DEÜ MÜHENDİSLİK FAKÜLTESİ
FEN VE MÜHENDİSLİK DERGİSİ
Cilt: 10 Sayı: 1 sh. 1-14 Ocak 2008

RESEARCH ON ARCHITECTURAL DESIGN AND CONSTRUCTION OF ENERGY EFFICIENT APARTMENT BUILDINGS IN IZMIR

(İZMİR'DE ENERJİ ETKİN APARTMAN TASARIMI VE YAPIMI ÜZERİNE BİR ARAŞTIRMA)

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ABSTRACT/*ÖZET*

It is a known fact that most of the energy consumed daily is produced from nonrenewable fossil fuels. When the energy used in the world is consumed in the building sector is considered as corresponding to nearly half of the worlds' consumption, the importance of energy efficiency in buildings becomes self evident. The amount of energy consumed in buildings is related to both the decisions made at the design phase like orientation, architectural design, material decisions and the behavior of the users. The aim of this study is to determine energy problems in residential buildings and to investigate architectural design and related technological measures as a solution to these problems in the apartment buildings for city of Izmir. Chosen buildings share the same microclimate and orientation yet their construction methods differ. The existing relationship between energy consumption and architectural design is evaluated with the help of a field study model proposed and carried out in Karşıyaka district of Izmir, Turkey. As a result, it was found that the examined buildings were designed according to the economical use of land while disregarding the climatic data of the surrounding environment. Reduction of some problems in the usage and maintanence phase would be possible with design regarding the climate.

Her gün tüketilen enerjinin çoğunun yenilenemeyen fosil kaynaklardan üretildiği bilinen bir gerçektir. Dünyada tüketilen enerjinin yarısından fazlasının yapı sektöründe tüketildiği göz önüne alındığında yapılarda enerjinin etkin kullanımının önemi ortaya çıkmaktadır. Yapılarda tüketilen enerji miktarı tasarım evresinde alınan yünelim, mimari tasarım, malzeme kararları ve kullanıcıların davranışlarıyla ilişkilidir. Bu çalışmanın amacı konut yapılarında karşılaşılan enerji sorunlarını belirlemek ve apartman yapılarında bu sorunlara çözüm olarak mimari tasarım ve ilgili teknolojik önlemleri İzmir kenti için araştırmaktır. Seçilen yapıların mikroiklimsel ve yönelim özellikleri aynı olup yapım sistemleri farklıdır. Enerji tüketimi ve mimari tasarım ilişkisi İzmir'in Karşıyaka ilçesinde gerçekleştirilen bir alan çalışması ve anket yardımıyla değerlendirilmiştir. Sonuç olarak, incelenen yapıların planlaması, bulundukları çevrenin iklimsel verilerine bakılmaksızın, arsalarının ekonomik kullanımına gore tasarlandığı tespit edilmiştir. Yapının kullanım aşamasında ortaya çıkan bazı sorunların azaltılması, tasarım yaparken iklimsel verilerin göz önünde bulundurulması ile mümkün olabilir.

KEYWORDS/*ANAHTAR KELİMELER*

Energy efficient architecture, Passive system, Active system, Apartment building architecture
Enerji etkin mimarlık, Pasif sistem, Aktif sistem, Apartman mimarisi

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1. INTRODUCTION

Designing and orienting buildings with relation to nature (and environment) to benefit from natural resources available to the site is not a new concept. In fact, it is one of the keystones of architecture. Though with the industrial revolution, many changes were wrought with the availability of serial production and easy transportation, architectural outlook continues to evolve with relation to lifestyle and comfort standards of users.

In search of the better, more beautiful and more comfortable buildings new building materials, techniques and technologies are devised. New indoor conditions, sometimes even isolated from the environment, are created with the ideal needs for bodies in mind by using the latest technology has to offer. Today, environmental conditions fit for a king in the Middle Ages is not acceptable even for the most poor in many countries (Behling and Behling, 1996).

1.1. Problem Description

New residential buildings are continuously being built to meet the sheltering needs of humans due to the population increase, thus, cities continue to grow and new settlements arise. Today a big part of existing building stock consists of residential buildings. In this setting, projects with the basis of using energy efficiently and using renewable energy sources are increasing. Consequently "energy efficiency" concept in architecture is born. The scope of energy efficiency in architecture generally lies in the discussion of methods developed to improve energy efficiency and energy efficient design strategies. Nevertheless, discussing why these methods and strategies are not applied commonly in practice is also necessary.

Energy policies are an integrated part of sustainable development plans, especially in the developing countries. Various targets for energy consumption in buildings are found in each country's energy policy, codes and regulations.

In Europe, nearly 50% of energy consumption is consumed for the buildings' heating, cooling and lighting needs (Schittich et al., 1999). In the European Union, the energy consumption distribution for the tasks in residential buildings during operation phase is 57% for space heating, 25% for water heating, 11% for usage of electrical appliances and 7% for cooking (Menna, 2003). As for Turkey, DİE (Governmental Statistics Institute) has published the value of heat loss per building as 200-250kWh/m^2 (DİE, 1998). However, by making energy conscious architectural design decisions, it is possible to decrease energy consumption in buildings. It is assumed that the energy consumption of new buildings can be decreased by 50% with the help of TS825 "Heat Isolation Codes for Buildings" in 1999 and "Heat Isolation Regulations for Buildings" in 2000.

1.2. Aim and Scope of the Research

Energy consumed in the buildings is closely related to decisions taken during the architectural design processes such as orientation of building to the sun, massing, spatial design, materials used and detailing as well as the occupants' habits.

Energy is used in the buildings as part of construction, operation, reconstruction, demolition and recycling phases. Since energy can be used in buildings in various ways, its assessment is very difficult. Only the energy usage in the building operation period is taken into consideration within this study.

It is proven, by both experiments and calculations that the energy needs of a conventional building can be considerably reduced by careful planning and implementation of solar processes and other technologies, yet these technologies are not commonly implemented in the design process. The aim of this research is to find out how conventional design and construction methods effect energy usage in İzmir by determining what users appreciate or find problematic in their buildings.

İzmir is Turkey's third biggest city and lies by the Aegean coast. İzmir has been an important commercial center as a coast city in the historical course, today its cultural and touristic identity is in the forefront. It takes immigration from rural parts and other cities. These population movements make it imperative to attentively analyze the residential formations. Also, the city of İzmir has great potential in energy saving with both having favorable Mediterranean climate conditions that help the challenge of designing climate conscious buildings, which would help reduce the energy consumption greatly, and in having good access to many types of renewable energy; like sun, wind and geothermal; for most of the city area.

1.3. Methodology

This study is comprised of two parts. In the first part; physical, geographical and climatic characteristic data of İzmir city, which is required to generate energy efficient architectural design criteria, have been assembled. In the second part, a field and questionnaire study is proposed and carried out in the existing texture of Karşıyaka district, to evaluate the existing relationship between energy consumption and architectural design (Tokuç, 2005).

2. CITY OF IZMIR

In the determination of architectural design criteria and selection of solar process systems, climatic and geographical characteristics of the site play an important role.

İzmir is on the 38º 43' N latitude, 27º 17' E longitude and is 25 m above water level. It belongs to the "Middle" of solar climatic belts because of its mathematical position. It is on the northern hemisphere, in the "Temperate" climatic zone. With cool and rainy winters and hot and dry but humid summers, the "Aegean Cost" type of "Mediterranean Climate" is effective. The climate shows the characteristics of "Terrestrial Mediterranean Climate" with respect to distance to the sea, orientation and geographical forms (Demirbilek and Eryıldız, 1999).

Winter in İzmir continues from December to March. In no month does the average temperature fall below 0 ºC. The coldest month is January with an average temperature of 8.6ºC. The coldest day measured in many years has been in January 4th 1942 with -8.4 ºC.

Transition from inter to summer is usually fast. Hot and humid summer season is from the middle of March to September. The hottest months are July and August with average temperatures of 27.6 ºC and 27.2 ºC respectively. The hottest day measured in many years has been in August 24th 1958 with 42.7 ºC. Northern winds prevail in the İzmir Bay in summer months. Western "İmbat" winds, which carry coolness from the sea to the land, start near 10 o'clock at noon and goes on till 18 o'clock in the afternoon. İmbat winds somehow lighten the effects of the oppressive hotness. Although in some days, northern winds carry hot air and cause distressing hotness. The most frequent winds are from the west. The average speed of summer winds is 3.4-4 m/sec (Figure 1).

Pressure and winds are not stable in the winter months. Prevailing cold winds are from the north and northeastern direction and they bring rain. Winds with the highest blowing frequency are from the southwest. The average speed of winter winds is 4.6-6.1 m/sec (Gündüz, 1980).

Precipitation shows great yearly changes in a small area. More than half of the rain falls on December and January and the driest months are July and August.

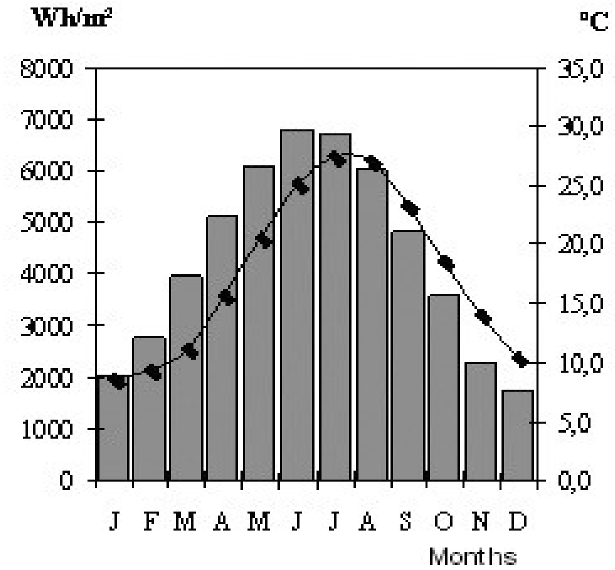

Figure 1. Izmir city irradiation and temperature

3. QUESTIONNAIRE STUDY

The center of İzmir metropolis encloses the İzmir Bay, likewise there exists a bond with the sea in most of the city. Therefore the studied cases are selected by the sea. In addition, since climate and microclimate plays an important role in the interrelation between architectural design and energy efficiency, another criterion for case selection is to have the same microclimate.

When we look at the above criteria, we see that the buildings selected to characterize a part of İzmir city are apartment buildings next to the sea. These buildings are mostly built by using reinforced concrete skeletal system on site. These buildings are built by “conventional technique”. However, in some housing practices, tunnel formwork is used. While the number of these buildings built with this semi-industrialized construction technique is low, some of the advantages this construction system has makes us think it would be widely used in the future. The cases selected are a row of apartments in Karşıyaka district and Mavişehir I blocks built nearly 3 km further (Figure 2).

3.1. Mavişehir I

Mavişehir I project, which is constructed between 1992-1996, is the VIIth stage of a housing scheme in Bostanlı since 1969. The building site consists of two building islands with a total area of 260.000 m². The lot is acquired by filling the old Gediz River delta and the banks are organized by filling to the north. The lot is surrounded by Şemikler squatter houses, which are being reformed with Squatter Reformation Plan of İzmir Büyükşehir Municipality, to the south, by old Gediz riverbed to the west and by Atakent, a housing settlement, to the northeast and east. The site is situated 50 cm above sea level.

Figure 2. Case sites on Izmir city map

Mavişehir accommodates 2872 dwellings. It consists of 20 blocks of which 3 are 16-storeyed, 10 are 18-storeyed, and 7 are 19-storeyed and 88 villas. 12 of the blocks are prisms oriented to the south-north and 8 to northwest-southeast longitudinally. The questionnaire study has been carried out to 45 apartments of the 1142 apartments oriented northwest southeast. These blocks are lined up in two rows of four with 11 m. distance in between. Villas are situated between these two rows. The southern row affects the winter sun coming to the blocks behind it. The blocks all have the same plan and their area/volume ratio changes from 0.6 to 0.55 according to their heights. Their length is 51.6 m. The building length/depth ratio is 2.3 at the sides and 4 at the middle of the blocks (Figure 3).

The facades of blocks are mostly symmetric. In the southeast and northwest facades lie 4 bedroom windows. The transparency ratio is 20%. In the southwest facade, there is hierarchy between function of the spaces and appearance. While the living rooms, kitchens and balconies project outwards, in the centre are six rhythmical room windows. The transparency ratio is 42%. In the northeast facade the fire stairs, which are not symmetrically placed, are made visible with the use of hollowed concrete blocks. In addition, the hierarchy between the outer appearance and inner function is broken by setting back a living room. The transparency ratio is 50%.

Although the blocks give a strong sense of symmetry from the outside, their plan scheme is not symmetrical. Each block has two entrances. It is possible to reach four apartment units from each entrance, thus there are 8 apartment units in a floor. The circulation is solved near the centre with the fire stairs placed to the northeast. There are 4 three-room, 2 four-room, 1 one-room and 1 two-room apartment units on each floor. 4 of the units are corner unit and 4 are middle apartments units. 3 of the corner apartments are 3-rooomed and one is a 4-roomed (Figure 4).

The living rooms of the corner apartments face either southwest or northeast and are situated between the living room balconies and the kitchens. Some of the users of these apartments are troubled because they can only see the next block or water evacuation canal from their living rooms while two of the bedrooms face northwest or southeast and the southeastern ones have a view to the bay.

Figure 3. Mavişehir 1

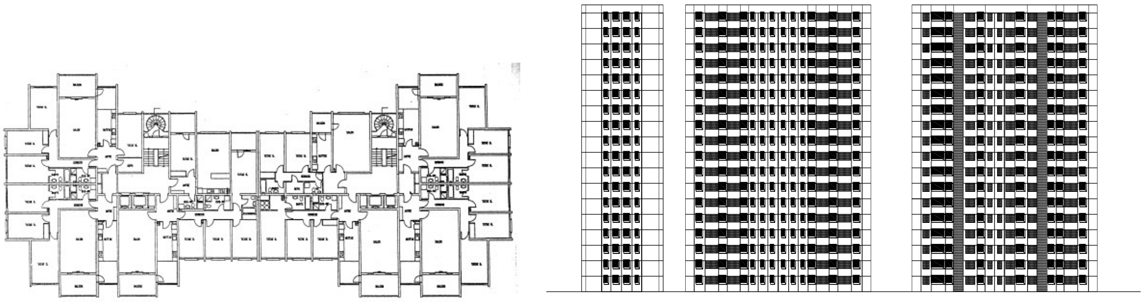

Figure 4. Plan and facades of the Mavişehir I blocks

The middle apartments facing west are either 3-roomed or 4-roomed and their living rooms are behind their balconies like the corner apartments. One of the rooms of the 4-room apartment faces east and has its own balcony. The living rooms of the middle apartments facing east are directly related to the outside. In the one-room apartments, the living room and kitchen are together and room has a balcony. In the two-room apartments, the balcony gives service to both the living room and the kitchen.

Structural elements are reinforced concrete walls constructed using tunnel mold. Nonstructural facade walls are prefabricated elements mounted on site. These elements consist of two concrete blocks with styropore heat isolation in between. The structural walls are isolated with styropore from the inside. The windows are PVC with blinds. Partition walls are gypsum.

3.1.1. User Profile

73.2% of the users answering the questionnaire are owners and 59% are the first users of the apartments. In 53.7% of the apartments live 4 people and in 36.6% live two/three people. 51.2% of the users are dwelling there for five to ten years and 34.1% for one to five years.

3.1.2. Survey of Energy Usage

The space heating system is central system using fuel oil. Although the system is successful when in use, since the prefabricated elements do not store heat spaces cool rapidly after it is closed. 35% of the users declared they have heating problems and 34% of these users use auxiliary electrical devices to heat in winter (Figure 5).

Natural ventilation is used to prevent overheating in the summer. 56.1% of the users declare they find this method insufficient. It is conspicuous that most of the users declaring insufficiency in the method live in the middle apartments rather than the corner apartments. The users not comfortable with space cooling declare they use air- conditioners, especially in the spaces they use most (Figure 6).

Natural ventilation method is used in ventilation of the building. 31.6% of the users declare they have problems due to ventilation. The users declared different problems due to their apartment types. While draught is a problem for the corner apartments, the middle apartments are found very stuffy. The ladies find air movement in the kitchen inadequate (Figure 7).

34.9% of the users are not satisfied with day lighting and say that especially the living rooms need more light. The hot water needs of the apartments are provided for 24 hours a day by central system using fuel oil. 63% of the users say they choose to use energy efficient electrical appliances to lower the energy consumption, but only 17% mounted intelligent counters to their apartments (Figure 8).

3.1.3. Evaluation of Questionnaire

Only 17% of the apartments surveyed are not changed architecturally. When assessed with other questions, it is seen that these untouched apartments' users are tenants.

Most common architectural change is closing the balconies. 46% of the users have closed their balconies and 32% of the users who have not closed their balconies show a desire to close them if they have the means. All of the users who have closed their balconies declare an aim to be protected from the outer elements. In addition to this, 50% of these users say they desired to have more space and 50% say they wanted to be protected from the wind. Second most common architectural change is to change the floor coverings.

The users said they wanted to change the windows the most when they were asked to define what kind of architectural change they wanted to do most if they had the chance, while 29% of the users declared they have already changed the windows. All of these users said they changed their windows with the aim to improve thermal performance. 53% of these users said they also wanted to improve sound performance and 48% of these users also wanted to change the aesthetic properties. Especially the users having windows facing the sea complain of the quality of the windows.

When it was asked if they wanted to change the places of the walls only 12% of the users have answered in the affirmative, which is positive also since the construction system is tunnel mold and it is not possible to make too many changes inside the apartment. The percentages of users declaring they are comfortable with their apartment's architectural design are: due to heating, cooling, natural ventilation and daylighting by 73%, 76%, 88% and 76% respectively.

3.2. A Building Block at Karşıyaka Yalı

Karşıyaka district has shown a big transformation in 20th century. The lots by the sea have evolved from fruit gardens to houses and apartment buildings. Municipality has filled the sea belt, realizing bigger roads and additional green areas. With the filling studies to the Gediz river delta on the shore, Bostanlı and Mavişehir neighborhoods are added to the Karşıyaka district.

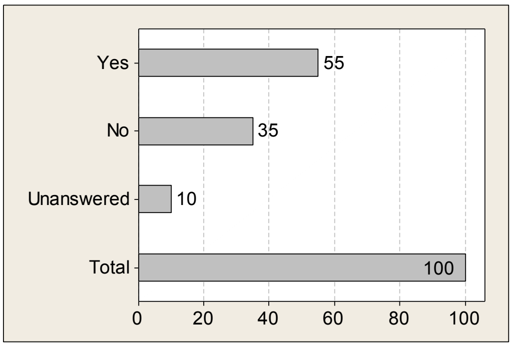

Figure 5. If you have heating problem, is the proposed method sufficient for you?

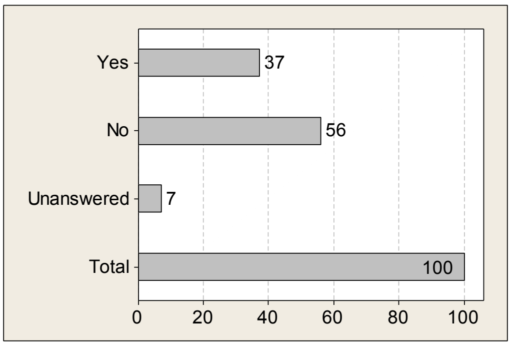

Figure 6. Can you dwell comfortably without taking measures for overheating in summer?

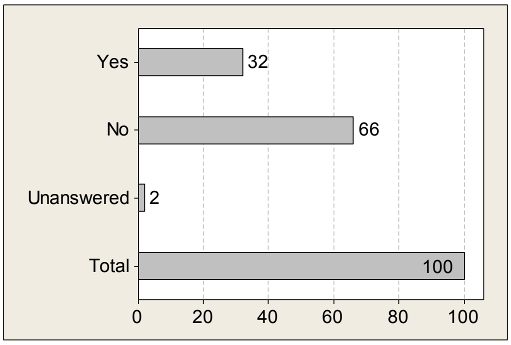

Figure 7. Do you have any problems with ventilation?

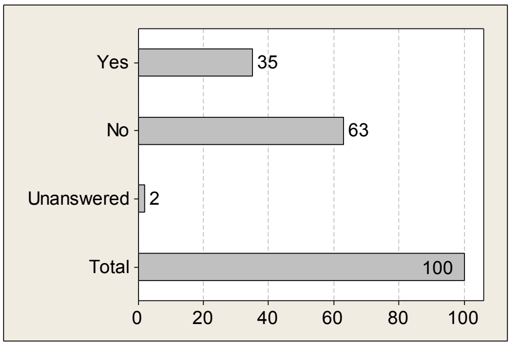

Figure 8. Do you have problems with daylighting?

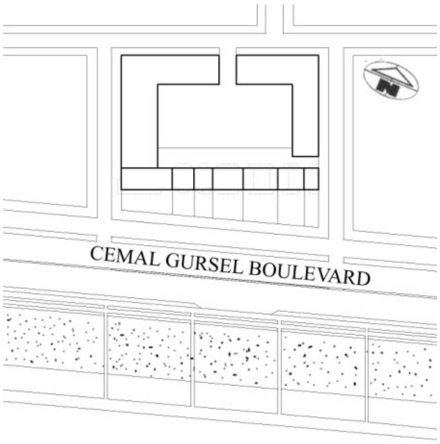

Figure 9. Site plan for Karşıyaka row apartments

A building block, which resides on Karşıyaka Yalı, between streets 1746 and 1748, is examined in the questionnaire study. This building block consists of 7 apartment buildings numbered evenly between 406 and 418. These buildings are situated parallel to the main street and mainly have facades facing southeast and northwest (Figure 9).

One of the buildings examined has seven, another has eight and the remaining five have nine floors. Four of the buildings have shops in their ground floors. There are a total of 73 apartment units. The selected buildings form a side of a courtyard. The courtyard contains and the gardens of surrounding buildings and car parks. Passing under the three buildings numbered 406, 408 and 410 to park the cars in the garden is possible. Between the building and sea are situated a lane for car parking, three lane roads for two directions, bus stops, bicycle road, tennis courts and pedestrian walkways. Shadows on the southeast facades of buildings only come from the palms planted on the pedestrian way.

Although the building depths are approximately the same, the facade widths change from 5 to 17,5 m and the floor heights change from 2,80 to 3,40 m. The total width of the block facade is 68 m. The building width/depth ratio changes between 2,33 and 0,625. The building area to volume ratios of the buildings change from 0,2 to 0,28. Only southwest and northeast facades exist for the non-corner buildings. However since the number 418 has another apartment adjacent on the north side, so its northeast facade does not have a balcony, but the southwestern balcony continues to the southeast.

The building facades are different from each other. In the southwest facade; usually the living rooms and in some buildings the kitchens or balconies of a room are projected. The transparency ratio of the facade is 65%. In the northeast facade the balconies project outwards. 60% of these balconies are closed and included to the inside. Although mainly glass partitions are used to close these balconies, some are closed with balustrades or brickwork. The transparency ratio is 42%. The transparency ratio of southeast facade is 40% while the transparency ratio of northwest facade is 24% (Figure 10).

There are two plan scheme types for the buildings; either there are two apartments per building served by a central stairway (with a recessed garden for the loft) or there is one apartment per floor with a central stairway and lift.

Figure 10. Southwest facade of Karşıyaka row apartments

Four buildings of the seven have one apartment per floor. These buildings are all between other buildings in the row and have only two facades. The placement of living room in the southwest looking at both the main road and the sea is common in all plan schemes. Another room or kitchen is placed next to the living room when there is space in the facade. Bedrooms are placed to the northeast facade. Wet spaces and service spaces are solved in between.

Number 418 is a neighbor to 1748th street. It has seven floors and all floors except for the loft have two apartments. At the corner apartments; living room and a room face southwest and living room and kitchen face southeast. It is possible to reach all spaces from the entrance hall. At the same time a washbowl is placed in a niche in entrance hall. The loft is set-back and has only one apartment. The elevator in the building serves only this apartment. The plan scheme of numbers 416 and 414 resemble each other. Both have nine floors and the singular apartment units are reached with the help of stairway or lift from the entrance door. Only the living room faces southwest. The reflection of the living room to the facade is different. While in number 416, a balcony protrudes from front of the living room, in number 414 the living room itself projects and the two balconies on each side of the living room are set-back. Number 412 has nine floors and has one apartment on each floor. Living room both projects outside and is recessed on the point where the balcony resides. Two circular columns are seen inside the balcony. Numbers 410 and 408 resemble each other in plan schemes. Number 410 has eight floors whereas number 408 has nine. Cars can access the back garden from the ground floor. Entrance to the buildings is placed near the centre of the buildings. One can reach the core of stairway and lift from this entrance. Number 406 is next to 1746th street and has three facades. An apartment is placed on each floor of the building. The buildings are constructed using conventional reinforced concrete construction methods. The outer walls are built from bricks. The windows are from aluminum or PVC.

3.2.1. User Profile

69,4% of the users are apartment owners and 16% are also the first users of the apartments. In 37,3% of the dwellings 4 people reside and in 46,6% two or three people live. 43.8% of the users have dwelt in the dwellings for from five to ten years time and 37,3% have dwelt for longer than ten years.

3.2.2. Examination of Energy Usage

Space heating systems are either central systems using coal or apartment-based systems using fuel oil. Living rooms, with their southwest exposure, are places that can be lived in without heating except for two winter months. 88% of the users in the questionnaire have reported they do not have heating problems in winter (Figure 11).

Natural ventilation, sun breakers, air conditioners, ventilators and sun reflecting glass are used to prevent overheating in summer. Air conditioners are used in every apartment (Figure 12).

Natural ventilation is used for ventilation. 23% of the users said they have problems with ventilation. 37% of the users say they use electric fans in addition to air conditioners to create air movement (Figure 13).

Although 88% of the users say they are content with natural lighting all users say they use elements like sun breakers, Venetian blinds and curtains to prevent excessive light in spaces oriented to south, southeast and southwest (Figure 14).

Hot water requirements of the dwellings are solved by different systems such as central, apartment based or electrical thermosiphonic heaters.

37% of the users reported they choose and use instruments that use less electricity for lessening electricity consumption. 58% of the apartments have intelligent electric meters installed.

3.2.3. Evaluation of Questionnaire Results

There are many differences between Mavişehir I blocks and apartment blocks in Karşıyaka Yalı; mainly of construction techniques, time of construction and orientation.

Many architectural changes are made in all of the studied apartments. The biggest architectural changes are done before new owners start dwelling in the apartment.

The users define these changes as "We built the inside again leaving only bare walls." The most carried out change was to change worn out floor and wall coverings, doors, and windows. The replacement of aging water or electrical installations was evaluated in this phase. It is conspicuous that 60% of the balconies facing northeast are closed.

Mavişehir I blocks have been designed as a new housing scheme, giving the designer a freedom that does not exist in Karşıyaka buildings. This freedom can extend from site planning to mass and volume relationships and space orientation. However, while the users are content with the relationship between spaces, an analysis of site and questionnaire studies on the topics related to energy use such as "space heating", "space cooling", "space ventilation" and "space lighting".

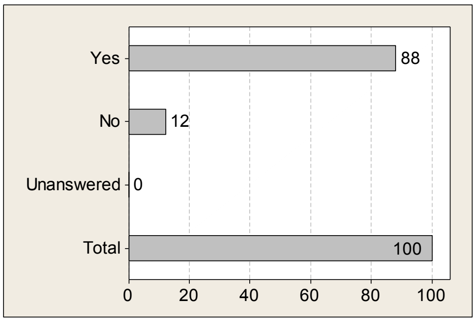

Figure 11. If you have heating issues, is the method provided sufficient for you?

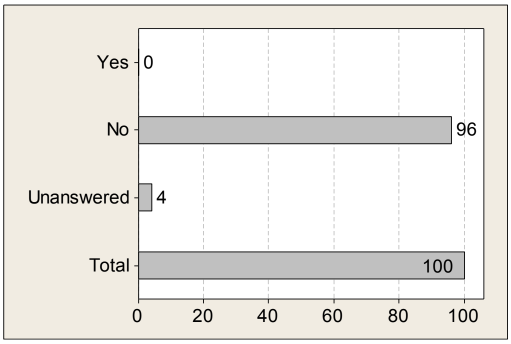

Figure 12. Can you dwell comfortably without taking measures for overheating in summer?

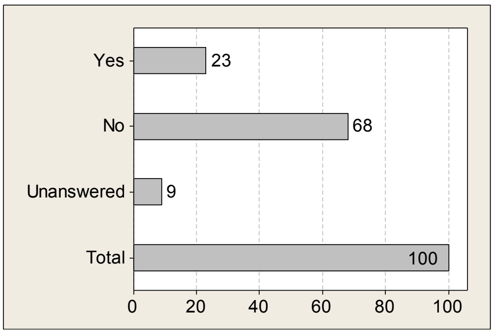

Figure 13. Do you have problems with ventilation in the dwelling?

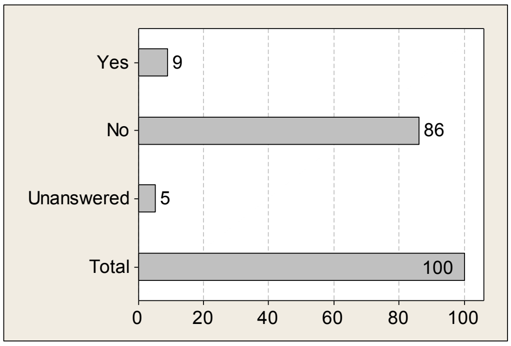

Figure 14. Do you have any problems with daylighting?

The users of Karşıyaka block are more content than Mavişehir I concerning space heating. We can see the orientation as an important design factor. When the examples are compared due to overheating problems, the factors that help heating in winter cause adverse effects. Although the number of users that say they can dwell in Mavişehir blocks with only natural ventilation in summer are many, nearly every apartment has air conditioning units can easily be seen from the outside. The users in Karşıyaka say they are content with cooling with the help of air conditioning units. Similar results are reached in the topic of space ventilation, although nearly every space in Mavişehir I blocks have access to exterior while there are most spaces which look to skylights in Karşıyaka Yalı blocks. Users have reported that they are comfortable as long as the spaces they spend most of their time in are lighted. Although the living rooms in Mavişehir I blocks are dark, in Karşıyaka blocks there is glare problem due to too much sunlight. Glare was a problem even if precautions were taken with shading elements.

4. CONCLUSION

Different studies aiming to decrease the energy consumed in buildings with the help of architectural design and yielding the most from used amount of energy are being conducted. Yet it is interesting that, although the usage of energy efficient design strategies would be beneficial to human comfort, users' budget, national treasure, social costs etc., in spite of all these studies these methods are not being used.

To investigate and learn about commonly implemented methods and technologies in existing buildings and how much the user likes or dislikes them, a field study and survey method is proposed and carried out in a small scale for İzmir city Karşıyaka district. The results of this research are as follows:

- The examined buildings were designed according to the economical use of land while disregarding the climatic data of the surrounding environment.
- Thinking about the problems that may arise in the operational phase of buildings will result in less risk of damage to the aesthetic quality in the future.
- Users think that buildings and their architecture is not responsible for internal environmental comfort but mechanical environmental systems are responsible.
- Users like to change the old dwellings they bought before starting to live there according to their own personal needs. These changes can be spatial, infrastructural, building element based and others. The most applied change is to change building elements that have served their time such as; floor covering, wall covering or window work. In addition to these, users close balconies not used for reasons such as creating buffer zone with environmental conditions and gaining additional space when legal or aesthetics are not an issue. They also install intelligent electrical meters and prefer buying equipment that uses energy efficiently.
- Users cannot implement the changes they want if the dwelling does not belong to them.
- Although air conditioners are adopted as a solution to overheating and ventilation problems by the users, they are not thought in the architectural design stage causing ugly sights. Similar problems may arise on the facades also with elements such as louvers.

Although these results are drawn at the end of a field and survey study, it has to be kept in mind that the evaluation could only be done in a rather concentrated area as far as İzmir city is considered, and the users of the evaluated buildings all have high income. More studies and evaluations would allow for a better definition of the problem and healthy solution proposals.

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