Thermal comfort conditions in the building of the School of Architecture, D.U.TH.

P. Kosmopoulos[1*], C. Gouzeli[1], G. Karkanias[1], E. Titoni[1]
[1]Lab of Environmental and Energy Design of Buildings and Settlements, Democritus University of Thrace, Department of Environmental Engineering, 67100, Xanthi, Greece.
*Corresponding author: E-mail: pkosmos@env.duth.gr, Tel +30 25410 79382, Fax: +30 25410 79382

Abstract
This paper examines the thermal comfort conditions of the building of the Architecture School of the Democritus University of Thrace in Xanthi Greece with the evaluation of the environmental conditions and the users' attitudes, with both measurements and questionnaires. The subject of this study is of special interest: it is a building that was originally designed to house the New Central Library of the University, but instead, it was offered to the Architecture department, after some improvised modifications. This is the reason for the main problems of the building, associated with the thermal comfort in the interior. It is a necessity to take some measures such as replacing the existing opening frames by systems with improved technical specifications, providing shading blinds on the South facet for protection from overheating in sunny summer days, repairing the defects of the roof, placing insulation at the North part of the building, and installing thermostats for proper operation of the active systems.
Keywords: Thermal comfort; building of architecture; energy; environmental conditions

1. INTRODUCTION

The term thermal comfort refers to those conditions under which a subject does not feel the need to find a warmer or colder environment. Apart from the technical consideration of a building and the passive or active systems that have been incorporated to achieve the desired thermal comfort, an important factor is also the human behavior. Also, very important in thermal comfort is the subjective factor. For example, if we suppose that the ideal temperature of a living space set at 22^{o} C, does not mean that everyone feels comfortable at that temperature.

2. CASE STUDY

The School of Architecture (figure 1) is located in the campus of DUTH, in an open rural undergrowth area, about 5 km east of the city of Xanthi. The building was originally designed to house the New Central Library of DUTH (1998), but after some improvement modifications to the original floor plan, it was offered to the Architecture department, a function with entirely different heating and cooling needs. The lack of substantial redesign is the reason for the main problems of the building associated with the thermal comfort in the interior. The building consists of two floors and a basement with auxiliary spaces. A key element of the architectural design is the atrium located in the center of the building, which also includes the staircase.

2.1 Construction features

The windows of the building are aluminum, sliding and single glazing without thermal insulation properties. The shading is obtained by internal blinds, which have suffered extensive damage. This system results in a minimum protection of the building against the cold winter weather, while in summer months the building is exposed to overheating and glare, which has a negative impact on the lighting conditions.

Figure 1. The northern façade of the building.

The design of the roof creates rooms with high ceilings and lightwells for further illumination. Some technical failures and the lack of proper drainage of the rainwater, have resulted in water accumulating on the roof after rain, which creates moisture problems inside the building. Furthermore, there are similar problems associated to the atrium in the center of the building. Due to construction defects that allow the water to penetrate in the building during the rainy days, there is damage from humidity. Also on days with high temperatures, the atrium acts as a "green house", accumulating the hot air, as there is no provision of blinds or other mechanism that would allow the warm currents move offsite. Finally, the natural lighting of the interior, is not well accomplished so that even during the sunniest days, additional artificial lighting is required at the functional area around the atrium.

2.2 Energy conditions

The heating of the building consists of a central oil burner and an HVAC system that is integrated above the ceiling. The north-facing areas have a remarkable difference in air temperature, as these areas were destined to be warehouses of books. The heating system is operating on a daily basis, from 08.00 to 13.00 and from 16.00 till 19.00. It is observed within the building that during the operating hours of heating, there are prevailing conditions of extreme heat, causing inconvenience to the users. In contrast, the rest of the time the thermal conditions are rather poor, and equally inconvenient to the users. As a result, when the building is not being heated the use of additional heaters that consume electricity, such as air heaters, has been observed.

3. METHODOLOGY

In order to assess the thermal comfort of the building on site measurements of air temperature, relative humidity and wind speed on specified locations outside and inside of the building have been performed. Overall measurements were taken during two months: from 12.19.2012 to 07.01.2013. During those days there were two or three measurements at different times of the day, so as to give an overview of the thermal comfort of the building in different hours. During the first two days of measuring the heating was out of order due to technical problems. Alongside the measurements, detailed comments were noted. The third part of the methodology involved the use of questionnaires, which included the subjective factor. The results of the above three methods of analysis were correlated in order to suggest measures for improving the thermal comfort conditions.

4. RESULTS AND DISCUSSION

4.1 External Conditions

The variations of air temperature, relative humidity and wind speed were recorded on specific spots around the exterior of the building. The average air temperature gradually increased during the month of January, almost evenly. Respectively, from 9 to 14 January moisture levels progressively increased, although at different rates. Moreover, the wind speed decreased inversely until it is reduced to zero on 14 January. This enables us to correlate the wind speed with the levels of relative humidity as well, as the higher the wind speed is, the quicker the air moisture evaporates and the atmosphere goes drier. This has been observed the days from 14-16 January when we observed that increasing the wind speed, the upward trend of the curve of the moisture stops and tends to stabilize.

4.2 Internal Conditions

Inside the building the environment is protected from the wind and the measurements taken focus mainly on the air temperature and relative humidity. The relation between them is inversely proportional (figure 2), with deviations of lower temperatures at the entrance of the building and the non-heated north section and higher temperatures at the classrooms with high internal temperature.

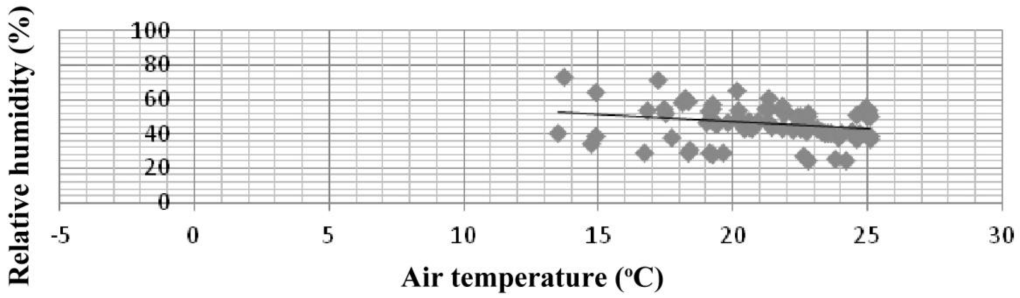

Figure 2. Correlation of temperature and humidity for each internal measuring point.

On January 8 the lowest day air temperatures have been recorded, given that the heating system was out of order. Since January 9, higher temperatures have been recorded in the southern classrooms due to the restored heating system. Also, it has been observed that due to the high temperatures, the users tend to leave the windows and doors wide open and wear light clothing. This could be described as indication of inconsiderate consumption of energy, as part of it evades the building because the users consider it as redundant. Lower temperatures, respectively, are recorded in the under-heated northern wings and on the ground floor, especially near the building entrance.

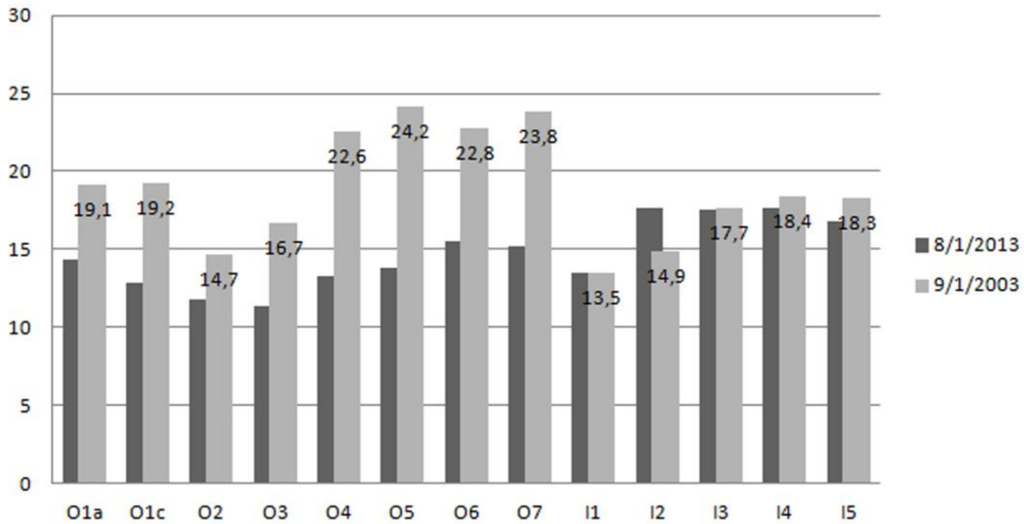

Figure 3. Temperature measurements for 8/1/2013 & 9/1/2013.

Finally, each inner air temperature has been charted according to the mean external air temperature respectively (figure 4). Next to the columns that are being formed out of the distribution of the measured locations per day, the three spaces of maximum and minimum internal air temperatures are stated. It can be also concluded that among the warmest spaces of the building are the southern classrooms (O7, O6, O5, O4) and part of the atrium next to them (O1b). The lowest temperatures are spotted in the ground floor, near the building entrance (I1) and in the northern wings of the 1st floor (O2, O3).

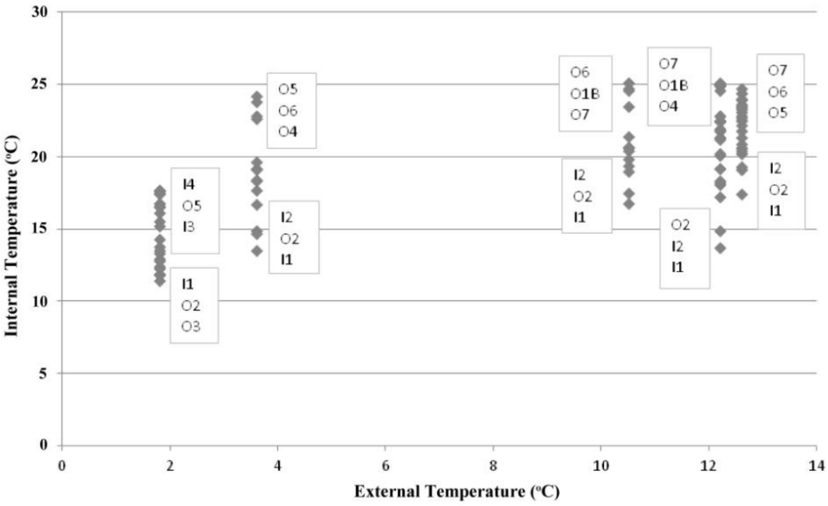

Figure 4. Average internal and external air temperatures; distribution of measurement positions.

4.3 Subjective factor

The subjective factor has been approached with the use of questionnaires (30 questionnaires were examined). The basic questionnaire has been the standard one of the Laboratory, designed to acquire data regarding subjective factors towards thermal conditions. .

In the diagram of thermal comfort- internal air temperature (figure 5a), the answers given to the questionnaires have been sorted according to the thermal comfort of the subjects in relevance to the in situ internal air temperature. The distribution of the spots on the vertical axis represent the subjects that perceive the temperature as satisfactory, while on the negative (left) part of the axis, the subjects perceived the conditions as cold. In general, the answers given by the population are homogenous and proportionate to the measurements of air temperature in the corresponding space. Following, the values of internal temperatures have been replaced by the mean external air temperatures (figure 5b).The purpose of this diagram is to emphasize those spaces of the building where the external temperature exceed 16 ^{o} C, whereas the subjects have answered that the feeling of the temperature was rather warm. Those spots are located in the positive part of the axis of thermal comfort and refer to the atrium and in general to all the classrooms of the 1st floor.

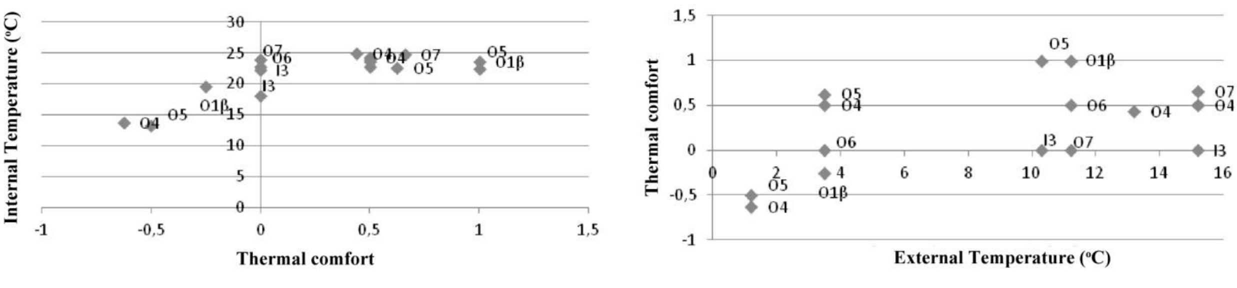

Figure 5.a. Thermal comfort & internal temperature. b. Thermal comfort & external temperature.

Finally, it is observed that on January 8, when the heating system didn't work, the sense of the subjects about the temperature ranges from cold to neutral, while everyone desires its increase. There is absence of subjects that desire no thermal change (figure 6). On the contrary, on January 9 while the heating system had been restored, the building users have a neutral sense with a tendency to warm. The dominant desire, however, continues to be lower temperatures (figure 6).

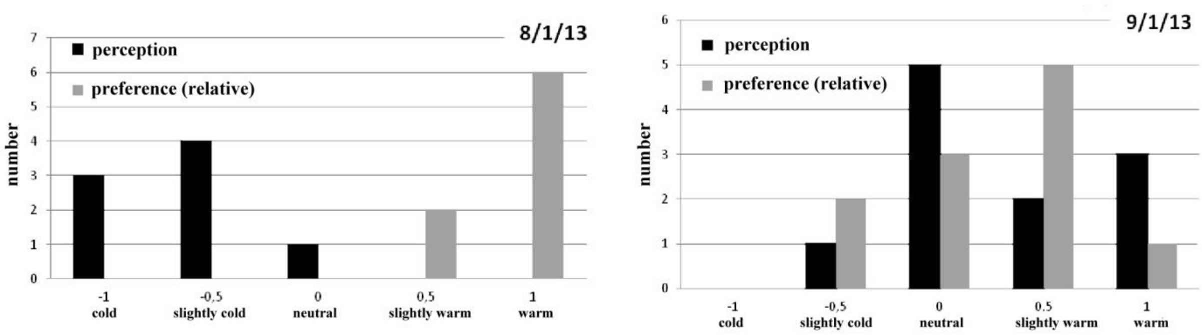

Figure 6. Perception-preference of temperature 8/01/2013-9/01/2013

5. SUGGESTIONS

5.1 Window frames

The replacement of the current window frames by new ones of higher standards (lower thermal conductivity and double glazing) is necessary. The installation of solar protection is of great importance too. Moving or fixed blinds should be adapted to the exterior of the frames. Through the proper use of frames and blinds, the solar thermal gains during winter months are increased, by functioning as passive systems and providing positive energy equilibrium and reducing the heating needs. Respectively, during summer, the proper solar protection reduces the cooling loads.

5.2 Ceiling/Roof

Another technical issue that requires immediate solution is the repair of the roof and the provision of a proper gutter system that will fend off the water after a rainfall. By resolving this technical issue, it is expected that the high humidity problems in the building will vanish, as the humidity and the leaks deteriorate the thermal comfort conditions and cause decay on the building elements.

5.3 Atrium

In order to minimize the humidity problems, further amendments have to be made in the atrium. The addition of cupolas and hatches that would open during summer, thus driving the warm air away from the building, could greatly improve the thermal comfort conditions around the atrium. A maximum benefit could be accomplished by installing a solar chimney in the atrium that would function during the summer months. This could generate an intense air flow from the lowest to the highest air layers. As a passive cooling system it could reduce the cooling load and as a passive ventilation system it would provide an improved air recycling at the internal of the building.

5.4 Northern Wings

The northern wings on the 1st floor face noticeable problems. Due to their orientation and lack of thermal insulation, the wings do not get sufficiently heated. It is remarkable that during the measurements that took place, even in different hours of the day, the offices and the rooms remained vacant. In this case, these spaces could host secondary functions that do not require constant heating, such as the library. Also, this part of the building should be externally insulated and as in the rest of the building, the window frames should be replaced.

5.5 Heating and insulation

The matter of heating refers mainly to the human factor and is related to the misuse of the heating system. The proper use of a temperature regulating system, according to the needs of the users, is of utmost importance. This could be achieved by placing autonomous temperature regulators in each classroom, so that the users select themselves the desired temperature levels. It is also important to upgrade the heating system in the northern wings, so that they become functional and viable. An additional way of heating that could assist or replace the central boiler, could be the installation of alternative and renewable sources of energy. It is suggested that the vacant areas around the building should be used for the installation of a geothermal heating pump system. Such a system could also be used for the cooling needs of the building during summer, thus reducing the total amount of the consumed energy. Also, the application of thermal insulation would benefit the building, as the temperature would remain in the desired levels, even during the non-combustion hours, reducing the oil consumption and by keeping relatively low temperatures during summer.

5.6 Planting

In front of the northern façade of the building, it is suggested that evergreen trees should get planted, so that the cold northern winds can be diverted and their impact to the building gets reduced. In front of the southern façade, it is suggested that deciduous trees get planted, which during the winter allow the solar penetration in the building, whereas during summer they avert it.

6. CONCLUSIONS

The building of the architecture school of DUTH faces some serious problems concerning its internal thermal comfort conditions due to its initial design, the misuse of the building and its energy systems, lack of insulation, poor maintenance etc. Both the measurements and the questionnaires indicate that the building suffers from under-heating and over-heating depending on the operating hours of energy systems. The research indicates the necessity to apply measures of energy upgrading such as the replacement of window frames, the insulation enhancing, the installation of energy systems' controllers, and the repairing of atrium and roof damages.

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