SUSTAINABLE GREEK TRADITIONAL DWELLINGS OF CYCLADES

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The Greek traditional dwellings of the Cyclades epitomize sustainable design principles to create optimum comfort environment. This paper evaluates specific traditional dwelling type in terms of its response to climate and thermal comfort based on passive design principles that could be adapted to current architectural practice in the area, in order to optimize the relationship between site, building and climate. This study especially deals with building envelope (walls and roofs: construction materials, type of insulation), that demonstrate sustainable design principles. The paper discusses relevance of the study in the context of the integrated energy and climate change policy of the European Union. Finally, the study is important from the point of socio-cultural identity and regional character of the Cyclades, which are under preservation status as per law.

Keywords: sustainable, traditional, dwelling, Cyclades

Introduction

The Cyclades is an island group in the Aegean Sea, south-east of the mainland of Greece. It comprises of approximately two hundred twenty islands of varying sizes, out which twenty four are inhabited. The word Cyclades is derived from the ancient Greek word, *Kyklos*, which means circle. The islands were given this name because they roughly circle the island of Delos, which is the sacred birth place and shrine of the god, Apollo. The islands are peaks of a submerged mountainous terrain, with the exception of two volcanic islands, Milos and Santorini (Thira). The city of Ermoupolis, in Syros island, is the main town and administrative centre of the Cyclades islands. The total area of the Cyclades is approxm. 2,572 km^2, population is 1,12,615 as per 2001 census and density is 46/km^2. "The masterly, correct and magnificent play of masses brought together in light" was the comment of Le Corbusier on the regional architecture of settlements in the insular complex of Cyclades, Fig. 1.

The traditional dwellings of the Cyclades, is a remarkable phenomenon, because it is an appropriate architectural and technological response to the local context and subtropical climate of Mediterranean region for providing summer and winter comfort. Greek vernacular architecture was studied in general by Pelekanos [1] and Coch [2] and the traditional architecture of Cyclades was studied by Siatitsa and Exarchoy [3]. A field study involving temperature measurements was done by Sinou [4] to compare thermal environment of traditional and contemporary dwellings in the Cyclades. This study aims to take up a holistic analysis and evaluation of Greek traditional dwellings of the Cyclades islands. The study is significant in the context of integrated energy and climate change policy of the European Union and the insulation regulations in Greece.

Methodology

The term ‘bioclimatic architecture’ was coined by Victor Olgyay [5] and the process of building a climate-balanced house divided into four steps: study of climate, human biology, technology and lastly architectural expression, with a strong advocacy of architectural regionalism. In many ways he can be considered as an important progenitor of what we now call ‘sustainable architecture’ [6]. Bioclimatic design is concerned with the layout of the building (orientation in relation to sun and wind, aspect ratio), the site planning (the spacing), the air movement, the openings (size, position, protection) and the building envelope (walls, roofs, construction materials, type of insulation). The hypothesis of the research is that optimum environment is the one with the most stable conditions within the comfort zone. Bioclimatic design strategies are effective for “envelope-dominated” structures, this

Fig. 1. Panoramic view of an island of the Cyclades

paper, therefore, evaluates thermal behaviour of building envelope (walls and roofs: construction materials, type of insulation). Bibliographic research is used for the presentation of the general data of the traditional dwellings of Cyclades; climate, thermal comfort, the buildings' form, typology and technology. Finally admittance procedure is used to evaluate thermal environment of a typical house and its variation during hottest and coldest month.

Climate

All the islands of Cyclades have Mediterranean climate that is characterised by mild and rainy winters and relatively warm and dry summers. There are important climatological changes due to geographical location, the size and distance of the islands from the nearby coasts of mainland. The islands can be differentiated into two groups with similar climatic data. The Central and South Cyclades- Folegandros, Paros, Milos, Kimlos, Sifnos, Serifos, Syros, Myconos, Naksos, Amorgos, Anafi, Thera, Ios, Sikinos. North Cyclades- Kythnos, Kea, Andros and Tinos. Fig. 2 is presents climatic data of Milos island.

The peak summer months, July and August, are warm with the mean air temperature about 25 ºC in most of the islands. The peak winter months, January and February, are mild with average temperature that in many islands of the Cyclades is over 11 ºC. The diurnal mean range varies between 4.4 and 7.8 K, the larger diurnal variation occurring during summer. Relative humidity is steadily high, between 59 and 73 %. The strong solar radiation causes strong evaporation from the sea. The moisture is, however, not precipitated, but remains suspended in the air, creating intensely uncomfortable conditions.

Precipitation is very low; the annual average rainfall in the Milos island is 411 mm. Sky conditions are cloudy. Winds are mostly local, strong coastal winds, caused by the unequal heating and cooling of land and sea surfaces. The main wind in the area are north with a percentage that reaches 38.2 followed by the north-east winds with a percentage of 16.3%. The salt laden atmosphere accelerates corrosion.

Biology: thermal comfort

Thermal comfort is that condition of mind that expresses its satisfaction with the thermal environment [7]. A study sponsored by American Society for Heating, Refrigerating and Air-conditioning Engineers [8] compiled an extensive database from past field studies to study, develop, and test adaptive models (psycho-physiological), an empirical model of thermal perception. In general, the value of using an adaptive model to specify set points or guide temperature control strategies is likely to increase the freedom that occupants are given to adapt throughout the year (e.g. by having flexible working hours, locations, or dress codes).

The term "thermal neutrality" refers to a specific value of the indoor thermal environmental index (e.g. operative temperature) corresponding to a mean thermal sensation vote of zero on the seven-point scale (i. e. "*neutral*"). This study would use the regression equation given by Auliciems [9] correlating thermal neutrality (t_n) and mean monthly outdoor Dry Bulb Temperature (t_m):

$$t_n = 17.6 + 0.31\, t_m \qquad (1)$$

Although there are different opinions about the lowest and highest limits of neutrality, this study uses the neutrality limits given by Auliciems are accepted as: $18 < t_n < 28$ °C. The width of the comfort zone is taken 4 K for unconditioned environment. Fig. 3 presents summer and winter comfort zones overlaid with

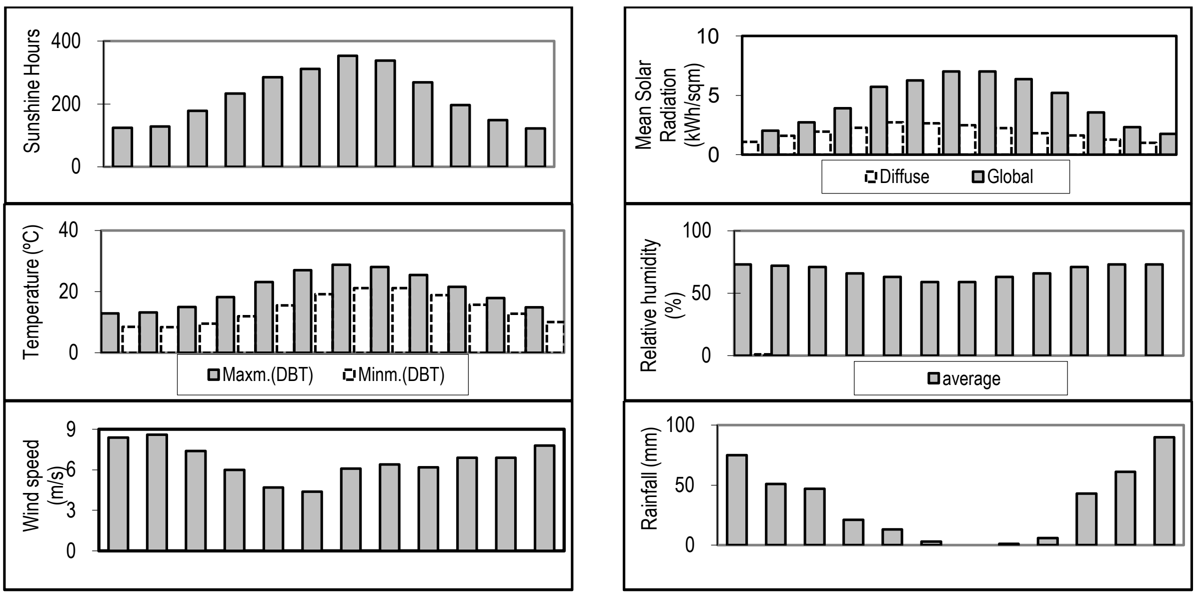


Fig. 2. Monthlyclimatic data of Milos island, Latitude 37° 43'N, Longitude 24° 27'E, Altitude 183 m.
Source: Meteonorm software v. 6.1

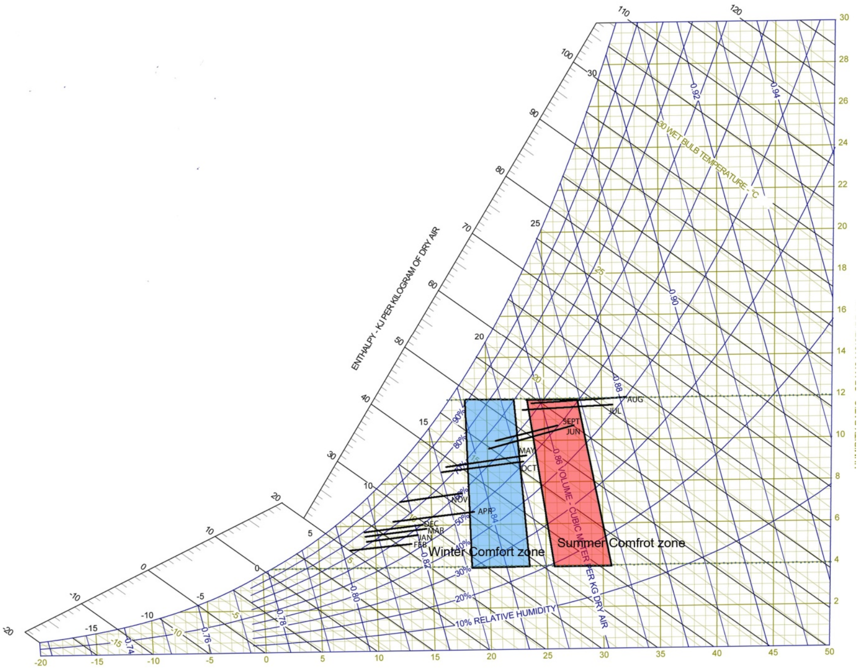


Fig. 3. Psychrometric chart delineating winter and summer comfort zones overlaid with climate of twelve months for Milos island (Analysis by B.Arch. graduate Mr. Kapil Grover)

twelve months climate. In winter, passive solar heating is useful and thermal mass is required to reduce heat losses and lower the indoor average temperature, though temperature swings are less critical in this season. In summer, solar protection is required to avoid increase in the average indoor temperature and thermal mass (relatively heavy construction) to reduce thermal swings.

Building Technology

The traditional settlements in Cyclades are characterised by linear series of row houses arranged either in a polygon leaving an internal space as in Antiparos and Kimolos or along narrow paved streets on slopes of mountain as in Kastros in Siphnos and Pyros in Santorini. Two specific types of houses have been identified in the traditional settlement of Kastros [4] and Andros [10]. The first type is referred to as "one-unit" house, deep rectangular plan house, the width is less than 3m and the length varies from 6 to 12 m. The house has two rooms separated by a wall; the front living room is bigger than the back sleeping room. The second type of houses is formed by the union of two or more one-unit houses. The settlement developed within limited space, the houses, therefore, expanded vertically and became two or three storey.

Walls and roofs

The traditional houses in the Cyclades use natural and locally available materials. The materials are reusable and recyclable [11]. Structural stones are reused in new construction. Natural and organic materials such as reeds and sea weeds are fully biodegradable.

The walls, approximately 600 to 900 mm, are built from locally quarried schist or slate, bound with a fine-earth sieved mortar or cement mortar and they are usually plastered, inside and out. The floors of the ground level houses are also constructed with slate stone slabs on the soil or over the stone vaults of the basement, while the upper floors are made of timber. The generalised use of flat roof is mainly due to scarcity of rainwater and the need for its efficient collection. But the use of materials in construction differs according to the island. In islands with wood availability the flat roof sub structure is constructed from wood, whereas in islands without trees able to provide structural wood, the wooden elements are minimised and are replaced by built elements, such as stone arcs (volta) in the middle of spaces, and slate. The substructure is first covered either with reeds or with schist tiles or both. A second layer of 30 mm of seaweed is used as insulation, while as third layer 12 mm volcanic argil or kourasani (a plaster of crushed bricks or tiles with some sand), acts as vapour barrier. The exterior surfaces of high thermal capacity walls and roofs of houses in the Cyclades are all whitewashed with olive oil as highly reflective useful in reducing the heat load during the day-time.

Openings

The solar heat gain, the direction of wind and the daylight are the governing factors in deciding the size and orientation of openings. As the air temperature marginally (summer) reaches above the upper comfort limit, there is no need for physiological cooling by air movement rather there are strong north winds to be avoided. The strong light also created the need for shelter with lower light levels. The openings are,

Fig. 4. Small openings in traditional houses

therefore, very small in the Cyclades residence and mostly facing the south (Fig. 4**)**.

Space use

In addition, the single most powerful tool used in traditional houses was the willingness and the ability of the occupants, to organize daily activities in space and time so that comfort is achieved by optimising space use. In summer verandas or shaded courtyards are full of people having their lunch, cooking, drinking their coffee on the afternoon or even sleeping there during the night, enjoying the cool night breeze. In winter day, the terraces are filled with women doing the laundry for the house and getting advantage of the sun, to dry the clothes. People will be sitting on the entrance steps of the house conversing with their neighbour opposite the narrow street. In the winter night, the family gathers around the main-central room of the house which may have a fireplace to heat the place and warm the atmosphere.

Evaluation-thermal environment

The study includes a preliminary analysis of the thermal environment of a typical house with the use of admittance procedure [12]. A single unit house 3 m wide, 6m long and 3 m high is chosen (Fig. 5**)** as it is the basic type of house that is most commonly found in the traditional settlements of the Cyclades and this basic unit is used in multiples for making bigger houses.

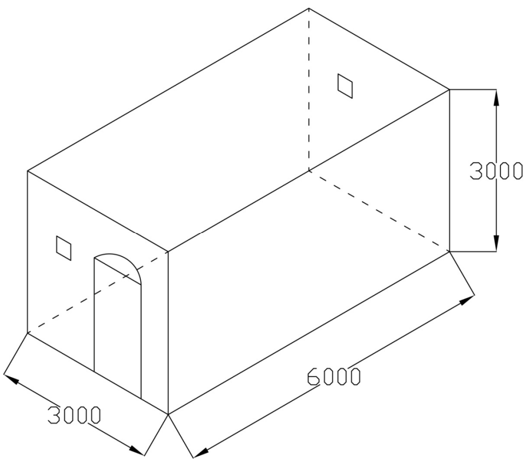


Fig. 5. Model of a typical traditional house (dimensions in mm)

The aim of the thermal analysis is to obtain a representative picture of the passive thermal behaviour of the house, mainly its behaviour without active heating systems (fire places, braziers etc.) during the period that the house is on a free-running regime. Number of air changes is presumed to be two per hour and occupancy of two people is taken.

For thermal analysis, four variations are constructed and analyzed, in order to represent the different roofs since the roof is by far the most important, as it receives the greatest amount of solar radiation during day time. All the external walls (south and north) are constructed with stone (thickness 60 cm, U value 2.47 W/m^{2}K, time lag 12.5 hours, decrement factor 0.10, admittance 5.84 W/m^{2}K).

In the first variation of roof is constructed with both reeds and slate tiles, in the second one with only reeds, the third one is only schist tiles, while for the fourth variation 20 cm Reinforced Concrete (RC) roof is assumed with stone walls. In the first three variations traditional insulation materials sea weed and volcanic earth are used, which is plastered and white washed. In the fourth variation polystyrene 10 mm thick is topped with bitumen and cement render. In all four variations, the model had southern orientation, east and west walls are unexposed.

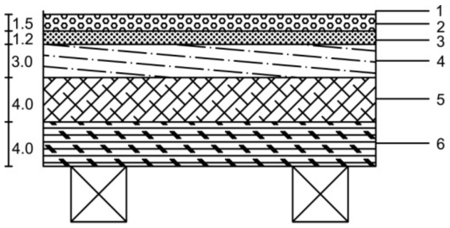
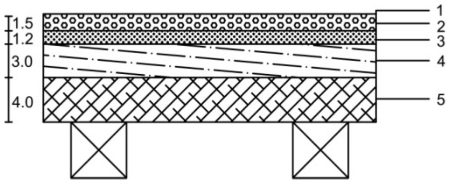
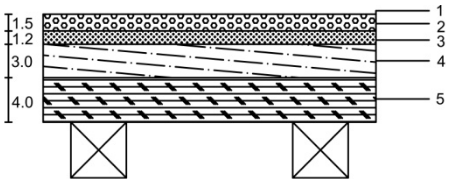
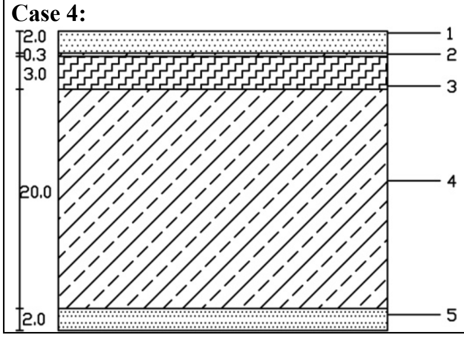
Thermal properties, air to air thermal transmittance U value, decrement factor time lag and admittance are calculated for four roofs (three traditional and one contemporary) (Table 1). In case of three different variations of traditional roofs, case 1, 2 and 3, the U value ranges between 0.68 to 0.98 W/m^{2}K, the time lag ranges between 2.67 hours to 5.61 hours and the decrement factor ranges between 0.39 to 0.88. While as in case of RC roof the U value is 0.84 W/m^{2}K, time lag is the highest 12.61 hours and decrement factor is the lowest 0.17.

Analysis

The results of the thermal analysis indicate that the combination of high mass shell construction with small openings (0.3 x 0.3 m for two windows and 1 x 2.1 m for the door) enclosing a high volume room, resulted in an internal temperature fluctuations following the external with small time lag but reduced amplitude. For winter month the environmental temperature shows that the diurnal range is very small (1 K, from 13.8 to 14.6ºC) for two traditional roofs (case 1

Table 1

Thermal properties of flat roofs (dimensions in mm)

Roof sections (all dimensions in cm)	Layer	Resistance m²K/W	Conductivity W/m K	Density Kg/m³	Specific heat J/kg*K
Case 1: 	Outside film	0.04[a]			
	1. White wash				
	2. Argil	0.01875	0.8[c]	1300[c]	880♀
	3. Volcanic earth	0.01333	0.9[c]	3000[c]	840[d]
	4. Sea weed	0.79787	0.0376[b]	55[b]	1050♀
	5. Schist tiles	0.0125	3.2[c]	2200[c]	921[c]
	6. Reeds	0.44444	0.09[a]	270[a]	1300♀
	Inside film	0.14[a]			
	Performance	U value (W/m² K) **0.68**	Dec.fact **0.39**	Time lag (h) **5.61**	Admittance (W/m² K) **2.92**
Case 2: 	Outside film	0.04[a]			
	1. White wash				
	2. Argil	0.01875	0.8[c]	1300[c]	880♀
	3. Volcanic earth	0.01333	0.9[c]	3000[c]	840[d]
	4. Sea weed	0.79787	0.0376[b]	55[b]	1050♀
	5. Reeds	0.44444	0.09[a]	270[a]	1300♀
	Inside film	0.14[a]			
	Performance	U value (W/m² K) **0.69**	Dec.fact **0.88**	Time lag (h) **2.67**	Admittance (W/m² K) **2.90**
Case 3: 	Outside film	0.04[a]			
	1. White wash				
	2. Argil	0.01875	0.8[c]	1300[c]	880[d]
	3. Volcanic earth	0.01333	0.9[c]	3000[c]	840[d]
	4. Sea weed	0.79787	0.0376[b]	55[b]	1050♀
	5. Schist tiles	0.0125	3.2[c]	2200[c]	921[c]
	Inside film	0.14[a]			
	Performance	U value (W/m² K) **0.98**	Dec.fact **0.88**	Time lag (h) **2.73**	Admittance (W/m² K) **2.82**
Case 4: 	Outside film	0.04[a]			
	1. Cement render	0.02353	0.85[c]	1000[c]	1047[c]
	2. Bitumen	0.006	0.50[e]	1700[e]	1000[e]
	3. Polystyrene	0.85714	0.035[c]	2800[c]	1507[c]
	4. Reinforced Concrete	0.09756	2.05[c]	2400[c]	880[c]
	5. Cement render	0.02353	0.85[c]	1000[c]	1047[c]
	Inside film	0.14[a]			
	Performance	U value (W/m² K) **0.84**	Dec.fact **0.17**	Time lag (h) **12.46**	Admittance (W/m² K) **3.12**

[a][13][b][14],[c][15], [d]assumed values, [e][16]

and 2), while as the third traditional roof using schist tiles (case 3) is slightly hotter (by 0.5 K), Fig. 8. It is interesting to note that the diurnal range of the exterior temperature is 4.8 K (from 8.4 to 13.2ºC).

For a summer month with exterior environmental temperature fluctuating between 21.2 to 28.8ºC (range of 7.6 K), the respective interior temperature presents a small diurnal range of less than 2 K (from 28.8 to 30.6º C) for traditional roofs (case 1 and 2), while as the third traditional roof (case 3) is slightly hotter (by 0.5 K) (Fig. 6).

During both the seasons, the RC roof in combination with traditional massive stone walls (case 4) shows the lowest swings of temperature in comparison to traditional roofs. However, the contemporary RC roof in combination with the brick walls does not create stable environment [4]. This shows that the wall is as important as roof in creating stable environment in the traditional houses.

The indoor temperatures are out of the comfort limits, the overheating occurs by 2 K in summer and the underheating is of the order of 3 K in winter. This is ameliorated by passive means, by natural ventilation in summers and solar heating in day time in winter. However, in winter nights active heating becomes inevitable.

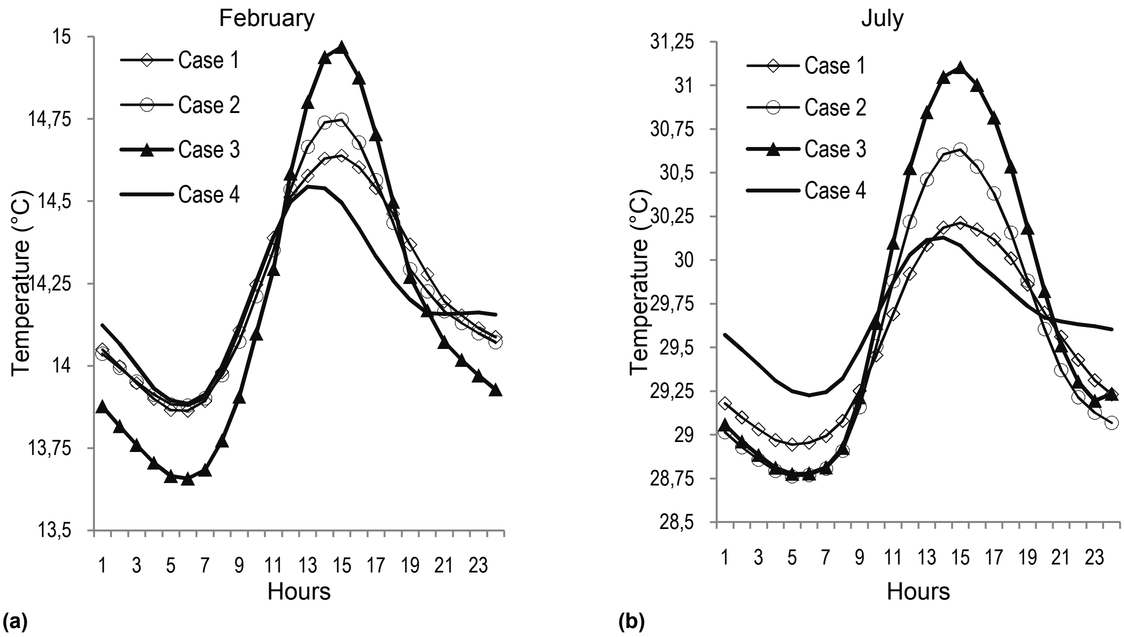


Fig. 6. Environmental temperatures in coldest month (February) and hottest month (July)

Conclusion

This paper argues that in the quest for the sustainable building, the traditional Cycladic dwellings are of a particular morphological character and offer valuable information. In contrast, the contemporary spacious residences with wider openings, large facades and modern construction materials are a challenge to energy conservation and energy efficiency. In December 2008 the European Union adopted an integrated energy and climate change policy to set Europe on the right track towards a sustainable future by:

- cutting greenhouse gases by 20 %
- reducing energy consumption by 20 % through increased energy efficiency
- meeting 20 % of the energy needs from renewable sources.

In consonance with the above objectives CRES and DAFNI [17] have prepared Sustainable Energy Action Plan 2020 for Cyclades. Besides using renewable energy sources, the employment of bioclimatic buildings techniques and technologies in the Cyclades could address the continuously increasing future energy demands. The Greek legislation the Act 3661 – Measures to reduce energy consumption of buildings; Gazette 89/19 May 2008 KENAK [18] was introduced in line with the Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002. According to new legislation the country is divided into four climatic zones depending on the Degree Days for Heating. The Cyclades falls in zone A. The new legislation describes maximum permitted rates of thermal transmittance (U) values for building components wall $\leq$ 0.7 W/m^{2}K, roof $\leq$ 0.5 W/m^{2}K, floor $\leq$ 2.0 W/m^{2}K and openings $\leq$ 3.85 W/m^{2}K for the zone A. The massive walls and roofs in the traditional houses do not meet the requirement of maximum permitted U values of the Greek legislation, but creates stable environment due to mass effect, high time lag and low decrement factor.

The traditional houses of the Cyclades form a significant cultural heritage and have been under preservation status since 1970. Further research should include a detailed survey-documentation of all existing building types, in-situ environmental measurements and detailed computer-based analysis.

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ЭКОЛОГИЧЕСКИ БЕЗОПАСНЫЕ ТРАДИЦИОННЫЕ ГРЕЧЕСКИЕ ДОМА НА КИКЛАДСКИХ ОСТРОВАХ

Читрареха Кабре

Традиционные греческие дома на Кикладских островах воплощают в себе принципы экологического проектирования, целью которого является обеспечение оптимально комфортной среды. На основе принципов пассивного проектирования, которые могут быть адаптированы к существующей практике архитектурных решений в данном регионе, автор статьи описывает конкретный тип традиционного жилья с точки зрения его реакции на климат и тепловой комфорт с целью оптимизации взаимосвязи между строительной площадкой, зданием и климатом. В статье детально изучаются ограждающие конструкции (стены и крыша: строительные материалы, тип изоляции), которые демонстрируют принципы экологически безопасного проектирования. В статье рассматривается актуальность исследования в отношении интегрированной политики Европейского Союза в вопросе энергии и изменения климата. Данное исследование имеет важное значение с точки зрения социокультурной самобытности и региональных особенностей Кикладских островов, которые находятся под защитой согласно законодательству Греции.

Ключевые слова: экологически безопасный, традиционный, жилище, Киклады.

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