Bioclimatic Strategies for Seaside Resorts on Greek Islands

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The focus of this paper is on passive cooling strategies raising the question of the need for and dependence on mechanical air conditioning in seaside resorts on Greek islands. Through deliberate research in literature, field work and analytic work in form of thermal simulations, it is shown that thermal comfort can be achieved by means of nocturnal convective cooling and roof ponds. Additionally the cooling loads are reduced by 87% in the case of night time cooling.
Keywords: passive cooling, energy, comfort

INTRODUCTION

Tourist resorts are among the most energy intensive building types in Greece. Over the next 20 years the number of tourists travelling to Mediterranean resorts is expected to rise by 50% [1]. Coupled with climate change, the seasonal operation concentrated in the summer months from May until October and the adoption of mechanical cooling as a mandatory feature suggests that energy consumption may increase further. The function of tourist resorts is complex and occupants can be extremely demanding especially at the luxury end of the sector.

This paper will summarise the research and the findings of a dissertation project conducted during a master course in Sustainable Environmental Design. The hypothesis was to test the necessity of mechanical air conditioning in seaside resorts on Greek Islands. Initially, facts and figures about hotels are helping to get familiar with the sector. Following this, climate and thermal comfort studies will guide to the potentially effective passive cooling strategies through deliberate research in literature. The hypothesis is then tested in field work and finally proved through analytic work in form of thermal simulations. Eventually, appropriate passive cooling techniques are indicated for this type of buildings and this climate.

HOTELS: CHARACTERISTICS – ENERGY CONSUMPTION

Hotels are classified according to their characteristics. Size, capacity, category and location are determinant factors regarding their energy consumption. Equipment, services and facilities cost energy. Also, hotels situated in rural rather remote areas away from cities have to deal with high seasonal energy loads, low supply and at the same time high energy costs. On the other hand most of these hotels have a shorter operating period than the ones in cities. A typical example would be a resort on an island, which would operate only during the summer and maybe also in May and October. This type of hotels situated in particular on Greek islands was the focus of this research project.

Another significant issue affecting the performance of hotels is their construction type. Most of the hotels in the Mediterranean are old constructions built from 1970 until 1980 and compared to today's standards they are low quality buildings with low performance equipment and energy consuming installations [1]. To make matters worse, thermal insulation, which can reduce heat losses in winter and heat gains in summer, was appointed compulsory in Greece after 1979, when the relevant law was implemented. Consequently, all hotels constructed before that law have no insulation and demonstrate higher annual energy consumption [2].

Furthermore, it is essential to keep in mind that this type of buildings operates 24h per day and incorporate spaces of continuous use which require to be constantly lit and accommodate services with energy consuming equipment like computers, elevators and kitchen facilities. In addition, only rough assumptions can be made concerning occupancy patterns based on the high, middle and low season of the operational period. This situation means that the energy consumption can vary from very low to very high according to the number of visitors and the duration of their stay.

Last but not least, the occupant's behaviour plays a defining role in the energy profile of hotels. It is generally accepted that occupants tend to have different behaviour in a hotel environment in comparison to their home or office in terms of energy consumption. The fact that they pay a fixed price no matter how much hot water they use or how long they use the air-conditioning and the artificial lighting is probably one of the reasons visitors think they can waste as much energy as they want without making any effort to reduce consumption. Overall, they might even change their normal behaviour and feel that they can spoil themselves by not caring about the energy bills. At the same time they are very demanding in terms of visual and thermal comfort. For example, it was reported during field work that occupants have been setting the thermostat temperature at 17°C during the night in August in Paros Island, Greece, and sleeping with blankets as if it was winter.

In Greece hotels come second after hospitals with an annual total energy consumption average of 273kWh/m^2 [2]. Other Mediterranean countries show similar annual values: 215kWh/m^2 in Italy, 287kWh/m^2 in Spain and 420kWh/m^2 in France [3].

Looking closer to the annual energy consumption, it is important to see the energy demand breakdown in order to realise which systems require most of the energy and understand how this building type functions in terms of energy loads, thermal and visual comfort and occupancy. The main energy consuming systems are: cooling and heating, hot water production, lighting, catering (kitchen facilities) and other equipment [2].

Finally, it is also worth highlighting the fact that nowadays no new hotel will be approved to be constructed without having air-conditioning installations according to the specifications of the Greek Tourist Organisation. This fact on its own will dramatically change the picture of cooling loads, because once the air-conditioning units are available in the rooms, the occupants will not refrain from using them.

In the direction of energy conservation in the hotel sector, most initiatives and programmes suggest implementation of renewable energies and cutting edge technologies, omitting to firstly explore the possibilities of design and passive cooling techniques.

SEASIDE RESORTS – CHARACTERISTICS

Focusing on seaside resorts, it became evident that the most important design parameter is the view. Privacy is also important and is usually enhanced by landscaping. Concerning the occupants' behaviour, the general characteristics described previously also apply here. Regarding energy consumption, the main difference to the other hotel types is that heating is not an issue since most of the seaside resorts operate only during the summer months.

There are several different typologies of seaside resorts on Greek islands. Mainly they could be categorised as large compact multi-storey buildings and small stand alone buildings like bungalows. There are also complexes of stand alone buildings connected to each other creating large configurations like small villages.

It is noteworthy that regardless of the typology, the typical double room is very similar in all examples, which allows studying this type of room and covering for the majority of the hotels.

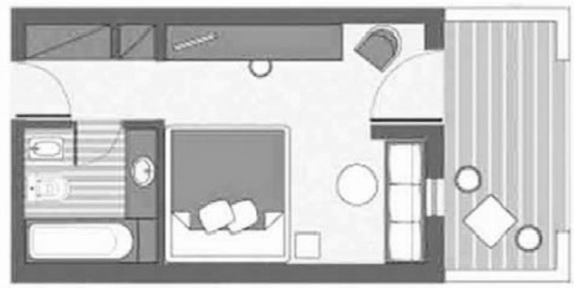

Figure 1: Typical double room in the seaside resorts (Source: www.grecotel.com)

GREEK ISLANDS

In order to explore the applicability and efficiency of passive cooling techniques on the Greek islands, the climate was studied and the thermal comfort range for the guests was defined.

Climate Greece is situated in the most south-eastern part of Europe and its latitude ranges from 34° to 42°N and longitude from 19° to 28°E comprising a large number of islands at the east, south and west of the mainland. The climate is typical Mediterranean with mild and rainy winters and relatively warm and dry summers. There are extended periods of sunshine throughout most of the year. The average monthly air temperature on the islands ranges for the hottest months namely July and August from 26–28°C, while the average maximum temperature does not exceed 31°C. During this time the high temperatures are dampened from the north winds blowing mainly in Aegean, well known as 'Etesian' [4].

Thermal comfort in seaside resorts Focusing on the behaviour of guests in seaside resorts it is important to keep in mind that the main purpose of such vacations is to enjoy the warm climate and the sea. This means that from the psychological point of view people are ready to cope with higher temperatures without complaining. In fact they expect and desire warm weather conditions. They even lie in the sun for hours raising their skin temperature way above the normal levels of 31-35°C (According to field work, after one hour of sunbathing, the skin temperature reached 38°C).

Accordingly, after calculating the neutral temperature according to Nicol and Roaf (1996) equation (T_n=17+0.38T_m, T_n: neutral temperature and T_m: mean monthly outdoor temperature) [5], the comfort range was defined by adding and subtracting 3°C to the neutral temperature [6].

Potential passive cooling strategies In the climate shortly described previously, several passive cooling techniques can be applied with potentially successful results. The fact that the mean daily temperature lies within the comfort range for the hottest months shows the potential of achieving such temperatures without mechanical means.

In order to cool down any building the heat absorbed in its mass needs to be dissipated using any natural heat sink available, for instance the air, the sky, water and even the soil under the earth's surface. These heat sinks can be utilized by applying different techniques.

The simplest way to start is by exploring the potential of ventilation. During the day the comfort can be improved by opening the windows and thus provide higher indoor air speeds. In this way the upper limit of the comfort zone can be extended because of the physiological cooling effect achieved by the higher air speed even when the air is as warm as 30°C [7]. Normally, when cross ventilation is applied during the daytime, the interior of the rooms get coupled with the environment and indoor temperatures follow the outdoor fluctuations. Accordingly, there is a point in using this type of cooling strategy only when the outdoor temperatures and the arising indoor wind speed fulfil the requirements of comfort. In the case of the Greek islands, daytime ventilation is applicable most of the operating season (apart from the hottest period) as the average maximum outdoor temperature does not exceed 30°C. Indoor wind speed can be controlled by the openings.

Ventilation can also be effective during the night. The so called nocturnal convective cooling needs a high mass well insulated and well shaded building to be effective. In Greece buildings have the potential to be heavyweight because of the earthquakes. The idea is that the building is cooled during the evening and night hours by cross ventilation and so the heat absorbed during the day can be dissipated during the night when the air temperature is significantly cooler than during the daytime. During the daytime openings remain closed and because of its heavy mass the building can potentially keep the indoor maximum temperature lower than the outdoor maximum by 45 to 55 percent of the outdoor range [8]. It is important to have a large diurnal range of about 12°C to 15°C or even more, while the night minimum temperature in summer should be below about 20°C. Such conditions are available on the islands for most part of the hot season.

Finally, the technique of the roof ponds (indirect evaporative cooling) was identified as a potentially effective solution. The requirements of high wet bulb depression, wet bulb temperature below 24°C and clear sky conditions are met by the climate in question.

FIELD WORK

The purpose of conducting field work for this project was mainly to document customer's behaviours through questionnaires and to establish a model for the simulations to follow concerning construction, dimensions and use of the rooms, so that simulations and reality can be correlated. By calibrating the simulations according to the construction of the particular hotel the researcher can claim that the results can be applied in reality and that they do not stand in theory only. The field work was conducted in a 4star seaside resort on the island of Paros, Greece. It included monitoring two unoccupied rooms under different conditions and interviewing hotel guests. Summing up the findings, it was shown that by using the strategies suggested by the literature review, it is possible to achieve comfort conditions as defined previously. This indication needs to be proven by means of analytic work.

ANALYTIC WORK

So far, it has been shown by the literature review and the field work that there is high possibility to achieve thermal comfort without air conditioning in seaside resorts on Greek islands. It will now be proven by thermal simulations with TAS software.

Thermal simulations After calibrating the model with the real construction, the process was to isolate each parameter involved and define its level of impact to the thermal performance of the room. Subsequently, natural ventilation strategies were tested. Understanding these relations and comparing the energy loads for cooling at several stages of the process lead to the appropriate strategies for cooling. In the end, climate change was also taken into account.

The exploration of the ventilation strategies initially involved testing daytime ventilation, since -as documented before- the indoor temperature exceeds the outdoor, meaning that by opening the window during the day cooler temperatures could be achieved. This was not enough, so 24 hour ventilation was studied. During the daytime the coupling of the interior with the exterior allows for very high temperatures inside as documented already in the daytime ventilation. During the night there was no overheating problem, so the significant drop in temperature was welcome but did not solve the overheating problem during the day.

This is the reason why the next logical step was to shut the windows during the daytime and explore the advantages of night time convective cooling. Windows are opened at 20:00 and are shut at 08:00. The results are satisfying. The indoor air temperature remains 2.5 degrees lower than the outdoor on average, still exceeding the comfort limits during the late afternoon hours by 0.5°C on average.

By extending the hours of having the windows open (18:00-10:00), the results are even better. This comprises the best practice achieved with a total of 213 overheating hours which corresponds to just 5% of the total operating hours. In this case the indoor temperatures are out of the comfort limits for this period, but at the same time they are mostly kept below the outdoor. This 5% of the operating hours is not such a high percentage and one could claim that the air conditioning could be used. The overheating mainly occurs in the afternoon hours when according to a typical vacation schedule - as recorded during field work – the occupants are still at the beach or in general outside the room. Compared to the base case which is considered to be the case with internal gains and the necessary fresh air supply and results in 1363 hours of overheating, energy consumption would still be minimized as shown in table 1. Nevertheless, there is a further solution to be considered, namely the indirect evaporative cooling by means of roof ponds.

Before going on with the exploration of the roof ponds it is important to see how much energy is needed to cool the room so far, so that it can be compared to the base case.

Table 1: *Comparison of overheating hours and energy consumption of base case and best case*

Frequency (Hours) of Air Temperature for Year >29°C							
	May	June	July	August	September	October	Total
External - Naxos	0	6	65	53	12	0	136
Base case	0	181	547	475	159	1	1363
Best case	*0*	*2*	*104*	*75*	*32*	*0*	*213*
Annual cooling load (kWh)							
	May	June	July	August	September	October	Total
Base case	0.00	26.11	109.45	77.12	29.47	0.01	242.16
Best case	*0.00*	*0.16*	*17.66*	*10.47*	*4.58*	*0.00*	*32.86*

The cooling load for one room is for the whole operating period 32.86kWh (table 2), which can be translated into 1.12kWh/m^2 for the guest rooms (29m^2 each guestroom). The energy saving achieved in terms of cooling loads from the base case to the best case is 87%.

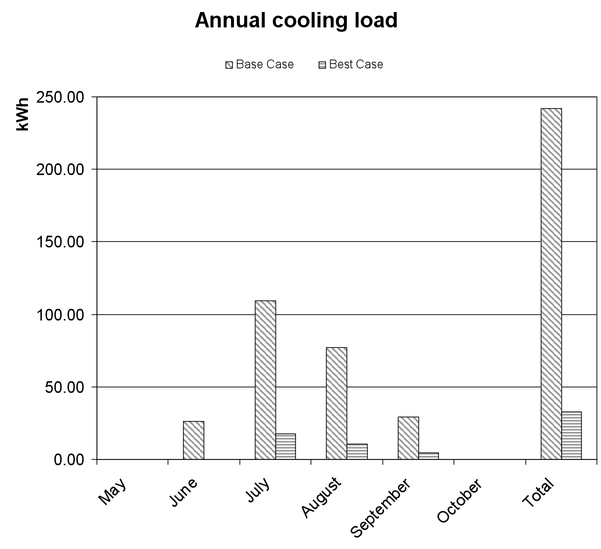

Figure 2: Graph illustrating the annual cooling loads for the base case and the best case. In total the base case demands 242.16kWh and the best case just 32.86kWh.

Roof ponds Looking for a way to further lower the air temperatures of the hotel room during the day, the application of a roof pond seems promising. As described earlier, the climate fulfils the requirements for this strategy to be successful. The water in the roof pond actually acts as an intermediate heat sink absorbing the heat captured in the building throughout the day and dissipating it to the night sky by longwave radiation. It is important to cover the pond during the daytime, so that the water does not get too warm from the direct solar radiation and the high ambient temperatures. During the daytime there is also the option of spraying the pond in order to achieve cooling by evaporation [9].

In the model used so far with an insulated roof the performance of the pond is not at its best. For a 300mm depth it can cut down the cooling demand by 41.6% (for indoor temperature of 25°C) and allow for indoor temperatures as high as 30.8°C in the climate of Athens [9] which is much hotter than the climate of the islands.

Using a lightweight construction improves by far the cooling effect, while the best performance of the pond is achieved when the pond support consists of a metal deck and there is no insulation in the roof. In this case energy savings of about 77.2% (again for maintaining indoor temperature of 25°C) and a maximum indoor temperature of 29.8°C can be attained. Again, this applies for a roof pond with 300mm depth in Athens [9].

Taking into account that the incident solar radiation in Athens and on the islands is similar , but the mean maximum temperature is much lower on the islands (29.38°C in Naxos, while in Athens it is around

34.55°C, according to Meteonorm v.6.0 softwarre) and the built environment is not as dense, it is logical that the indoor temperatures can be much lower than those of the tables. Besides, such temperatures have already been reached with cross ventilation in the previous thermal simulation studies. If the mean maximum indoor temperature in Athens can be 30.8°C with a mean maximum outdoor of 34.55°C, then it can be expected that on the islands the mean maximum indoor temperature will be around 26°C since the mean maximum outdoor temperature is around 29.38°C. This temperature satisfies the comfort conditions calculated for this project by far. Last but not least it should be noted that the energy savings shown in the tables refer to a saving in energy required in order to maintain an indoor temperature of 25°C. In this case when the comfort zone can be as high as 29.3°C, the percentage of saving will be even higher.

Climate change Obtaining the climate change data from Meteonorm v.6.0, a significant raise in the maximum temperature can be observed. A weather file for TAS was created from this data, in order to run a simulation of the best performance attained for the current climate conditions with the weather file containing the climate change. The results showed similar performance of the space but with higher indoor temperatures as expected. In fifty years, the temperatures at night will not be as cool as nowadays, so the nocturnal cooling will not be as effective. In addition, the daily temperatures will reach higher values, so the days when the comfort conditions will be met only by cross ventilation during the night will be fewer. The hours exceeding 29°C used to be 5% of the total operating hours, but now it is 21%. It could be argued that by then the human body will have adapted to the gradual temperature rise, so the adaptive comfort range will be expanded, but the writer has not the knowledge to justify or calculate such an assumption.

Concerning the roof pond, it will still be effective in fifty years when the mean maximum daily temperature of the island of Naxos will be 31.4°C (according to Meteonorm v.6.0), which means that indoor temperatures within the thermal comfort zone will still be achievable at around 28°C. Results will be even better if the lightweight construction of roofs will be applied in new buildings, so that in the future even cooler conditions than 28°C can be viable.

APPLICABILITY-CONCLUSIONS

Exploring the potential of cross ventilation, it was concluded that the most efficient option is the nocturnal convective cooling. In fact the energy required for cooling can be reduced by 87% as was shown in the best performance achieved with night time convective cooling. In reality, this solution bears two potential constraints; security and daylight. It is highly likely that the hotel guest will not feel safe to leave windows open during the night, not to mention that the morning daylight might be annoying and it would be preferred to keep the shutters closed. One solution to be considered are operable clerestories which by definition are located high enough to be safe and not to introduce too much light in the room especially since the openings are shaded. Another proposal is shutters with louvers which combine security and less daylight as well. It is important for any applications in the room to be manually controlled, so that the guests have available "adaptive opportunities" and at the same time the psychological benefit of manipulating their own space which adds to their comfort feeling.

Figure 3: Example of shutters with louvers from the Greek architectural tradition

In cases of applying a roof pond in new resorts, there is the option of choosing the type of roof construction and consequently the type of roof pond. It is suggested to select the option with the metal sheet as the ponds support which is the most effective. This configuration allows for the most substantial temperature drop as well as the most considerable energy saving. The problem that might evolve is the maintenance of such systems. In the case of a seaside resort with the configuration of bungalows - which is the most common typology today and the future trend - the cover of roof ponds should be operated mechanically since it would be impractical for someone to open and close all the covers every day. Having all these mechanisms raises questions of their durability and maintenance in such environments near the sea, where the salt and the humidity can cause damage and corrosion to practically everything during winter. Details of this nature have to be carefully considered and solved before reaching the application stage mainly because they will inevitably influence the costs of the construction and maintenance.

Exploring the passive cooling techniques for the seaside resorts incorporated taking into account the human presence and activity in those places. It is very positive that the target of thermal comfort conditions in the rooms was accomplished by incorporating in the study the most intense scenario of room use by the occupants assuming that they spent around 16 hours of the day inside and use a considerable amount of energy. This allows for better results in practice as the majority of the occupants stay in the room from ten to fifteen hours according to the field work. However, the typical guest behaviour should not be neglected. There are measures that could be implemented aiming at gradually changing the excessively energy consuming mentality of the hotel guest. Apart from introducing to the customers their "adaptive opportunities", practical benefits could provide the necessary incentives to become more energy conscious. For instance, discounts could be applied for the customers not using air conditioning or penalty fares could be imposed on the ones consuming too much energy. For such practices to be implemented, energy monitoring of each room is required. At the same time data from the monitoring could be useful in research for this field.

Finally, there has been consideration about the future climate. Needless to say, new constructions should be designed for the future climate; otherwise they will have to face serious overheating problems. Old buildings should undertake the necessary repairs or additions to become less energy consuming. The analysis for the future showed that nocturnal convective cooling will not be enough to provide comfort, but with the addition of roof ponds comfort conditions will be feasible for the next fifty years. Suggesting a further expansion of the comfort range due to the human adaptability and acclimatization ability, the time period of fifty years might be possibly lengthened.

At this point it is important to highlight that the bioclimatic strategies adopted in this project are tested on the typical double hotel room configuration as presented previously. The next step is to explore the design of the hotels in general as a configuration and the rooms in particular to propose better planning and configurations enabling higher efficiency of the strategies.

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