for improving the thermal behavior of this building in terms of reduction the heating loads as well as the overheating problem in summer.

Data and method of simulation

Thermal building simulation with TRNSYS is performed within a subprogram, the so-called TYPE 56. The large number of building data and weather data, which influence the thermal behavior of the building, is passed to TYPE 56 via external data files. The climatic boundary conditions were calculated by the climate data generator Meteonorm[2]. The measurement period for the ambient temperature as well as the radiation was between 1961 and 1990. The climate data generator

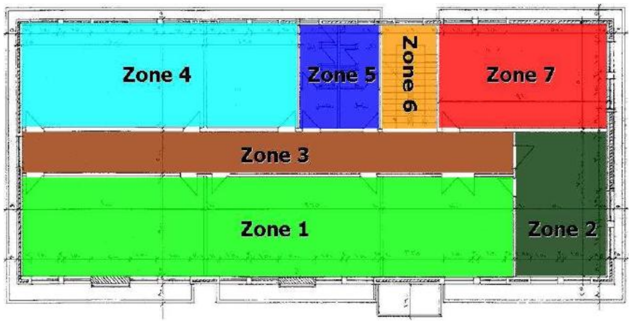

Figure 1 : Plan view of the first floor showing the 7 thermal zones that used in the building simulation

program Meteonorm uses monthly averages and creates climate data for a typical year with a statistically procedure weather. For the actual building simulation climate data on an hourly time step were used.

No shadings of the building envelope due to objects that are not associated with the building are considered (i.e. neighboring buildings, trees).

For the dynamical building simulation, this rectangular building was divided into so called thermal zones. The first floor was partitioned into 7 thermal zones since it is the most critical section of the building in terms of heating loads as well as overheating problem during the summer months due to the high external surface.

The floor areas, the room heights, the zone air volumes and the detailed geometrical evaluation of each zone were used in the simulation. In addition, the layer structure of all wall, floor and ceiling constructions with their thicknesses and thermo-physical properties, the windows types and their association within the thermal zones and the radiation types with the slope and azimuth of each surface were also used in the simulation.

The building orientation in North-South direction and the effect of the shading of the windows on the South façade by the overhangs due to the terraces were taken into account in the thermal building simulation by using the so-called overhang and wingwall TRNSYS component (TYPE 34).

For the initial scenario, movable shading devices, night ventilation, roof insulation and internal gain were investigated. These parameters of the initial scenario can be summarized in the following list:

- Movable shading devices: only on South façade.
- Night ventilation: air change rate of 0.5[h^{-1}].
- Roof insulation: no thermal insulation of the roof.
- Internal gains: power consumption of 1 PC = 140[W].
- Each of the four parameters mentioned above was changed separately.

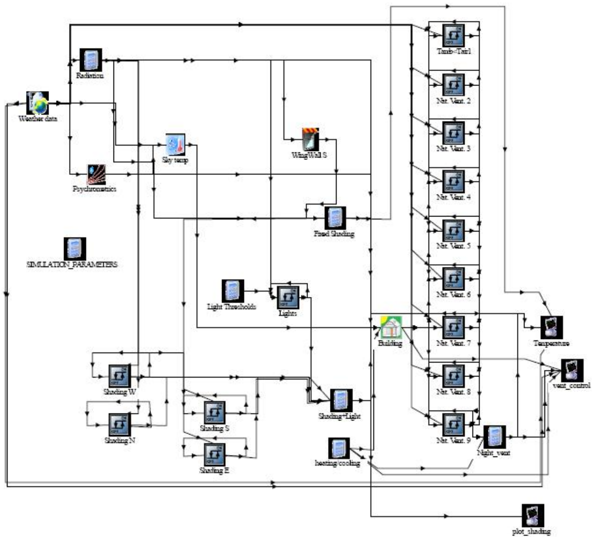

Figure 2 : Model representation in TRNSYS simulation studio for the thermal building simulation

To investigate the influence of the movable shading devices on the room temperatures during the summer period, three scenarios were defined:

(1) No shading devices.
(2) Shading devices only on the South façade.(identical with the initial scenario).
(3) shading devices on all facades (South, West, Earth. And North).

To investigate the influence of the air change rate during the night (night ventilation) on the room temperatures during the summer, three scenarios were defined:

1. Night ventilation AC = 0.1[h^{-1}] (corresponds to a situation where the windows are closed during the night).
2. Night ventilation AC = 0.5[h^{-1}].
3. Night ventilation AC = 6.0[h^{-1}].

To investigate the influence of the roof insulation, two scenarios were defined:

1. No roof insulation (identical with initial scenario).
2. 5[cm] of roof insulation with a thermal conductivity of $\lambda = 0.035$[W/m.K].

To investigate the influence of the power consumptions of the personal computers (PC) on the heating demand and heating loads as well as on the room temperatures during the summer period, three scenarios were defined:

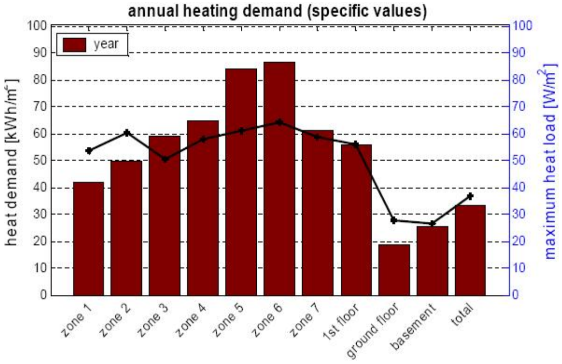

Figure 3 : Initial scenario: the specific annual heating demand for the (columns, left axis) and the maximum specific heating loads (lines, right axes)

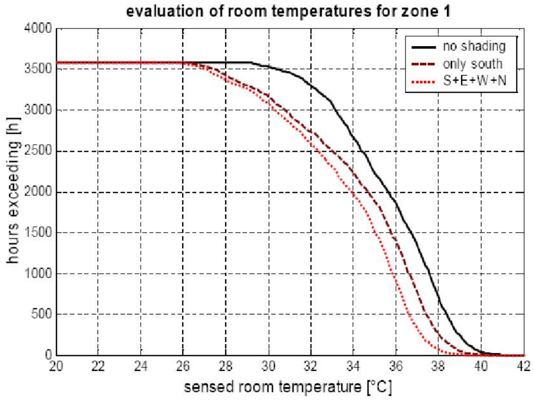

Figure 4 : Evaluation of the sensed room temperatures in zone 1 for the period between May, 15th and October, 15th

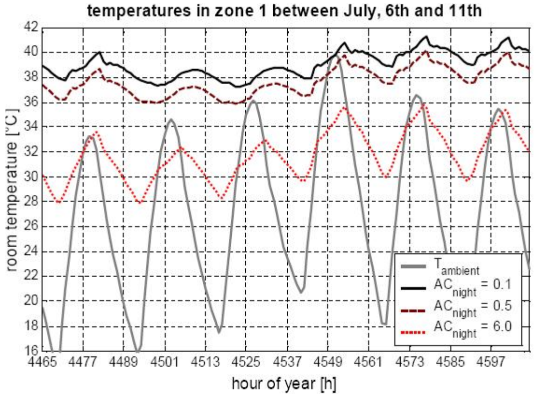

Figure 5 : The sensed room temperature in zone 1 between July 6th and 11th

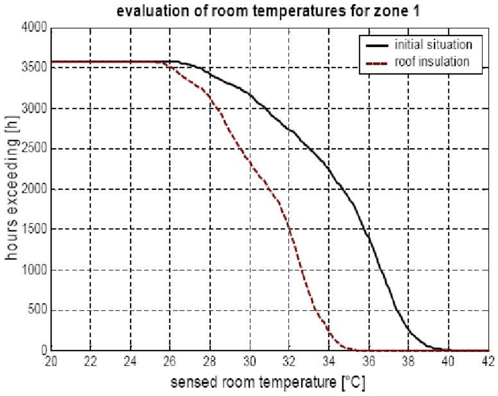

Figure 6 : Evaluation of the sensed room temperatures in zone 1 for the period between May, 15th and October, 15th

1. P = 80[W/PC].
2. P = 140[W/PC].(identical to the initial scenario)
3. P = 230[W/PC].

This series of scenarios was planned for reaching the possible refurbishment of this building in order to optimize the thermal performance.

The model representation in TRNSYS Simulation Studio for the thermal building simulation of the Renewable Energy Building is shown in figure 2.

RESULTS AND DISCUSSION

The results of the thermal building simulation due to two stages are presented by: the initial scenario and parameters variations.

First of all the results available from the initial scenario showed that the first floor has the highest heating load and heat demand compared to the ground floor and basement due to the larger external surface to volume ratio.

The maximum heating load of the first floor is about 55[W/ m^2] while, for instance, the ground floor only half of that value. The difference in heat demand is even larger, the first floor requires 55[kWh/m^2 year] while the heat demand for the first floor is below 20[kWh/m^2 year] (Figure 3).

The simulation showed also that for the initial scenario – without any cooling equipment — there is a considerable overheating problem in zone 1 with maximum room temperatures of roughly 40°C. Thus, the zone 1 is the most critical one in terms of overheating since it is subject to high solar gains:

(a) Directly through the South-oriented windows
(b) In-directly through solar absorption on the roof and heat conduction through the ceiling construction

The other zones of the first floor (zone 2-7) have similar overheating problems during summer though to a less extent than zone 1. The maximum room temperatures are 35°C and 30°C, respectively, for the ground floor and basement.

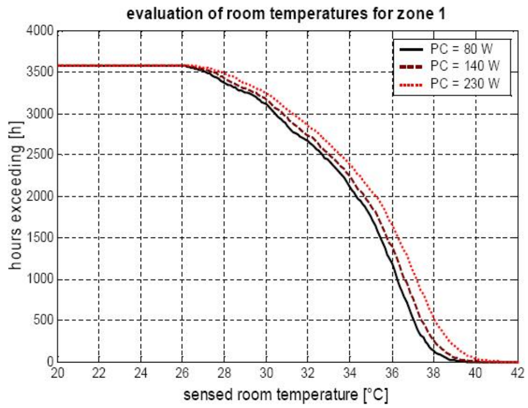

Figure 7 : Evaluation of the sensed room temperatures in zone 1 for the period between May, 15th and October, 15th

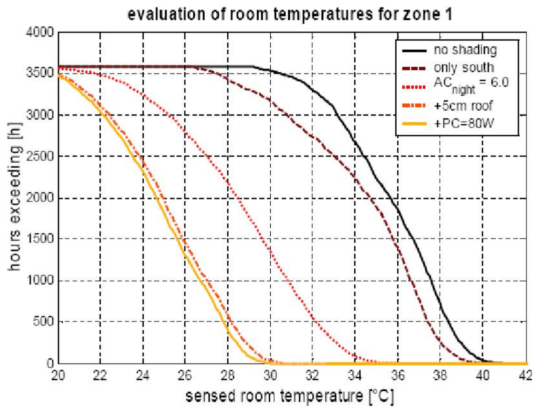

Figure 8 : Evaluation of the sensed room temperatures in zone 1 for the period between May, 15th and October, 15th

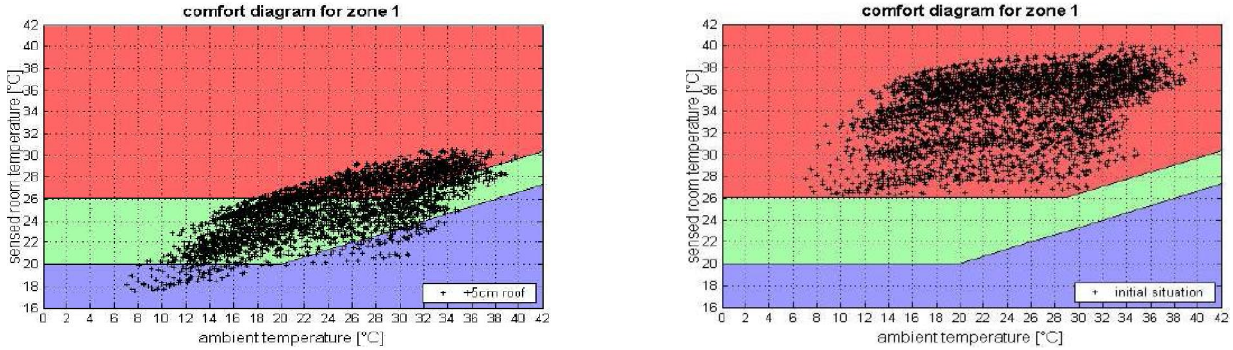

Figure 9 : Step 5 of the optimization scenarios: Sensed room temperatures in zone 1 versus ambient temperature evaluated

The second series of the results obtained from parameter variations studies the effect of the several possible measures to improve the overheating problem of the initial scenario as well as to reduce the heating demand for during the winter period.

Figure 4 indicates that the maximum room temperatures in zone 1 can be reduced by roughly 1°C by using the shading devices on the South façade. If there were also shading devices on all other facades (East, West and North) this would further decrease the maximum temperatures about 1°C.

Figure 5 displays the sensed room temperature in zone 1 in a typically hot summer week between July 6th and11th for the three scenarios defined previously. Scenario 1 with an infiltration rate of only 0.1$[h^{-1}]$ results in a maximum temperature of 41°C, while an air change of 0.5°C reduces the maximum temperatures to about 40°C. A large reduction of the maximum temperatures to about 36°C can be achieved in scenario 3 with a night ventilation rate of 6.0$[h^{-1}]$. Similar findings can also be gathered when of the sensed indoor temperature in zoon 1 is evaluated over the whole summer period. For instance, it can be observed from Figure 5 that the number of hours above 30°C is reduced from 3100[h] for the initial scenario (0.5$[h^{-1}]$) to about 1250[h] for scenario 3 with an air change rate of 6.0$[h^{-1}]$ during the nights.

Thus, night ventilation-'free cooling'-in combination with large thermal masses in the wall, ceiling and floor constructions is a very effective way to reduce the indoor temperature during summer.

The hot climate with large ambient temperature variations between day and night allows for a passive cooling concept which uses the cold air of the nights to cool down thermal masses in building helping to reduce the indoor temperatures during the day.

By analyzing the heating demand and the maximum heating load the annual heat demand will be reduced from 56$[kWh/m^2$ year] without roof Insulation to only 23$[kWh/m^2$ year] for the first floor. For the whole building the roof insulation diminishes the heat demand from 33 to 2o$[kWh/m^2$ year] in specific values, i.e. a reduction by 37%. Besides of the heating demand, also the maximum heating load can be obviously reduced by insulating the roof: for the first floor the maximum specific heating load can be diminished from 55 to about 32[W/m^2].

Figure 6 explores the influence of the roof insulation on the summer indoor temperatures in the thermal zone 1 (first floor). It shows that the number of hours above 30°C is considerably reduced by the thermal insulation of the roof.

The variation of inner gains has also a minor influence on the heating demand of the building, while the maximum heating loads are not affected by the inner gains since they are not present 24 hours a day. The reduction of the inner gains can also help to reduce the overheating problem during the summer months as can be observed in Figure 7 The maximum temperatures in zone 1 are reduced by about 1°C when changing the power consumption of the computer equipment from 230[W/PC] to 80[W/PC].

Figure 8 compares the sensed room temperatures in zone 1 over the whole summer period for the five scenarios mentioned previously. Starting from the initial case without shading on the south the maximum room temperatures are decreased by approximately 1°C by using the movable shading devices on the South facade. Using the cold air temperatures during the night to cool down the thermal masses (“free cooling”) reduces the maximum indoor temperatures by further 4°C. If in addition to “free cooling” by night ventilation the roof construction is thermally insulated with 5[cm] of polystyrene, the maximum temperatures can be diminished by additional 5-6 °C resulting in maximum indoor temperatures of only 30.5°C.

Finally, a further reduction of the overheating problem can be accomplished by using economical computer equipment leading to maximum indoor temperatures of 30°C.

By compare the comfort diagram for the optimized scenario with the corresponding diagram for the initial scenario (Figure 9) a remarkable reduction of the indoor temperatures can be noticed. The maximum temperature in zone 1 is reduced from 40°C to 30°C and for a considerable period of time the sensed temperatures are in the comfortable region of the comfort diagram. According to DIN 1946-2[3].

CONCLUSIONS

An educational building (a renewable energy building) has been simulated using the simulation software program TRNSYS in order to optimize the thermal performance of the building in terms of reduction the heat demand as well as the overheating problem for the first floor of the building. Thus, the path to the “optimized building” can found. The path consists of the following steps:

(1) No window shading devices
(2) Shading devices only on the south facade (identical to the standard case)
(3) Night ventilation with an air change rate of 6.0[h^{-1}]
(4) Roof insulation of 5[cm]
(5) Reduction of the electrical power consumption of the PCs to 80[W/PC].

REFERENCES

[1] TRNSYS; Version 16, Transient System Simulation Program, Solar Energy Laboratory, university of Wisconsin-Madison, **(2005)**.
[2] Meteonorm; Version 501, METEOTEST, Fabriksstrasse 14,CH-3012 Bem, **(2005)**.
[3] DIN 1946, Indoor Temperature Comfort Diagram, DIN 1946 (German Industry Standard), Part 2, **(1994)**.