208: Low Energy Design Strategies for Different Climates of Turkey: Comparison of Traditional and Modern Samples

A. Zerrin Yılmaz[1*]

Faculty of Architecture, Istanbul Technical University, Istanbul, Turkey[1]*
yilmazzer@itu.edu.tr

Abstract

In this paper low energy passive strategies in building design have been analysed for five different climatic zones of Turkey through comparison of traditional and some modern samples. The climatic zones of Turkey are; mild humid, mild dry, cold, hot humid and hot dry zones. All of the traditional samples in these zones, which were built before nowadays' construction and energy supply technology, are well responsive to the local environmental conditions and therefore they are energy efficient. But the modern samples constructed with today's advanced building technologies have no same consciousness in spite of the possibilities offered by the sophisticated simulation tools in energy area. We should not forget that sustainable architecture should start with understanding of vernacular architecture. Therefore the aim of this study is to remind designers that they should take lessons from the traditional samples through implementation of their strategies with new materials and technologies in new building design. In the study first, the climate responsive strategies in the traditional samples are introduced and then some samples in some climatic zones were compared with the modern buildings through energy simulations to see the importance rank of design parameters and priority rank between insulation and thermal mass depending on climatic characteristic of the zone. Finally, the importance of passive intelligence on energy efficiency has been stressed through the energy analysis of a high-tech building in Istanbul equipped with very expensive BMS (building management system).

Keywords: low energy design, climate responsive architecture, intelligence for energy effriciency

1. Introduction

Energy issue is becoming more and more important in today's world because of a possible energy shortage in the future and also global warming. Efficient use of energy has become a key issue for the most energy policies and buildings are one of the most significant energy consumers. Across the IEA countries, buildings consume over half of all electricity and one-third of natural gas, and are responsible for more than one-third of all greenhouse gas emissions [1]. Therefore, sustainable design and construction strategies are of great importance nowadays. From Vitrivius till today, problems and precautions in design and construction did not change fundamentally, although a lot of development was seen in materials and technology [2].

In this study energy efficient design strategies for five climatic zones of Turkey have been analysed through traditional and modern samples. Energy efficient design strategies for these zones are significantly different from each other as it can be easily seen by the climate responsive traditional buildings. In this paper climate responsive strategies in traditional buildings for different climatic zones of Turkey were introduced first and then some traditional and modern samples in mild humid and hot dry zones were compared through energy simulations. Finally the importance of passive intelligence on energy efficiency was indicated through the results of energy analysis of a high-tech automated building in Istanbul.

2. Energy Efficient Traditional Design Strategies in Different Climatic Zones of Turkey

Considering the climatic characteristics, there are five different climatic zones in Turkey. Black Sea and Marmara regions are mild humid zone, central Anatolia is mild dry zone, east Anatolia is cold zone, Mediterranean coast is hot humid zone and finally south east Anatolia is hot dry zone.

2.1 Mild Humid and Mild Dry Zones

Mild humid zone covers Marmara Sea coast and Black see coast. Mild dry zone is central Anatolia. In these zones there are neither extreme temperatures in winter and summer and nor high temperature difference between day and night. Humidity is high during the winter and summer periods in mild humid zone. Winter period is longer in both of the zones. Therefore the most important design strategy in these zones is to orient the buildings to south with reasonable size of windows to get maximum solar radiation during winter as it is represented by a traditional sample in Figure 1.

Fig.1. Traditional sample from mild humid zone

2.2 Cold Zone

Cold zone of Turkey is East Anotolian Plateau on high mountains and the winter period is very long with severe conditions. Therefore, climate responsive traditional buildings are always in compact form with minimum external surface area and small windows which are mostly oriented to south as it can be seen in Figure 2.

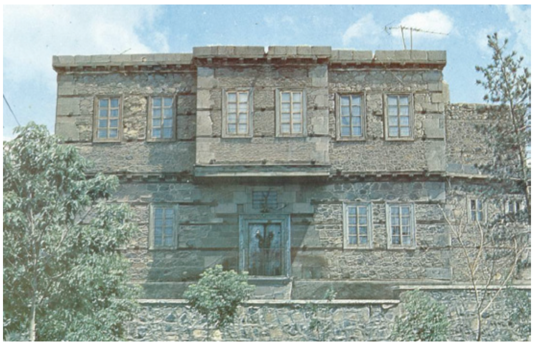

Fig. 2. Traditional sample from cold zone

2.3 Hot Humid Zone

This zone is the Mediterranean coast of Turkey. The winters are mild and short, but summers are very hot and humid. In order to avoid the uncomfortable effect of humidity on occupants, the climate rerponsive traditional buildings are oriented to dominant wind directions with big windows and external walls are usually built with light construction. One sample for traditional buildings from this zone is given in Figure 3.

2.4 Hot Dry Zone

The climate of the South-Eastern Anatolian Plateau is relatively similar to desert climate. This region represents the hot-dry climatic zones with a great temperature difference between day and night. Therefore, the most important energy efficient design strategy in traditional buildings is to provide big thermal mass on building envelope.

Fig. 3. Traditional sample from hot humid zone

All of the traditional buildings' envelopes are constructed with local stones with about 1.00 m thickness. This big thermal mass will slow down the heat transfer through the envelope and thus higher day-time temperatures will be reached indoors when outdoor air temperature is much lower and consequently more stable indoor thermal conditions will be provided. On the other hand this thermal mass, which has higher surface temperature on outer side, will rapidly lose heating energy to the atmosphere via thermal radiation at night to start the next day from a cooler level [3]. The high heat capacity of the opaque component provides a high time lag for the transmission of the outside temperature to the internal area while the low transparency ratio minimizes the direct solar radiation gained through the windows. One traditional sample from this zone is given in Figure 4.

Fig. 4. Traditional sample from hot dry zone

2.5 Comparison of Climatic Response of Modern Buildings in Mild Humid and Hot Dry Zones

The mild humid and hot dry zones are considered in the same degree-day zones by Turkish Standard-TS825 for heating energy conservation, however their climatic characteristics are totally different from each other as it is summarized above. Typical multi-storey residential building has been considered for thermal evaluation in case of this building is constructed in Istanbul and Mardin, which are representing mild humid and hot dry zone respectively, with the same envelope as it is instructed in the Standard [4]. The main facade is oriented to south and the apartment unit under consideration is located in the intermediate floor of the building. The plan of the building is shown in Figure 5.

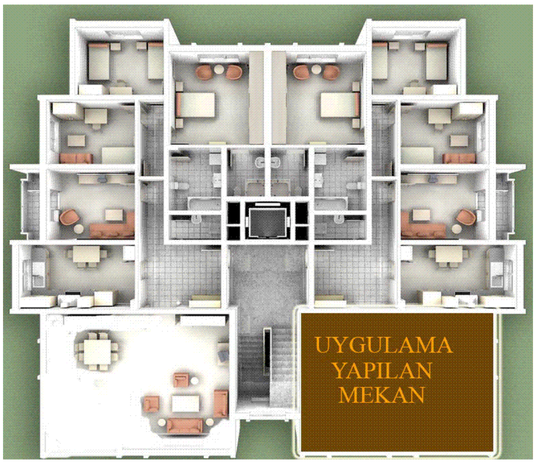

Fig.5. Plan of the case study building

Solar absorption coefficient of the external surface is assumed as 0.7 and transparency ratio of the south façade is 34%. Windows are double glazed wooden frame. It has been assumed that heat transfer coefficient of the external wall is 0.55 W/m^{2}K which is providing Standard's requirement for Istanbul and Mardin. Different external wall details, which are providing this required U-value, have been examined to see the effect of the other thermo-physical properties of the envelope. Masonry wall with a high thermal mass of 1.2 m thickness, which is traditional wall type for hot dry area, has also been examined for Mardin. The U-value of the masonry wall is 1.42 W/m^{2}K, which is much higher than the Standard's value. The details for external wall alternatives are given in Table 1.

Table 1: Selected wall types for case study building

WALL TYPES	Material	d (m)	U (W/m^{2}K)
WALL 1 Concrete Wall Insulated Inside	Plaster	0.02	0.55
	Concrete	0.12	
	Insulation	0.06	
	Plaster	0.02	
WALL 2 Gas Cocrete Wall Insulated Inside	Plaster	0.02	0.55
	Gas Concrete	0.02	
	Insulation	0.06	
	Plaster	0.02	
MASONARY WALL	Stone	1.20	1.42

Inner surface temperature of the external wall and indoor air temperature have been calculated by using finite difference method [5,6] to see the thermal behavior of different wall details having same U-value and stone wall having higher U-value and higher thermal mass. In order to see the effect of only building materials on indoor thermal conditions the windows are assumed to be closed. Maximum temperatures provided by the selected walls are given in Table 2.

Table 2: Indoor air and inner surface maximum temperatures for the wall alternatives oriented to south.

Max.Temp. (°C)			Ind. air	Inner Surf.
Istanbul	Jan.	Wall1	19.00	17.50
		Wall2	14.80	12.90
	July	Wall1	36.00	34.00
		Wall2	34.80	32.50
Mardin	Jan.	Wall1	22.50	21.00
		Wall2	17.50	14.00
		Masonry	20.00	18.00
	July	Wall1	44.00	43.00
		Wall2	42.50	40.00
		Masonry	35.00	33.00

As it can be seen in this Table, thermal performance of two wall details providing the same U-Value are significantly different from each other in the same city. Moreover, the same wall is showing very different thermal behaviour in Istanbul and Mardin. The inner surface and indoor air temperature are almost 10 °C lower in Mardin for the masonry wall in July, however its U-value is almost 3 times higher than the other walls constructed according to the Standard. That means that thermal mass is more important than the U-value in hot-dry climate and energy conservation standards should certainly consider this property of the envelope in this climatic zone where cooling energy conservation is more important than the heating energy conservation.

The heating and cooling loads have also been calculated for the sample flat for the heating and cooling periods of Istanbul and Mardin to keep the indoor air temperature at 19 and 24 °C respectively. The results are given in Figure 6. The heating and cooling periods for these cities are determined basing on the meterolgical data of ten years [7,8]. As it can be easily seen in Figure 6, the wall 1 and 2 are providing different heating and cooling loads in the same building in Istanbul and Mardin however their U-values are same. The masonry wall is proving the least cooling load in Mardin, repesenting the hot and dry climate, in spite of its much bigger U-value. Considering the heating and cooling loads together, wall 1 is better for Istanbul for the considered case and masonry wall is the best for Mardin area for energy conservation.

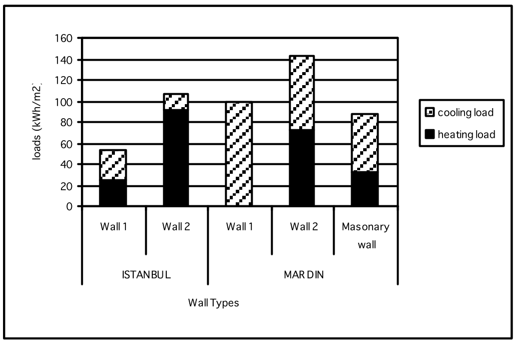

Fig.6. Heating and cooling loads for different walls in Istanbul and Mardin

In order to support these results a field study has been carried out in Mardin to take measurements in a traditional and a modern house at the end of may which is in the cooling period for this hot dry area [9]. The traditional house has been constructed in the middle of the 17th century with masonry walls in the old settlement in Mardin where all energy eficiency strategies of hot-dry climate have been apllied. The modern house is located in the new part of the city and this building has been constructed according to the above mentioned Turkish Standard, TS 825. As parallel to the measurements, questionnaires have been carried out for 68 traditional and 32 modern buildings to determine the users' perception for indoor environment. The questionnaire includes 34 questions about users' thermal, visual and air quality perceptions. The questionnaire asks users how they feel in their room, living room, eyvan, and courtyard and identify their thermal feelings by selecting a point between "cold", "cool", "normal", "warm" and "hot" alternatives. Users were asked to express their feelings both for winter and summer. The results of this questionnaire support the results of the measurements.

The details of this field study are given in the different publications [10]. Here, only the results of questionnaire for user's perception of indoor temperature in summer are given as sample in Figure 7.

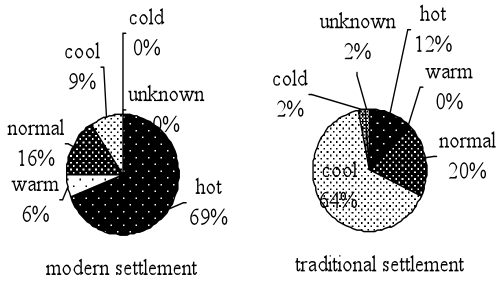

Fig.7. User's perception for indoor temperature in summer in Mardin

As it can be seen in Figure 7, under hot summer conditions, traditional houses can provide cooler indoor environment than the modern one. That means that masonry wall with big thermal mass will provide less cooling load for the traditional building in comparison to the modern building which has been built according to TS 825 in this hot dry climate.

3. Intelligent Building Approach for Energy Efficiency

As being nowadays' trend intelligent buildings aim energy saving with self-regulated amendments and automatic control of building elements and building energy systems to provide users' comfort by minimum amount of energy demand. Intelligent buildings that require expensive building energy management systems are usually anticipated for the commercial or communal buildings where the energy demand is higher than the residential buildings.

Intelligent buildings in Turkey are usually accepted as the buildings where HVAC and electrical systems of the building are automatically controlled by building energy management system and the advantages of architectural design to create energy efficient, comfortable and natural spaces by passive ways using renewable sources are neglected. As it is known, the building is entire of the sub-systems such as architectural design, construction system, structional system and the mechanical and electrical systems. Unless intelligence is valid for all of these building sub-systems the building can't be identified as truly intelligent energy saving, comfortable and safe building. Usually the energy systems of buildings are designed basing on the average meteorological variables, mostly only outdoor temperature is considered for HVAC system design and especially in Turkey there is no enough endeavor during the building design to use the renewable sources. As the result of this default in the intelligent building design, even in the buildings equipped with high-tech and expensive building energy management systems energy efficiency can't be provided at the expected level. Therefore, truly intelligent building design should be started from the beginning of the design stage by the integration of different disciplines and intelligence should be valid for all of the building sub-systems. As it is indicated above, passive system, which is defined by architectural design has the most important role in the whole intelligence.

İstanbul İsbank Headquarter buildings has been considered for the analysis of energy efficiency in this study. This headquarter is called as intelligent building and consisting of three towers, but their intelligence strategy does not cover the passive system. These towers are equipped with a high-tech and expensive energy management system to control the mechanical and electrical equipment. Energy simulation has been made only for Tower 2, since the detailed information for energy consumption is available for this tower [11]. All of the information for building construction and energy consumption has been provided by building energy manager Mr. Tuncer Kınıklı. [11]. The height of this tower 113 m with 28 floors and total floor area is 29,271 m^2

designed as open office plan. The elevations of the towers and site plan are given in Figure 8. Total façade area of Tower 2 is 11,725m^2 with a transparency ratio of 48.8%. Heat transfer coefficient for glass components is 1.8 W/m^2.^{o}K, for aluminium components is 0.46 W/m^2.^{o}K.

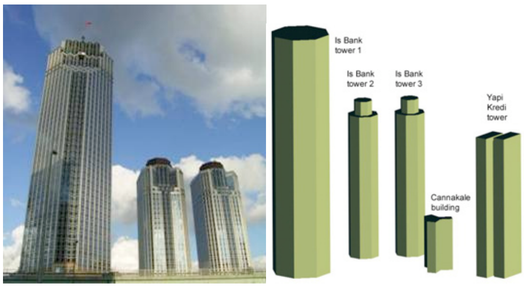

Fig.8. Isbank Headquarter Towers in Istanbul

The set point temperature of the heating system, which is operated by natural gas, is 22^{o}C. The relative humidity is also automatically controlled as max. 40%. For the cooling period these values are 24.5^{o}C and %50. The ventilation is provided by mechanical system, which use the exhaust air up to 50% if its CO_2 rate is in the acceptable range. Lighting is provided by electrical system and daylighting opportunity is not considered. In order to reduce the heat gain from the lighting system up to 36%, return air of the cooling system passes through the lamps. Low-e coated double window glasses with 11% solar radiation transmittance, 23% shading factor and 16% light transmission were selected to reduce the cooling loads. The energy simulation of Tower 2 has been carried out with these data to determine heating, cooling and lighting energy demand of the building and the results have been revised by using the information from the detailed energy bills to correct the assumption of the simulation models for internal loads. Figure 9 shows the consumption, cost and emission of natural gas for heating system, electricity for lighting and other facilities.

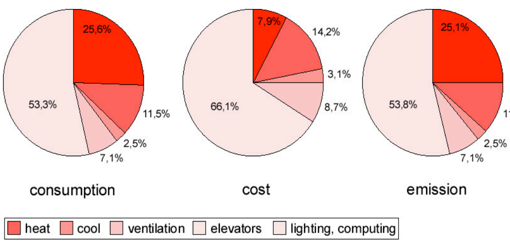

Fig.9. Natural Gas and Electricity Consumption Cost and Emmision of Tower 2.

As it can be seen from these results, Tower 2, which is equipped with a high-tech and very expensive building energy management system, is in the acceptable range from heating energy conservation point of view, but its electricity consumption is too high to be accepted as low energy buildings in the world. The results of energy analysis show that the most of the electricity is consumed for lighting because of the window glasses with very low light transmission coefficient. The window glasses have been selected to reduce only cooling energy demand and the importance of lighting energy in office buildings was neglected. Thus, the possibility of lighting energy saving through a proper daylighting strategy has been missed. These glasses with low solar radiation transmittance have been used for all windows oriented even to the North, where there is direct solar radiation. That means there is no energy saving strategy in the architectural design and material selection to cover all energy components to provide comfort in this building. As a result we can say that this high-tech and expensively constructed building has missed the opportunity to be a real energy efficient intelligent building in the rank of energy efficient buildings, since intelligence strategy does not cover passive solar architectural design.

5. Conclusion

As it can be concluded from the results of the theoretical and field studies, the heat transfer coefficient of the building envelope and the heat transfer amount calculated in steady state conditions are not sufficient to determine the real thermal performance of buildings. These, observed especially on the traditional construction technology, have a very important role in hot and dry climatic zone where the continental climatic effects are dominant. The Heating Energy Saving Standard of Turkey (TS 825) has made a significant mistake by neglecting the heat storage capacity of the building envelope especially for hot-dry climate. Theoretical study has been carried out for a residential building constructed with different wall details providing required U-value of the standard in Istanbul and Mardin and with also traditional masonry wall in Mardin. The most important conclusion of this study is; the masonry wall is providing the least energy consumption for heating and cooling of residential buildings in Mardin, however its U-value is almost three times higher than the other walls. On the other hand, dynamic thermal evaluation shows that energy consumption of the building with different wall details are different in the same city in spite of their equal U-values. Moreover it has been concluded that the same wall detail is providing different heating and cooling loads for residential buildings in Istanbul and Mardin. Therefore, we can say that the modern buildings in South-eastern Anatolia, which are constructed according to this standard, cannot correctly respond to the climate of the region and these two cities should not be considered in the same zone as the standard did by using degree-day concept. The results of the theoretical study are also confirmed by the results of the field study including the both of measurements and the users' perception in questionnaires, which have been done in hundred houses with both traditional and modern samples in Mardin.

Another conclusion of the study is; a truly intelligent building should provide comfort to its occupants while consuming minimum energy and working in harmony with its environment. It has to have some humanistic features like constant responsiveness to change in the environment and ability to learn. It should be self-adjustable. Moreover, to ensure high level of energy efficiency, intelligent building should benefit from the natural sources and minimize the need to import energy from nonrenewable sources. In order to achieve all these goals, design of an intelligent building should start at the early design stage and include passive solar approaches. Parameters like orientation and location of a building, shape and form, building envelope should be taken into account and analysed by designer at the initial design stage to obtain optimum solution specific to each building. The results of case study building energy analysis show that the energy savings and improvements in human comfort can be achieved with application of the passive solar intelligent approach to buildings. It is easy but also wasteful of recourses to rely on artificial means to keep occupants comfortable rather than designing the building itself for comfort. Buildings should be designed to stay comfortable passively. Reducing the thermal load passive solar methods can also reduce construction costs, downsize the mechanical equipments, minimize operating expenses and of course bring significant amounts of savings by making more energy efficient buildings.

6. References

1. International Energy Agency, Online Source, www.iea.org
2. Vitrivius, (1960). *The Ten Books on Architecture*, Dover Publication, New York.
3. Yılmaz, Z., (2004). The Effect of Thermal Mass on Energy Efficient Design, *VI. International HVAC+R Technology Symposium,* Istanbul, Turkey, May 12-15.
4. Osanmaz, I., (2005). *The Evaluation of Heating Energy Conservation Standard for Buildings for Hot-Dry Climatic Zone of Turkey,* Master Thesis (advisor: Z. Yilmaz), Istanbul Technical University.
5. Holman, J.P., (1986). *Heat Transfer*, 4. Ed., New York, Mc Graw Hill Book Co.
6. Yilmaz, Z., (1987). Evaluation of Built Environment from Thermal Comfort Point of View, *ASHRAE Transactions*, Vol.93 Part I.
7. Anon. (2004). *Turkish State Meteorology Headquarter Publications*, Ankara.
8. Anon. (2004). *Turkish HVAC Engineers Handbook,* Istanbul.
9. Anon. (1998). *Turkish Standards- TS 825: Rules of Heat Insulation in Building,* 1998.
10. Yılmaz, Z., (2007). Evaluation of Energy Efficient Design Strategies for Different Climatic Zones of Turkey: Comparison of thermal performance of buildings in temperate humid and hot dry climate, *Energy and Building*, Vol.39, No.3, s.306-316.
11. Sohmer, M., (2005). *Communal Energy Management,* Master Thesis (advisors Z.Yilmaz, U.Eicker), Istanbul Technical University and University of Applied Science Stuttgart.