Secondary residences: a problem of sustainability

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ABSTRACT: Construction sector in Spain keeps a growing process as a result of the investment in real states. Most new residential developments are placed in areas near to Mediterranean coasts, due to the tendency of buying a secondary residence for vacation purposes. Construction companies are seeking to erect buildings rapidly and not to improve their quality and thermal behaviour, since construction sector is a big business now in Spain. The seasonal over-population in these zones is causing strong problems of resources supplying, mainly water and energy supply. In this study we show the environmental conditions inside a traditional house placed in an inner area of Spain, as a sustainable alternative for secondary residences. The results show that the constructive techniques – thick bearing walls – joined to the use of vegetation make the indoor conditions comfortable with no need of mechanical cooling systems.
Considering the environmental problem associated to the "sun and beach" tourism, the use of traditional buildings, that are spread in abundance over inner Spain, during summer, can be valued as a sustainable practice.

Keywords: thermal mass, tourism, traditional architecture, reuse

1. INTRODUCTION

Construction sector in Spain is experiencing a gradual increase, as a result of the investment in real states. At the moment, 10.8% of the total number of dwellings in EU-25 is concentrated in Spain [1]. The amount of buildings finished yearly has increased from 197.000 in 1986 to more than 500.000 in 2001. This rapid growth involves some consequences with negative effects on the sustainable development, such as: 1) increase of the urban land surface, 2) increase of energy needs, 3) increase of empty dwellings and 4) increase of raw materials consumption and waste materials generation [2]. Most new residential developments are placed in areas near to Mediterranean coasts, due to the tendency of buying a secondary residence for vacation purposes (see figure 1).

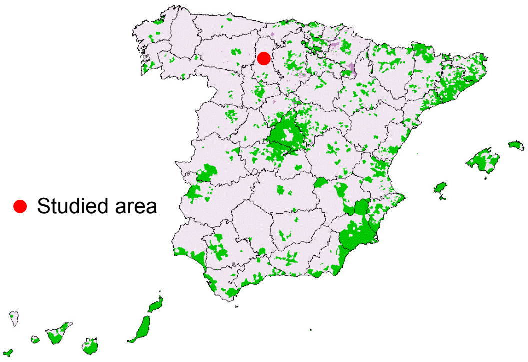

Figure 1: Map of Spain. In dark are the zones where the population density has increased more than 10% from 1991 to 2002. The point marks the studied area. Source: INE [3].

Moreover, because of the mild climate in winter and the relative low cost of dwellings, lot of people from other European countries, such as England and Germany, buy houses in the Spanish coasts when they are retired.

The seasonal over-population in these zones is causing strong problems of resources supplying, mainly water and energy supply. The drinkable water supply was restricted in some localities during summer 2005 due to the drought. This will be a common practice if the expectations about climate change are fulfilled. Furthermore, to increase the financial value of these new buildings, lot of golf courses are constructed around residential areas. In addition, the coastal areas suffered electricity cuts due to the peaks of energy consumption, since most secondary residences use powerful air conditioning systems to mitigate the high temperatures in summer.

In this study we show the environmental conditions inside a traditional house placed in an inner area of Spain, as a sustainable alternative for secondary residences with leisure purposes.

Not far ago, lot of people spent their holidays in their native villages of inner Spain. However, the increase of purchasing power has become our tourism sector into an unsustainable practice. The "sun and beach" tourism is responsible of the construction of a great amount of dwellings near the Mediterranean coast. Construction companies are seeking to erect buildings rapidly and not to improve their design, quality and thermal behaviour, since construction sector is a big business now in Spain. The current Spanish standard of thermal behaviour in buildings was approved in 1979, so the required U-values are less restricted than in other European countries. This fact, joined to the higher living requirements, caused the increase of the residential energy use during the last decades in Spain as well as in other Southern European countries [1]. In spite of the hot summers, the standard aims at reducing only heating needs and not cooling requirements.

During the 70´s, the changes in agricultural practices joined to the rural exodus from the country to the city, induced the abandonment of several rural buildings. In last years, some groups for rural development are promoting the reuse and restoration of these buildings with the aim of maintaining the legacy of vernacular architecture as well as a mechanism to improve the socio-economical sector in rural areas.

In Spain, 14% of the global amount of dwellings is vacant. However, the construction sector is still in growth.

The constructive techniques used more than 100 years ago in the inner Spain provide the buildings with thick bearing walls, built with local materials as stone and earth, therefore. So the thermal inertia of ancient buildings is usually high. High thermal mass envelope buildings reduce indoor air temperature and cooling load peaks, storing heat in the material and transferring the load to a later time [4,5].

According to information from INE (National Institute of Statistics, [3]), 16% of housing buildings in Spain were erected before 1950. Most of them, mainly those placed in rural areas, will have high thermal mass envelopes. Inside them, the temperature keeps almost stable and due to their capacity of storing heat, mechanical cooling systems are not necessary in summer. Next, the results from the thermal monitoring carried out in a rural building during summer 2005 are presented, in order to analyze the advantages of its use as a summer secondary residence.

2. LOCATION AND CONSTRUCTIVE DETAILS

The studied house is placed in the locality of Ribas de Campos, 277 km far from Madrid. It has 228 inhabitants and is placed at 760 m above sea level. The locality is crossed by the “Canal de Castilla”, a beautiful hydraulic work built between XVIII and XIX centuries, whose aim was to connect the inner Iberian Peninsula with the North coast to improve the freight transport. It was never ended, but today it constitutes an artificial river of high aesthetic value.

The locality belongs to the district of “Tierra de Campos”. It has a Mediterranean climate, but strongly continental due to the distance to the sea, with hot and dry summers and cold winters.

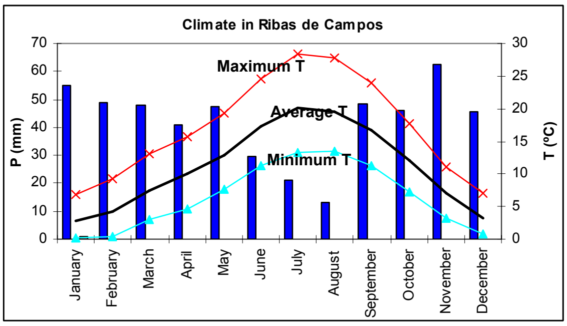

Figure 2: Monthly precipitations and temperatures in Ribas de Campos [6].

The district is a typical cereal producer region. The lack of materials such as stone and wood is the cause of the common use of earth as a construction material.

The environmental conditions inside a traditional house made of mud walls were monitored (figures 3 and 4). The owners do not know with accuracy the date of construction, although it is believed that the house was a bakery from a convent in XVI or XVII century. The original roof was made of tiles over a mud layer with a wooden structure, but due to the lack of maintenance it was replaced by a metallic one. In the restoration works, a wall of brick was built by the inner side to support the wooden beams.

Furthermore, the hygrothermal conditions inside a modern dwelling attached to the traditional one were registered (figure 5). The results from both buildings will be used to compare their thermal behaviour and to analyze the advantages of the high thermal mass envelope as a natural cooling system.

The traditional housing is a two storey building. Sensors were placed in each storey. The thickness of the exterior walls in ground floor is from 80 to 120 cm, while in the first floor is lower than 75 cm. The ground area is 315 m2 with an average height of 7.2 m.

The modern building was built of layers of common bricks with a coat of plaster.

Figure 3: Façade of the traditional house.

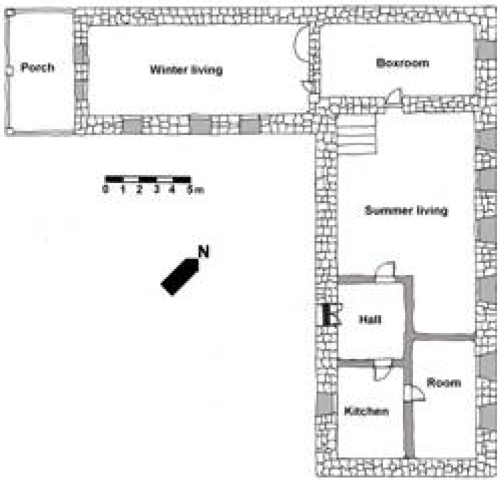

Figure 4: Plan of the traditional house.

Figure 5: Modern house.

In figure 4 it can be seen that the use of the rooms is in accordance to the season. Summer living has the openings oriented to the North and winter living to the South.

As well as the different envelopes, we think that the microclimate around each building can be different. Although both houses are placed in the same state, the traditional house is shaded by deciduous tress, so it takes advantages from the shade in summer. On the other hand, the modern house due to its situation cannot be shaded by vegetation (see figure 6). Two sensors were placed, one in the shaded zone and the other in the sunny one for the measurement of the microclimatic differences.

Figure 6: Aerial photo pointing out the location of both buildings.

3. MATERIALS AND METHODS

This study was carried out during summer, by means of registering the indoor and outdoor environmental conditions. Temperature and relative humidity sensors with loggers were used. The accuracy of the instrumentation is 0.2ºC and 3% of relative humidity. In addition, a thermographic survey was carried out with the aim of analyzing thermal differences and inspecting points of interest. The survey was made with an infrared camera ThermaCAM SC 2000 from FLIR SYSTEMS with 320x240 focal-plane array of non-cooled microbolometric detectors working in the wave length of 7,5 – 13 µm and accuracy of ± 2º C. This technique has shown good results for the building diagnosis, mostly in a qualitative way [7,8]

4. RESULTS

4.1. Microclimatic differences.

The microclimatic differences were registered by two instruments placed outdoors near each building (see figure 7).

Outdoor temperature and relative humidity was measured from 28th July to 27th August 2005. The results corroborate that near the modern house the temperature is higher than near the traditional one (see table 1).

Figure 7: Left: Instrumentation placed near the modern house. Right: Instrumentation placed near the traditional house.

Table 1: Outdoor temperatures in two points (degree C).

Temperature	Outdoor modern	Outdoor traditional
Maximum	33.3	31.3
Minimum	6.0	6.0
Average	18.8	18.3
Standard deviation	6.1	5.9

However, the temperature differences are low taking into account the accuracy of the instrumentation, and they can influence poorly the indoor temperatures.

Following figures show some results from the thermographic survey (figures 8 to 10).

Figure 8: Thermographic view of the traditional house.

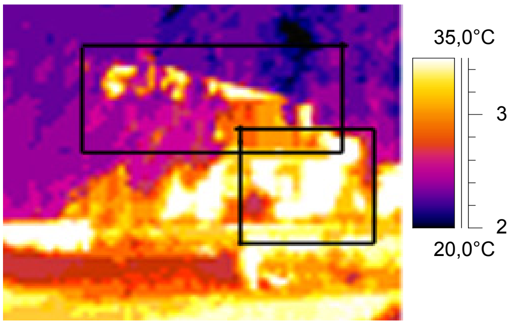

Figure 9: Thermographic view of both buildings. The upper box shows the traditional house and the lower box shows the modern one. The façade of the traditional house is cooler than in the other building.

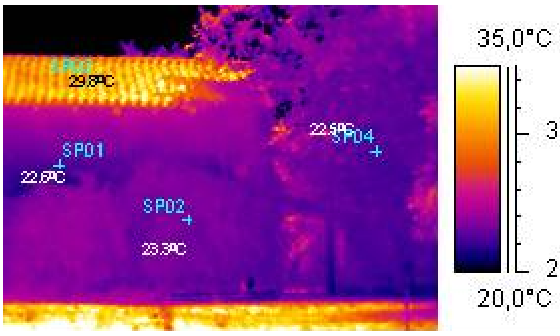

Figure 10: Thermographic view from traditional house. The trees act as a cooling system for the façade.

This technique shows higher temperature differences than those registered by the outdoor air temperature sensors. The thermographic views are surface temperature maps of inspected objects. Therefore, the advantage of having deciduous trees is the shading effect they provide and not the lower air temperatures. As everyone knows, surface temperatures exposed to solar radiation depends both on the outdoor temperature and on incident solar radiation. In this case, the presence of vegetation reduces the surface temperature of the traditional house by filtering the direct solar radiation.

4.2. Indoor thermal behaviour.

The temperature was registered inside both buildings in the same period (see figure 11).

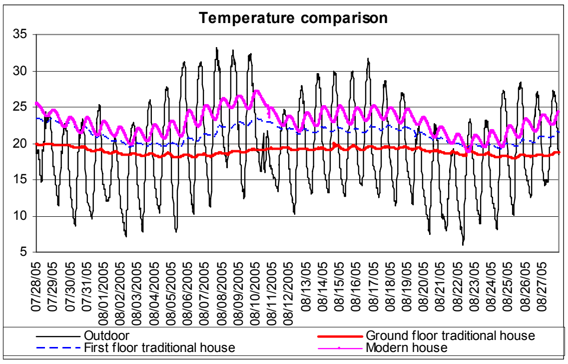

Figure 11: Registered temperatures in a summer month.

The maximum temperature registered in the ground floor of the traditional house was 20.1ºC, the minimum was 18.0ºC and the average was 18.9ºC. In the first floor, the temperature was higher. The maximum temperature was 23.4ºC, the minimum was 19.2ºC and the average was 21.2ºC. On the other hand, inside the modern building, the temperature is higher as well as its variations. The maximum temperature was 27.2ºC, the minimum was 18.8ºC and the average was 22.9ºC. Indoor temperatures follow the pattern of outdoor temperature but with a delay and a damping effect. The maximum temperatures of both buildings were under the outdoor´s maxima except during some days in the modern building.

As can be seen, the traditional house enjoys a great thermal stability, due to the high thermal mass of the thick walls. The thermal mass decreases in first floor, because of the thickness reduction and the roof replace.

Attending to the daily thermal variations, the average daily variation outside is 15.6ºC, in the ground floor of the traditional house is 0.4ºC, in the first floor is 0.8ºC and inside the modern house is 2.3ºC. Again, the effect of the thermal mass is seen in the results. The daily variations of outdoor temperature are diminished inside the traditional house (see figure 12).

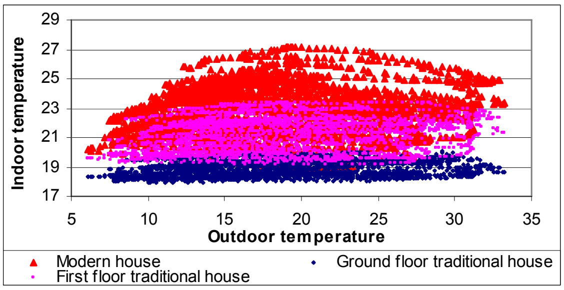

Figure 12: Indoor temperature variations according to outdoor temperature variations.

As suggested by Givoni [9] indoor maximum temperature can be estimated by some outdoor and indoor parameters:

$$T_{\max} = GT_{avg} + DelT + k(T_{avg} - GT_{avg})$$

where T_{max} is the indoor maxima temperature in a particular day, GT_{avg} is the average outdoor temperature of the whole period (in this study 18.77ºC), DelT is the average elevation of the indoor maxima above outdoors average (0.37ºC for the ground floor in the traditional house, 2.89ºC for the first floor in the traditional house and 5.36ºC for the modern house), k is a ratio depending on the mass level, and T_{avg} is the outdoor temperature average in a particular day.

The daily indoor maximum temperature was calculated by this method and then compared with the monitored data. Best results were achieved with k values of 0.15 for the ground floor of traditional house, 0.35 for the first floor of traditional house and 0.55 for the modern building. Hence, the thermal mass effect is confirmed. However, the previous formula does not take into account the delay of the thermal wave (see figure 13).

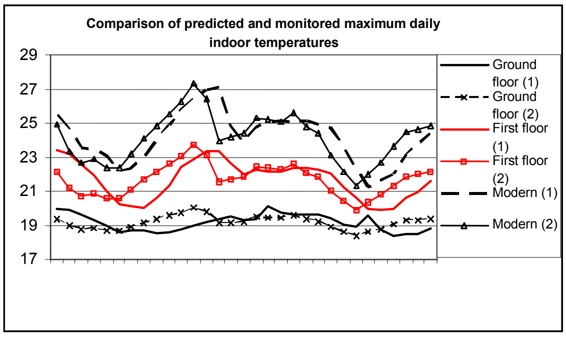

Figure 13: Comparison of predicted and monitored maxima daily indoor temperatures.

As can be seen, the predicted indoor maxima daily temperatures are in agreement with the monitored temperatures, except for the ground floor in the traditional house. The very thick walls in the ground floor, joined to the low incident solar radiation, involve a very stable thermal behaviour that can not be estimated by the formula stated by Givoni.

The damping and delay of the outdoor thermal wave depends on the physical properties of construction materials and the thickness of the exterior envelope.

The damping and delay of the thermal wave can be calculated following the next expressions:

$$f_a = 1 - e^{(-0.5265\sqrt{\frac{\Pi \rho c_e}{\lambda t}})d}$$

$$d_f = 0.5265\frac{t}{2}\sqrt{\frac{\rho c_e}{\Pi \lambda t}}d$$

where ρ is the material density (kg/m3), λ is the thermal conductivity (W/mºC), ce is the specific heat (kJ/kgºC), t is the time in hours (for climatic applications is equal to en 24 hours) and d is the thickness in m.

Values of damping and delay of thermal wave in relation to the thickness were calculated taking into account the thermal characteristics of a typical soil.

In figure 14 it can be seen that for a thickness similar to those of the traditional house the delay in the thermal wave is more than 20 hours and the damping effect is close to 100%.

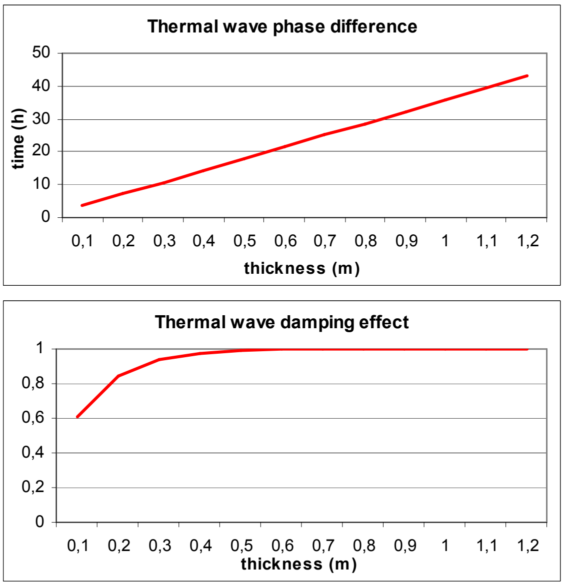

Figure 14: Damping and delay of the thermal wave depending on the thickness for walls made of earth. Used values for soil thermal properties are: λ=0.71W/mºC, ρ=1772 kg/m3 y ce= 962 J/kgºC, see Meukan, 2004 [10].

In addition, the attenuation, calculated according to Fernández et al [11], is 42.38 for the ground floor in the traditional house, 19.39 for the first floor in the traditional house and 6.73 for the modern house. These figures indicate the effect of the thermal mass on the variations of indoor temperatures.

Regarding the relative humidity, it is kept inside comfort ranges, being higher inside the traditional house.

Thermal comfort depends on various parameters such as geographical, personal and mainly environmental factors, therefore, its assessment is a difficult task. However, along history of bioclimatic design, some index has been used to measure in a certain degree the hygrothermal comfort inside buildings. There are direct index, such as indoor temperature, relative humidity and air velocity; derived index, such as the equivalent temperature, and experimental comfort index such as the predicted mean vote. First ones are easier for evaluation, but they do not take into account personal preferences. Here, the indoor air temperature is used for the analysis of thermal comfort. With this aim, the thermal comfort range is established from 21 to 25ºC in summer. According to this comfort zone, the results show that inside the traditional house the indoor temperature never exceeds the upper comfort limit, and even in the ground floor the temperature do not reach the lower limit. However, in the modern house the temperature is higher than the upper limit 10% of time.

As can be observed, the thick walls joined to the shade provided by the vegetation, makes cool the indoor temperature in traditional house.

5. CONCLUSIONS

This paper shows the results from the monitoring in a traditional dwelling made of local materials in an inner district of Spain. We can conclude that their thick exterior walls provide the envelope with a high thermal capacity for heat storage, therefore, the outdoor temperature is dampened and delayed.

Considering the environmental problem associated to the “sun and beach” tourism, the use of traditional buildings, that are spread in abundance over inner Spain, during summer, can be valued as a sustainable practice. In the studied case, the indoor conditions are below the comfort temperature for summer with no use of mechanical cooling systems. The high thermal capacity and the good use of vegetation and orientation are the passive design strategies used here.

As it has been indicated in the text, in Spain there are quite abandoned buildings, even more in rural areas. Most of them were built before 1950 with bearing walls design, therefore, they are thick and with a high thermal capacity that makes stable the indoor environment.

The restoration of these vacant buildings can liven up the social context in rural areas suffering from depopulation. In addition, it can improve our knowledge about the cultural heritage of traditional architecture.

ACKNOWLEDGEMENT

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