THERMAL COMFORT PERFORMANCE OF HEALTH CENTRE FACADE

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ABSTRACT

Since buildings are consumers of energy, achieving sustainability in buildings while being in harmony with the environment are of the main concerns in the developing countries. A climatic design can exploit a maximum indoor comfort with minimum use of energy. Orientation, location of the building, type of the building envelope and materials are some important factors which affect building thermal performance. It has been proven that passive building design reduce the energy consumption of buildings.

In this study, aim is to analyse facade performance of building in terms of indoor thermal comfort. Health centre of Eastern Mediterranean University "E.M.U" has selected as a case study. This research evaluated thermal comfort by use of dynamic thermal simulations of TAS software. Double skin facade (DSF) with 100 cm roof tower on top, closed windows during winter and 100 % open windows on tower provided almost thermal comfort during summer and winter seasons.

1. INTRODUCTION

Nowadays, as a result of global warming and high use of fossil fuels, architects and designers put more attention to the environment than before. Since buildings are big consumers of energy, achieving sustainability in buildings while being in harmony with the environment are of the main concerns in the developing countries. Finding appropriate envelope systems for each building type, usage, and climatic region can dramatically reduce the overall energy input to the mechanical systems.

Facade is an important element in buildings, so energy efficient building designers have started to develop their researches based on this matter. Today, energy usage in buildings have become an important factor due to the limited energy sources, hence, building construction materials and techniques should be considered accordingly in the design period. Building envelopes should respond to the requirements of the building in different climate. In each climate facade insulation is necessary facture such as, control heat flow and air flow, control water vapour flow and rain penetration, control noise and fire, control light, solar and other radiation, be durable, aesthetically pleasing and be economical. The main function of the facade of a building is to protect and distinct the interior from the exterior environment conditions [1]. Finding appropriate envelope systems for each building type, usage, and climatic region can dramatically reduce the overall energy input to the mechanical systems. Hence, better envelope designs can improve performance along with reducing energy consumption. A building envelope separates the interior environment from the exterior one [2].

The function and form of current facades and wall constructions are the result of a long process of development, which is related to the history of human shelter. Solid walls were built by available building materials, at later times in the development stage, openings were made larger to let the light in. After the development of glass as a building material, ancient people filled their openings in the walls with single panes of glass to allow natural lighting inside the building and also allowed the people inside to view out [3].

Development of glass technology made it possible to build much larger windows and transparent panes. The next step was the invention of box window, or double glazing. After several experiments with different methods of glass material, nowadays, the pane of glass is a usual material which is used in building facades [4].

Nowadays, different types of transparent facade are erected in new structures, especially in office buildings. These facades, which are called "Double Skin Facade", as a building envelope system, consist of a pair of transparent surfaces, separated by an air corridor. The extra skin can decrease both heating demand in winter and cooling demand in summer [5]. The aim of this facade type is to increase internal comfort and decrease energy consumption.

2. AIM AND OBJECTIVES

Achieving a suitable indoor environment condition, while declining energy utilization, is one of the most difficult strategies in hot and humid climates. This study analyse the facade performance of health centre building by use of dynamic thermal simulations of TAS software in terms of indoor thermal comfort.

Thermal comfort in health care buildings is a significant factor which architects have to consider carefully. The current study tries to achieve these main objectives:

To understand the problem of thermal comfort in hot humid climate.

To understand how environmental conditions may affect the therapy to speed up.

To evaluate the thermal comfort of health space through thermal standards [6].

To find out the advantages and disadvantages of double skin facades.

3. METHODOLOGY

In the theoretical part, data has been entirely collected from books, articles, scientific journals and previous researches regarding the specific topic [5-12]. After data collection process, evaluation of the data took place to find out the building's problems in hot humid climate conditions and naturally ventilated health care building. To calculate the existing health centre building temperature and compare it to the thermal performance of building modelling, TAS software was used [7].

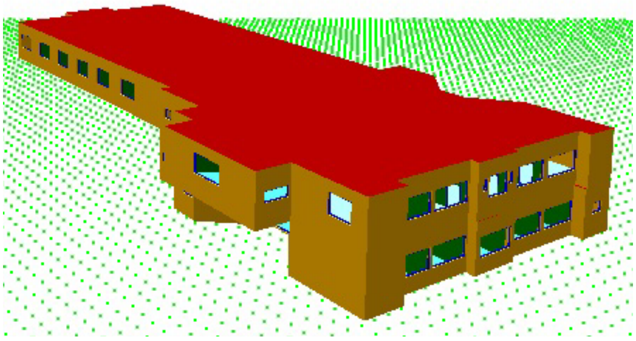


Fig. 1. Existing Building (Health Centre of EMU)

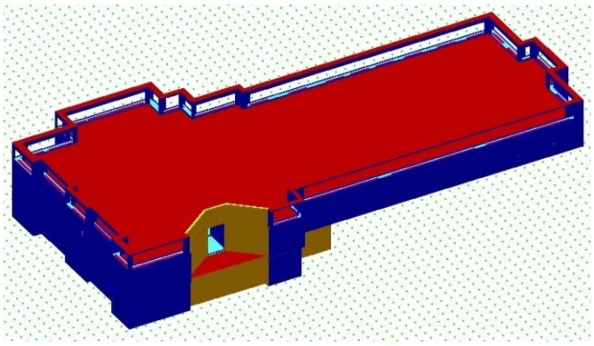


Fig. 2. Modelled Building by Double Skin Facade and Roof Tower

Thermal performance evaluation divided to two seasons, summer and winter time, the selected months were 21st of June as summer season, 21st of December as winter time, three times during the day, at 7:00 am as early morning, 12:00 as noon time and 19:00 pm as afternoon time, 0 means all the openings are closed; 0.1 means apertures were open around 10 % and 100 % means they were open completely whole the day (Fig. 1). Table one shows the first simulation which is the existing building by natural ventilation condition with 100 % opening, the second simulation considers multi-storey double skin facade with a 50 cm cavity composing of double clear glass with 50 % opening for aperture and the third simulation multi-storey double skin facade considered by chimney with 1 m. height which installed on the top. In this simulation all opening examined 10 % and roof tower with 100 % opening (Fig. 2).

Table 1. Simulations of the Health Centre Building

Simulation 1	Existing Building	All Door and Windows Open 10 %
Simulation 2	Existing Building with DCF	All Door and Windows Open 50 %
Simulation 3	Existing Building with DCF and Chimney with Consideration of Cross Ventilation	All Door and Windows Open 10 %, Chimney 100 %

4. LITERATURE REVIEW

Thermal comfort refers to the reaction which humans show toward heat and coldness in a place. The following factors affect the thermal comfort: four physical variables (air velocity, air temperature, mean radiant temperature, and relative humidity), and three personal variables (clothing insulation, activity level and body metabolic rate). Indeed the climate in each country with different climate zones varies in relative humidity, air temperature, global temperature and air velocity; therefore, comfort zone can have different values.

Thermal indoor environment and ventilation are important issues in a health centre in order to achieve human thermal comfort, health or improved productivity. The need for a special design and indoor thermal environment is the concerns of both engineers and inhabitants [8]. A suitable thermal comfort, in general, can be achieved by the temperature being between 24 °C and 26 °C.

Building envelopes should respond to the requirements of the building in different function. According to [9], the first example of a double skin curtain wall seems to be used in 1903 in Germany. At the end of the 1920s, this kind of facade was improved with other priorities. Knaack *et al.* [10] conducted a building envelopes should respond to the requirements of the building in different climate.

Alibaba *et al.* [11] compared double skin facade with single skin facade which has some advantages such as protecting shading devices, improving the acoustic insulation, and providing natural ventilation. Particularly this can be a good solution for buildings which are affected by great number of external factors such as daylight, different outdoor temperatures during summer and winter, noise pollution and etc. According to Alibaba *et al.* [5], the double-skin facade is a system of building involving of two skins, placed in such a way that air flows in the intermediate void. The cavity ventilation can be natural, fan supported or mechanical.

The outer glazing is usually a hardened single glazing, and insulating double glazed unit is used for the interior one; solar-control glazing and clear low-E coating can also be used. The extra skin can decrease both heating demand in winter and cooling demand in summer. The width of corridor is between 20 cm to 2 meters; it can change according to the function of the applied concept, and is naturally or mechanically ventilated, or fan supported. During the heating period (in winter), solar radiation will be absorbed, the temperature `inside of the cavity will start to increase, and the preheated air will provide good indoor climate inside the building. According to Poirazis [12], double skin facade further decreases heat losses within the cavity. On the other hand, during summer time, overheating problem appears when the facade is poorly ventilated (Fig. 3).

Due to the stack effect, around 25 % of the heat can be ejected by natural air circulation and the heat can be drawn off through the exterior skin by mechanical or natural ventilation systems.

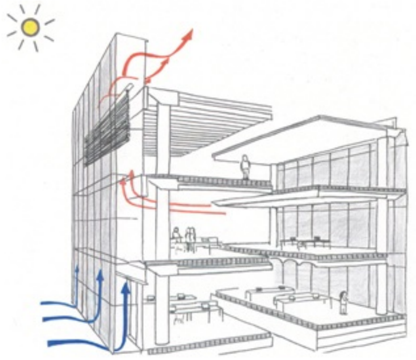


Fig. 3. Double Skin Facade and Chimney [12].

Hughes *et al.* [13], invented which, the integration of double skin facade (DSF) and wind tower improves air flow, and achieve more ventilation inside the cavity during the hot season, therefore generate acceptable thermal comfort within the buildings In this kind of system, the cavity in double skin facade is ventilated naturally, reduces the requirement for mechanical ventilation and provides environmental friendly atmosphere. Haase *et al*. [14] argues for improving the function of building envelope during the summer, it is suggested to integrate the chimney with the double skin facade, to increase air circulation between cavity and indoor climate. In this system, for natural ventilation, the air is brought into the channel and exhausted by two reasons: the stack effect and wind pressure. Wind pressure generally dominates the airflow rate (Fig. 4). If designed correctly, wind blowing over the facade can produce pressure differences between the inlet and outlet inducing air motion. Air will move into the inlet and out the outlet while ejecting the heat.

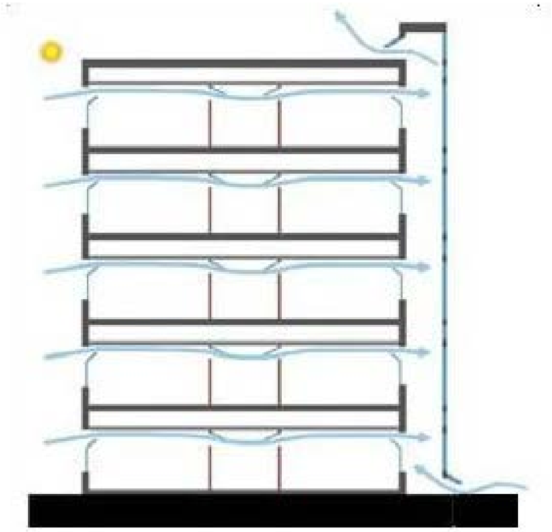


Fig. 4. Stack Effect and Wind Pressure [15].

Serra *et al*. [16], suggested during the cooling periods, open the cavity and chimney window's for extracting the heat from the channel, and close it during the winter for increasing of indoor temperature. Cavity can still ventilate without wind, due to the stack effect but during the summer, the solar heat gain within the facade cavity will increase the cavity temperature, which produces a burst of hot air in summer.

5. TAS FINDINGS

Cyprus has hot and humid climate. Hot summers, moderately cold winters and very high summer dryness with minimal yearly rainfall. Health centre building is located at Eastern Mediterranean University (EMU) Campus to serve the university staff and students. The building has two stories which the ground floor is using as official and doctor offices located in the first floor (Figs. 5, 6).

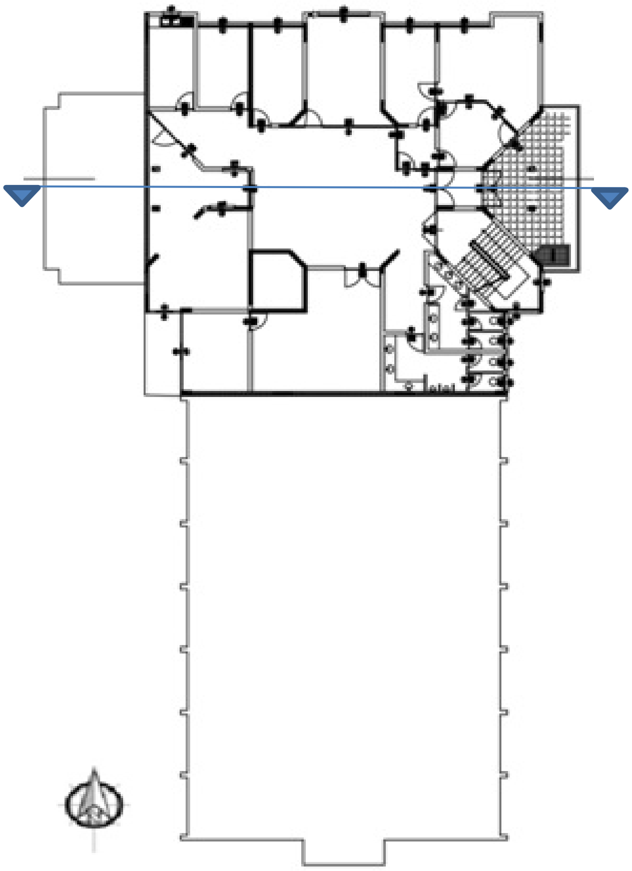


Fig. 5. Ground Floor of
Health centre Building (SC 1/500)

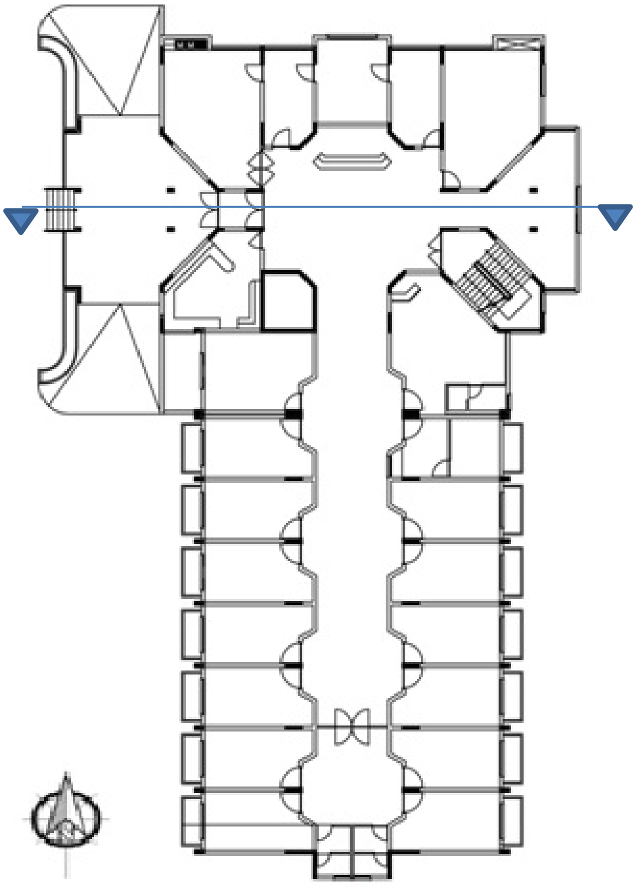


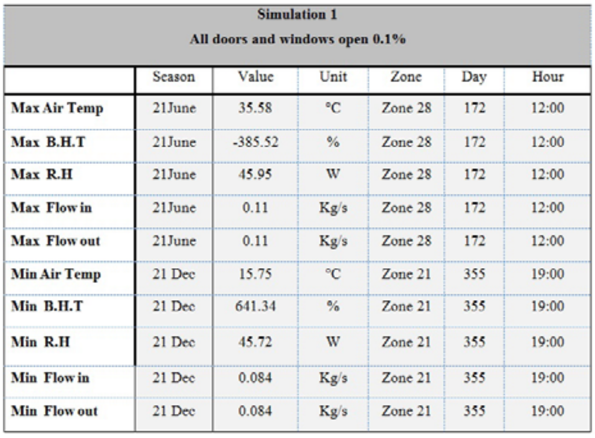
Fig. 6. First Floor of
Health Centre Building (SC 1/500)

Fig. 7. Health Centre west Elevation
(Taken by author)

It's rectangular shape and is 1370.97 m^2, composed of 42 zones. It is not surrounded by any other buildings (Figs. 7, 8).

Fig. 8. Health Centre North Elevation
(Taken by author)

Table 2: Summary Performance of H.C, Existing Building [7].



Simulation 1
All doors and windows open 0.1%

	Season	Value	Unit	Zone	Day	Hour
Max Air Temp	21June	35.58	°C	Zone 28	172	12:00
Max B.H.T	21June	-385.52	%	Zone 28	172	12:00
Max R.H	21June	45.95	W	Zone 28	172	12:00
Max Flow in	21June	0.11	Kg/s	Zone 28	172	12:00
Max Flow out	21June	0.11	Kg/s	Zone 28	172	12:00
Min Air Temp	21 Dec	15.75	°C	Zone 21	355	19:00
Min B.H.T	21 Dec	641.34	%	Zone 21	355	19:00
Min R.H	21 Dec	45.72	W	Zone 21	355	19:00
Min Flow in	21 Dec	0.084	Kg/s	Zone 21	355	19:00
Min Flow out	21 Dec	0.084	Kg/s	Zone 21	355	19:00

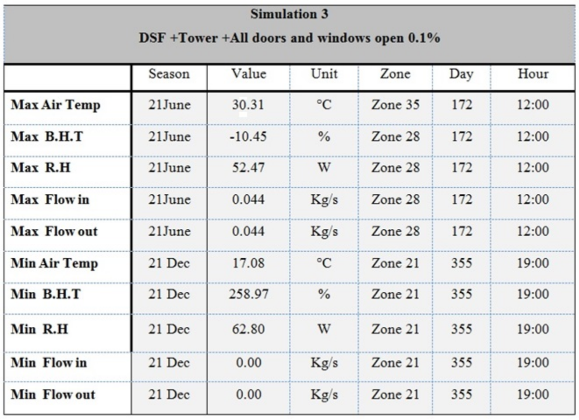
Cyprus, as the third largest island in the Mediterranean Sea, is located at the north-eastern side of the sea, and the city, Gazimagusa, is located on its eastern coast. During summer the temperature range is between 37 °C and 40 °C and in winter, it range from 9 °C to 12 °C, in each day.

The first simulation modelled the current building so to contribute to a better facade design for the health centre building concerning a hot humid climate. According to table two, with an overall look at the simulations it can be understood that west side of the building on June 21st, 12:00 pm, has the maximum internal temperature of 35.58 °C and 46 % relative humidity, higher than the other seasons, and the minimum temperature of 15.75 °C by 45 % relative humidity belongs to east side. According to the literature, thermal comfort standard in air-conditioned buildings is 26 °C with a 60 % relative humidity [7].

The second simulation was grounded on the first simulation. The second simulation considers multi-storey double skin facade with a 50 cm cavity composing of double clear glass. All openings were 50 % opened, no difference in comparison to the first one and this strategy could not solve the internal thermal problem.

In third simulation, multi-storey double skin facade was constructed by double clear glass and roof tower with a 100 cm height was installed on the top. In the lower section of the facade, a hole was placed to further improve the circulation of the air when there is need to more cooling; this element can be employed to suck the fresh air inside the building. In the present simulation, all openings such as doors and windows were 10 % open, with a 100 % open tower. Table three, on 21st June, at 12:00 pm, has the maximum internal temperature of 30.31 °C, and the minimum temperature of 17.08 °C.

Table 3: Summary Performance of Building+ DSF+ Chimney [7].



Simulation 3 DSF +Tower +All doors and windows open 0.1%						
	Season	Value	Unit	Zone	Day	Hour
Max Air Temp	21June	30.31	°C	Zone 35	172	12:00
Max B.H.T	21June	-10.45	%	Zone 28	172	12:00
Max R.H	21June	52.47	W	Zone 28	172	12:00
Max Flow in	21June	0.044	Kg/s	Zone 28	172	12:00
Max Flow out	21June	0.044	Kg/s	Zone 28	172	12:00
Min Air Temp	21 Dec	17.08	°C	Zone 21	355	19:00
Min B.H.T	21 Dec	258.97	%	Zone 21	355	19:00
Min R.H	21 Dec	62.80	W	Zone 21	355	19:00
Min Flow in	21 Dec	0.00	Kg/s	Zone 21	355	19:00
Min Flow out	21 Dec	0.00	Kg/s	Zone 21	355	19:00

6. FINDING AND DISCUSSION

Sections show that, in simulation one, (Figs. 9, 10) the current situation of the Health Centre Building with 10 % opening had been demonstrated. Because of the building direction, heat and sun radiation in winter time are lost and extra heat from east and west side in summer is gained. In summer time, inside temperature of the existing simulation was even more than outside, and in winter time it was the same as the external temperature. One of the influential issues in hot period which effected internal temperature of the Health Centre Building was that the north side had the lowest amount of opening. In summer time, inner temperature arrives around 35 °C and in winter time, it is 19 °C.

21st of June, at 12 o'clock internal roof temperature is around 35 °C and floor temperature is 32 °C. Windows internal temperature, arrive to 38 °C which in summer gained sun heat and loud it to inside the building. In 21st of December at 12 o'clock internal roof surface temperature is around 20 °C and floor temperature is 19 °C. The windows temperature in east of the building are around 13 °C and in west are 16 °C, which because of wrong building orientation, sun radiation in winter are lost.

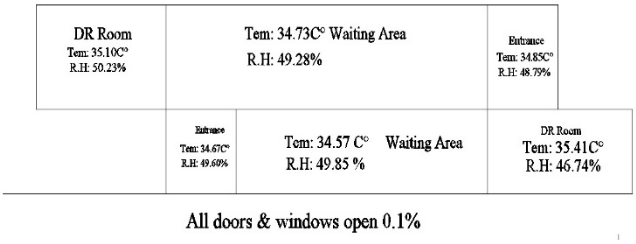


Fig. 9. Section of First Building Simulation
(21st Dec, at 12:00 pm.)

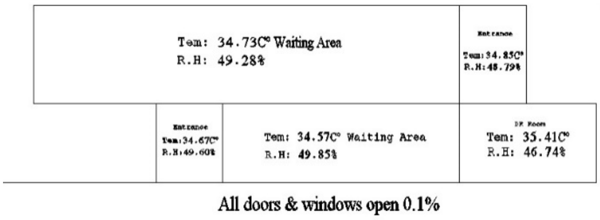


Fig. 10. Section of First Building simulation
(21st June, at 12:00 pm.)

In terms of reducing the heating need in winter and cooling need in summer, in simulation 3, the facade was covered by DSF plus the help of chimney which ejected the heated air by natural air circulation, drowning it off through the exterior skin in summer period. In this regards, DSF helps the building to increase the internal temperature. In winter time, by closing the chimney opening, solar radiation gets absorbed and the inner temperature of the cavity starts to increase so to provide a good indoor climate inside the building. In third simulation, 10 % apertures openings and 100 % opening for the chimney was considered in order to monitor the new effects on internal performance, because the building needed more ventilation to decrease internal temperature based on the former simulations during summer time. In building section (Figs. 11, 12) the results showed that on December 21st, at 12:00 am, inside temperature was around 21 °C with a 63 % relative humidity. At this time west side of the building was located in the comfort zone, being about 23 °C and 60 % relative humidity, and east side was two degrees lower than the west side. In June time at 12:00 am, inside temperature showed around 30 °C and 55 % humidity.

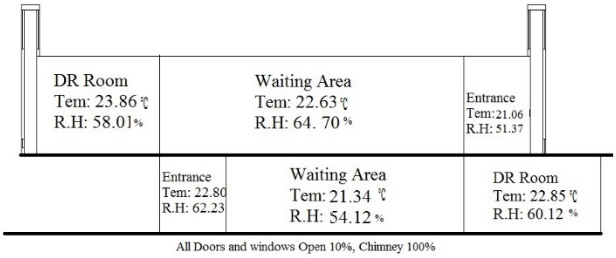


Fig. 11. Section of Third Building Simulation (21th Dec, at 12:00 pm.)

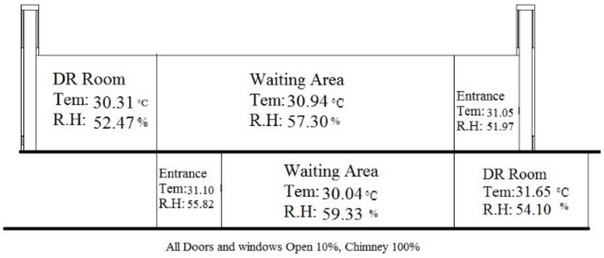


Fig. 12. Section of Third Building Simulation (21th June, at 12:00 pm.)

On 21st of June, at 12 o'clock internal roof temperature is 32 °C and floor temperature is around 30 °C. By adding double skin facade around the building, windows internal temperature, arrive to 33 °C and by help of air flow throw the cavity facade temperature arrive to 32 °C. In 21st of December at 12 o'clock internal roof surface temperature is around 21 °C and floor temperature is 22 °C.

Considering the first simulation, which displayed the existing situation of the Health-Centre Building, it was revealed that the building has the worst thermal performance. However, thermal condition in simulation two was near the first one, and DSF without the air flow and ventilation could not work well in this climate. The third simulation had an acceptable thermal condition. In summer time, the indoor temperature of the first simulation was even more than outside, and in winter time, it was near the outside temperature, especially in west side. Among the examined simulations, simulation two had no positive effect on indoor thermal performance, with 50 % aperture openings and a double skin facade. In simulation three, the effect of chimney combined with the double skin facade, with a 100 % open chimney window and 100 % aperture openings is demonstrated. The results did not work out 100 %, achieving the exact thermal comfort, but the strategy has some positive effects and reduces the temperature around 5 °C in summer time and is located close to the thermal condition in cold time.

Therefore, from the 1st and 2nd simulation, it was understood that June and December, as a hot and cold seasons, had crucial conditions. The building simulation in March and September, however, had an acceptable situation, located near the comfort zone. Temperature inside the cavity (between the Double Skin Facade and the existing wall) in summer season had increased, so the wind tower considered with DSF could obtain thermal comfort in all building zones. Consequently, it was realized that in the third simulation, by using these strategies, the maximum internal temperature decreased to 30 °C with a relative humidity of 50 % in summer and was about 22 °C with a relative humidity of 58 % in cold seasons. Therefore, in simulation three, building condition obtained was able to generate thermal comfort condition and the annexes used can be useful for future design plans.

According to the TAS simulations results, room temperature in the existing building were more than 33 °C on 21st of June and September which were considered as hot seasons. During the cold seasons on 21st of March and December, room temperature was around 15 °C.

7. CONCLUSION

This study aimed to improve the indoor thermal performance of the Health Centre Building, increasing internal thermal comfort quality of the building environment and decreasing energy usage while cooling and heating the building. In this regards, three dynamic thermal modelling of Health Centre Building via TAS software were examined to find out the thermal comfort zone based on the double skin facade strategies, without using mechanical systems. Moreover, the influence of double skin facade and chimney around the existing building, solar radiation, internal air circulation, relative humidity, external temperature and apertures opening percentage in thermal performance of the Health Centre Building was examined.

Summer time is a problematic period for reaching the thermal comfort in this kind of climate: on 21st of June, at the noon time, temperature arrived around 35-36 degrees and there was a high rate of humidity which was far from comfort zone. According to simulation three, considering DSF and chimney for the Health Centre Building, in the morning and afternoon time, temperature was around 24-26 °C with 55 % humidity and in noon time, compared to simulation one and two, inside temperature was reduced 4-5 degrees, reducing from 35 °C to around 30 °C and 58 % humidity. Although 30 °C is not in comfort zone, but the natural ventilation load through the building makes occupants to use less hours of mechanical air conditioner.

In December which is considered as cold season the average range of internal temperature was around 23 °C with 63 % humidity which in first simulation was around 19 °C with 55 % humidity; that means 4 degrees higher than the existing situation. In this study, finally, the thermal comfort inside the building reached near the comfort zone, through increasing the temperature in December as the cold season, and decreasing it in June.

Consequently, it was understood that in the first simulation, thermal situation in March and September had a moderate and acceptable condition, and in June and December it had a critical condition. In the third simulation, by raising the ventilation quality, an acceptable internal surface temperature was provided, and also heating need in winter and cooling need in summer was reduced. By using these strategies, lower amount of electricity would be needed to heat or cool the building, hence reducing the environmental impacts. Because of critical summer heat situation in Cyprus and the high cost of electricity, natural airflow would be a solution to answer these problems. By use of passive design techniques, such as sunlight, water and wind in buildings, maximum levels of thermal comfort can be reached, reducing the buildings' energy consumption levels.

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