Summer thermal comfort in traditional buildings of the 19th century in Florina, north-western Greece

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ABSTRACT

The main goal of this paper is to explore the summer thermal comfort conditions in traditional buildings of the 19th century in the town of Florina, which is situated in north-western Greece. This exploration is based on the analysis of the construction methods and the building materials, as well as on analysis using the Ecotect software.

1. INTRODUCTION

A basic feature of the traditional buildings in north-western Greece is the inter-seasonal use of the spaces. In most cases, the ground floor contains the winter rooms while the upper storey is used as the summer living space. This fact is reflected intensely in the construction of the house. The ground floor is built as a heavy structure with thick stone walls (in some cases with thick adobe walls) and small openings. At the same time, light timber-framed walls filled with adobe, construct the upper storey, giving the freedom for large windows and cross ventilation in summer rooms and in the common spaces.

2. CLIMATIC ANALYSIS

2.1 Location

The town of Florina lies in a mountain valley, which is crossed by a river from West to East. The longitude of the city is 21°23'59'', the latitude is 40°46'58'', and the altitude is 662 m.

2.2 Temperature and relative humidity

The prefecture of Florina has a cold continental climate, with long, cold, humid winters and short, warm, and dry summers. The mean maximum temperature in June reaches 26.2 degrees C, the average temperature is 21 degrees C, while the mean minimum temperature is 12.5 degrees C. The mean maximum temperature in July (hottest month of the year) reaches 28.8 degrees C, the average temperature is 23.1 degrees C, while the mean minimum temperature is 14.4 degrees C. The mean maximum temperature in August reaches 28.7 degrees C, the average temperature is 22.5 degrees C, while the mean minimum temperature is 14.2 degrees C. The corresponding relative humidity values are 59.8 % for January, 57.4 % for July, and 58,3 % for August as shown in Table 1. Florina has relatively high precipitation values during the summer period, with a monthly average value of approximately 34 mm, and about 6.4 days of rain per summer month.

2.3 Climate classification

The climate classification for Florina was defined using the software Meteonorm v4.0 (Remund et al., 1999) to generate hourly climatic data, which were then imported to the software Weather Tool v1.10 (Marsh, 2003). The psy-

Table 1: Monthly climatic data values for Florina (Hellenic Meteorological Service, 2004).

	Jun	Jul	Aug
Mean Min Temp (C)	12.5	14.4	14.2
Average Temp (C)	21	23.1	22.5
Mean Max Temp (C)	26.2	28.8	28.7
Rel. Humidity (%)	59.8	57.4	58.3
Aver. Rainfall	37.3	34	31
Days of Rain	7.4	6.1	5.8
Wind Direction	W	N	N
Wind Speed	4.8	4.6	4.3

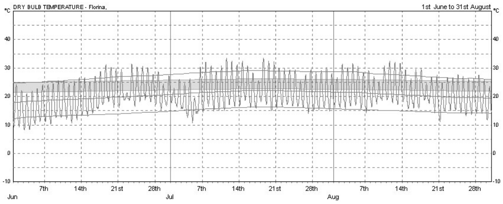

Figure 1: Dry-bulb temperatures for the summer period. (Weather Tool v1.10).

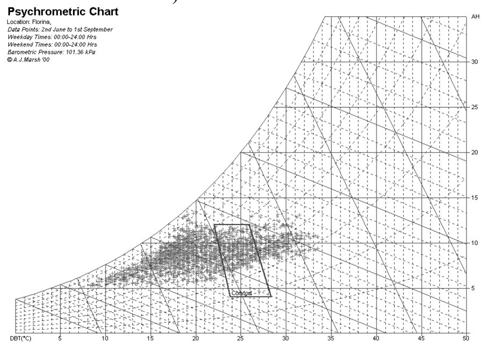

Figure 2: Psychrometric chart for the summer period. (Weather Tool v1.10).

chrometric chart generated with the Weather Tool, for the summer period for Florina demonstrates that for June, July and August, the climate is moderate to warm-dry (Fig. 2).

3. BUILDING CONSTRUCTION ANALYSIS

3.1 Construction elements and building materials

The structural elements of the ground floor are usually walls made of local stone or adobe bricks. These walls are 60 to 65 cm thick, and have an average height of 240 cm. Every 80 cm horizontal wooden beams are inserted.

Beams with dimensions 8 x 13 cm are placed every 50 cm upon the ground floor walls and always breadthwise. These beams support the floor of the upper level. The ceiling of the ground floor is also suspended on these beams.

The structural elements of the upper floor are usually lightweight walls called *tsatmas*. These walls are 20 to 25 cm thick, and are formed by a wooden frame structure, which is filled up with adobe bricks, or, in some cases, small stones and mud. The wooden frame structure comprises of horizontal, vertical and diagonal beams, with dimensions 8 x 8 cm or 10 x 10 cm.

Finally, the roof is constructed in the following way: beams with dimensions 8 x 13 cm are placed every 50 cm upon the upper floor exterior walls. Above the partition walls, wooden trusses are constructed with vertical (*orthostates* or *babades*) and diagonal (*ameivontes* or *tsimpidia*) beams of 10 x 10 cm. These trusses support horizontal elements 13 x 8 (*tegides*) placed every 120 cm. Afterwards, diagonal elements 8 x 8 cm (*epitegides* or *panotsimpida*) are placed every 50 cm. These elements support the final layer of the roof, which comprises of wooden boards, and clay tiles anchored with mud.

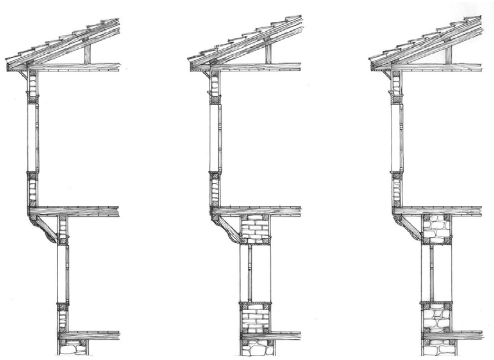

Figure 3: Typical wall configurations.

3.2 Thermal behaviour of construction elements

There are three main wall configurations found in traditional buildings of Florina: a thick stone wall, a thick adobe wall, and a lightweight wall (*tsatmas*). The thermal behaviour of these elements can be described by their properties (Table 2). The U-value data was derived from Ecotect software (Marsh, 2003), whereas the time lag values were calculated according to the Thermal Time Constant (TTC) formula cited by Givoni in (Givoni, 1998).

It can be seen that the first two wall configurations are characterised by an increased thermal lag, whereas the third wall configuration has a relatively low time lag. The high thermal inertia wall types were mainly used in the ground floor, which was occupied during the cold period,

Table 2: Properties of typical wall construction of Florina. (Marsh, 2003 and Givoni, 1998).

	Thickness (cm)	U- value (W/m^2K)	Time lag (h)
Stone	60	2.35	61
Adobe	60	1.02	109
Tsatmas	20	2.24	14

whereas the lightweight wall type was used in the upper floor, which was occupied during the warm period.

4. THERMAL ANALYSIS

4.1 Thermal analysis

The thermal analysis calculations were performed with the software Ecotect v5.2 (Marsh, 2003). The model of a representative building type with southern orientation was constructed (Fig. 4).

The thermal modelling was based on a series of assumptions. The different rooms of each level were used either throughout the day, or for specific hours during the morning. These diurnal differences in the use of the house were represented with different schedules. The summer comfort band was set at 18 to 26 degrees C. The winter spaces (ground floor) were assumed with no ventilation apart from the air infiltration, while the summer spaces (upper floor) had natural ventilation. The infiltration rate for all the zones of the building was set at 1 air change per hour. All the thermal analysis calculations, which are presented, concern only the zones of the upper storey of the building.

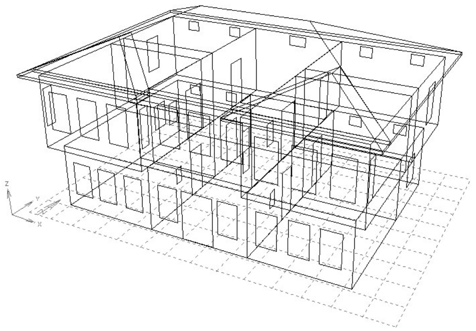

Figure 4: Model of representative building type (Ecotect v5.2).

Figure 5: Typical traditional house of Florina.

4.2 Hourly temperature profiles

Ecotect was used to calculate the hourly temperature profiles in the summer living spaces throughout the summer months. For the hottest day (July 12th), the exterior temperature ranges from 15 degrees C (early in the morning) to 33.5 degrees C (around noon). The summer living spaces of the house are warmer in the morning and in the night (25 degrees C), but significantly fresher than the outside around noon (29 degrees C) (Fig. 6). On the brightest sunny day (July 20th), the outside air temperature ranges from 17 degrees C to 32.5 degrees C, whereas the interior air temperatures of the main living spaces range from 26 to 29.5 degrees C.

When the calculations include natural ventilation, as a passive cooling strategy, the inside temperature on the hottest day (July 12th) ranges from 23.5 to 27.5 degrees C. (Fig. 7) On the brightest sunny day (July 20th), the interior air temperatures of the main living spaces range from 24 to 27.5 degrees C.

From the comparison of the two figures

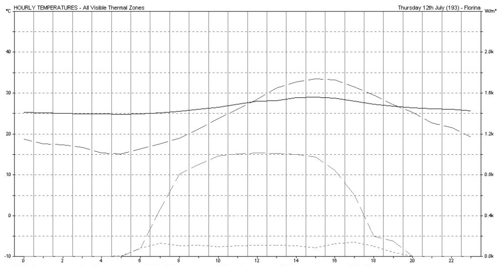

Figure 6: Calculation of the interior air temperature in one of the main summer living spaces for July 12th (Ecotect v5.2).

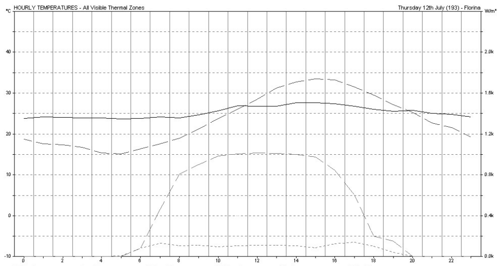

Figure 7: Calculation of the interior air temperature in one of the main summer living spaces with natural ventilation for July 12th (Ecotect v5.2).

(Figs. 6 and 7), it can be seen that natural ventilation lowers the absolute maximum and minimum interior temperatures by 1.5 to 2 degrees C. In both cases (ventilated and non-ventilated conditions) the diurnal temperature variation is the same (4 degrees C for the hottest day and 3.5 degrees C for the brightest sunny day).

The effect of the light-structure, combined with the natural ventilation results in lower night-time temperatures (1 to 2 degrees C) in the rooms of the upper floor compared to those in the ground floor (Fig. 8). This may constitute an explanation as to why people moved from the ground floor to the upper storey during the warm period.

4.3 Fabric gains

The fabric gains of the different zones of the house mainly depend on the construction materials of its external walls. The time lag of the walls is such (14 hours) that during the summer the maximum fabric gains occur in different hours according to the orientation of the room. For a south-eastern room, the maximum fabric gains occur late in the night (22:00 to 02:00), as shown in Figure 9, while for a south-western one, they occur early in the morning (04:00 to 08:00). Considering the mean diurnal exterior temperature fluctuation (17 degrees C), this fact is very desirable in order to have comfortable interior temperatures throughout the night.

The roof zone is characterised by very high fabric gains in the noon and afternoon hours of the summer (Fig. 10). During the night, the roof zone cools down, but its losses are not considerable.

4.4 Direct solar gains

The direct solar gains of the house are mainly based on its orientation and on the surface and orientation of the windows. The thermal model, which is analysed, has a southern main facade. As a result, the house has direct solar gains only around noon, during the winter, because of the southern windows (Fig. 11). During the summer, the roof eaves efficiently shade the southern openings of the summer living spaces. In this way, the direct solar gains are minimised, when they are not desirable. The windows on the eastern and western facades are few, and do not contribute to the direct solar gains of the spaces.

4.5 Ventilation

In one set of the Ecotect calculations, natural ventilation was used as a means of passive cool-

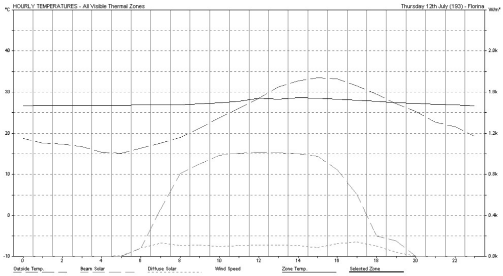

Figure 8: Calculation of the interior air temperature in one of the main winter living spaces for July 12th (Ecotect v5.2).

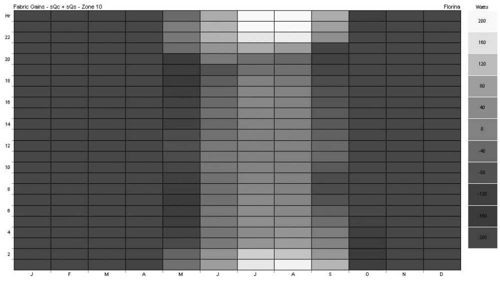

Figure 9: Fabric gains of a south-east orientated main living space (Ecotect v5.2).

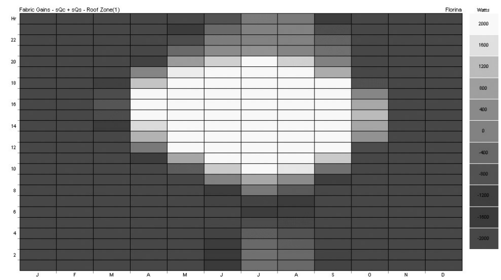

Figure 10: Fabric gains of the roof zone (Ecotect v5.2).

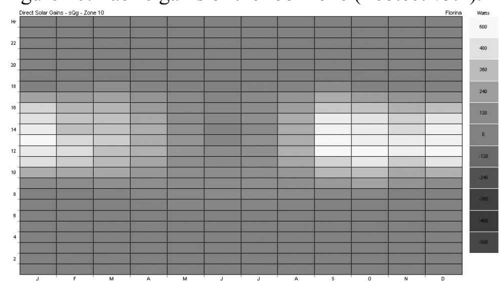

Figure 11: Direct solar gains of a south-east orientated main living space (Ecotect v5.2).

ing throughout the day. The thermal analysis showed that ventilation in the night and early in the morning could remove heated air from the upper floor rooms (Fig. 12). Consequently, interior air temperatures are lowered. On the contrary, the ventilation during the afternoon has a negative contribution to the interior temperatures, as the outside air is hotter than the inside. For this reason, people avoided opening the windows during these hours.

4.6 Inter-zonal gains

The inter-zonal gains of the upper floor are governed by the thermal behaviour of the roof. During the afternoon, the overheated roof zone thermally stresses the summer rooms, which are underneath it. Nevertheless, it is known that the efficient cross-ventilation of these spaces moderates this negative contribution. On the contrary, during the night-time, the quick cooling down of the roof zone draws up heat from the rooms. In this way, the natural cooling of the upper storey is further enhanced.

4.7 Summer thermal comfort

During the summer period, the household was moved to the upper storey, where the design of the rooms and the existence of many openings allowed the use of ventilation. This, combined with the fact that the walls have low thermal inertia, promoted the natural cooling of the spaces. Summer clothing was light and made of cotton, hemp and linen, and all the intense activities were transferred to the open air.

The summer thermal comfort was calculated using a lower limit of 18 degrees C and an upper limit of 26 degrees C. Based on that assumption, it was calculated that internal conditions exceed thermal comfort for 5 to 15 percent of the time for all three summer months, when the rooms were naturally ventilated. Thermal comfort was also calculated for the main winter living spaces (Fig. 15). It can be seen that during the summer months, thermal comfort conditions on the ground floor were considerably worse than on the upper storey. Internal conditions in the main winter living spaces exceed thermal comfort for about 35 to 65 percent of the time.

5. CONCLUSIONS

The thermal analysis of a representative building type with southern orientation, which was presented in this paper, constitutes a preliminary approach to the assessment of the thermal behaviour of 19th century traditional buildings of Florina with the use of computer software. This

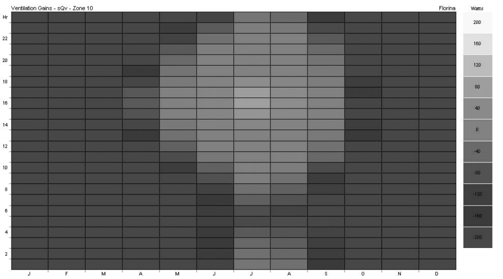

Figure 12: Ventilation gains of a main living space (Ecotect v5.2).

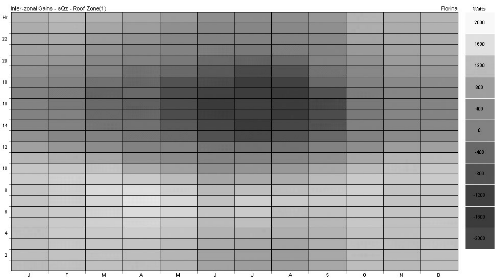

Figure 13: Inter-zonal gains and losses for the roof zone (Ecotect v5.2).

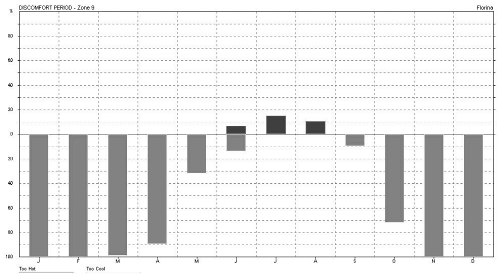

Figure 14: Thermal comfort in main summer living spaces (Ecotect v5.2).

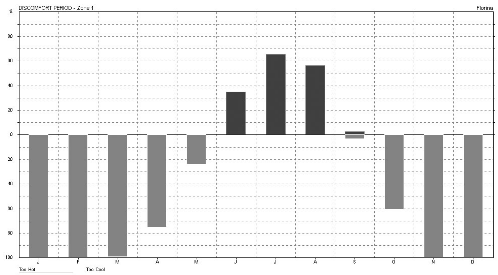

Figure 15: Thermal comfort in main winter living spaces (Ecotect v5.2).

approach demonstrates that traditional design and construction methods were influenced by the local climatic conditions. Therefore, the traditional architecture of northern Greece can be regarded as sustainable and energy efficient.

The design of the summer living spaces along with the creation of many windows and openings help achieve efficient natural ventilation. At the same time, eastern and western windows are very few, while the roof eaves shade the many southern windows. The time lag of the upper storey walls is such that the maximum fabric gains occur during the night or early in the morning, when the outside temperatures are relatively low.

In addition to all the above, it should be noted that the behaviour of the people, who lived in traditional houses at the second half of the 19th century, was highly adaptive. People lived in the more compact ground floor during the cold period of the year, and moved to the lightweight, upper storey during the summer months. Their clothing and activities also varied according to the seasons.

Finally, this paper revealed the need for a more detailed thermal analysis of the traditional houses in Florina. It is imperative that the study should be extended to include more building types. Furthermore, it is strongly believed that in order to obtain a more representative and complete idea concerning the thermal behaviour of traditional architecture of Florina, in-situ measurements of dry-bulb temperature and relative humidity should be conducted in remaining houses.

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