Energy Efficient Building in Third Climatic Region of Turkey

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Abstract: Residential and commercial buildings consume a considerable amount of the energy produced in Turkey. 82% of that consumed energy is heating related. A reduction to 25% to 50% of energy consumption is possible with only proper insulation of these buildings. Fossil fuels such as coal and petroleum produce CO_2. Tests have shown that CO_2 levels have reached 360 ppm in Turkey. In this context, buildings that are efficiently designed and configured will provide energy savings. Energy efficiency in buildings in Turkey, has gained prominence recently with the adoption of the Directive on Energy Performance of Buildings in 2008. The object of this study is to convert a building, located in the 3rd climatic region in Turkey, to an energy efficient one. Analysis of the building has revealed that it does not accommodate the TS 825 s tandards. New thermal insulation design has cut energy consumption estimates to 37,09 kWh/m^3, which is within the limits of regulation codes.

Keywords: *Energy Efficient Building, TS 825, Energy Performance of Building.*

1. Introduction

Fossil fuel reserves that provide a significant amount of world's energy requirement are rapidly coming to an end. Using energy resources efficiently is significant. It has been emphasized in several studies that only by using energy efficiently provide savings on energy consumption at the rate of 30% annually.

In Turkey, 82% of energy is used for heating. It is possible to provide 25% to 50% fuel savings only by building insulation. It is seen that the released CO_2 level as a result of fosil fuel burning is 360 ppm nowadays. Carbondioxyde is relatively 55% more efficient than other greenhouse gas on c ausing global warming. Therefore it is required that the living environments must be designed and configured to provide energy savings and efficient energy usage. In this study, by taking into consideration the requirements mentioned above, it has been intended to turn a building which is in Ankara, Gölbaşı in the third region, on the lakeside of Lake Mogan, away from the tall buildings, frontal to highway, having its own garden, independently oriented; consisted of a ground floor, one normal floor and a penthouse to an "Energy Efficient Building".

2. Heat insulation project

2.1. Heat insulation project for the current building

Considering the indoor temperature as 19°C in accordance with TS 825 Heat Insulation Regulations, conformity to standard has been reviewed by designing heat insulation project for the current non-insulated building. In the analysis for the current building, while the limited energy requirement is 33,77 kWh/m^3, calculated energy requirement for the building was 86,40 kW h/m^3. As it stands the building is not confirmed to TS Standard no 825 on Rules of Heat Insulation in Buildings in Turkey.

2.2. Variations on the architectural project and insulation application

To provide the building's conformity to TS 825 and reduce the energy consumption, various variations on external structure and roof has been proposed. Changes has been occured on the walls, windows and roof of the building as a result of the reconsiderations mentioned below and the analysis has been repeated in accordance with TS 825. Reconsiderations for the building were:

Window space has been increased on the south frontage of the building. 62% of window space increase on south frontage and 45% on total has been provided.

Roof gardening has been applied on the South and North frontages of the roof.

As a result of roof gardening application, the South frontage space of the building and the penthouse window space have been increased.

As a result of roof gardening application, “open air roof space” has been emerged.

Shadowing has been done on the North side of the building by planning evergreen plantation.

As a result of the studies made to provide conformity to TS 825 for the building, rockwool of 6 cm thickness for outdoor air contacted areas and 8 cm thickness for unheated inside walls have been used. 12 cm thick glaswool on the roof areas of the ceiling and 10 cm foamboard on open air roof because of the roof gardening application have been used in accordance with the fire code. Thickness of insulating material on flor has been calculated, considering the energy balance of the building, as 10 cm of foamboard. 10 cm floating floor boards have been used on floors next to unheated areas.

Instead of double-glass used in current situation, Low-E plated heat insulation bridged aluminum windows which has an Up value of 2,4 W/m^{2}K have been used. 3 cm thick cement mortar has been used on the external wall in current situation. In the new insulated condition of the building; 7 mm thick anorganic based palstering made of lightweight aggregates has been applied on insulation instead of cement mortar because of the nonconformity to structure physics.

2.3. Heat insulation project for the new condition

As the heat insulation done in accordance with TS 825 Heat Insulation Regulations energy requirement for the building has been reduced from 86,35 kWh/m^3 for current condition to 37,09 kWh/m^3. Therefore energy requirement for the building has been reduced from 37,12 kWh/m^3 as presented in the standard and confirmed to TS 825 standard. Annual energy requirement of non-insulated building has been reduced from 71544 kWh to 28572 kWh, provided energy savings of 60% and reduced CO_2 release with the insulation.

The comparison of heat loss values for construction element before and after insulation can be seen in Figure 1.

3. Alternate energy sources

Troubles, affecting whole world such as global warming, climate change and greenhouse effect caused by the usage of increasing amount of fossil fuel and so energy usage, prompts communities to develop new and clean alternate energy sources. Accordingly, new solution offers for active and passive systems to reduce the energy consumption in the current building are as follows.

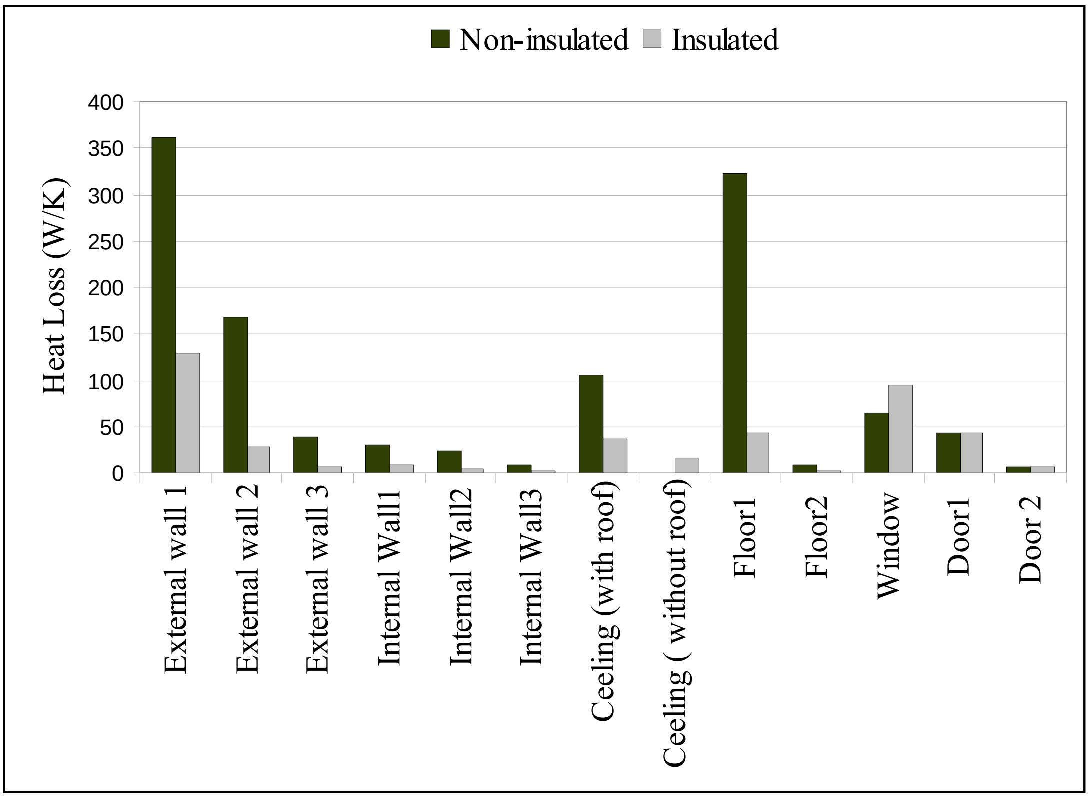

Fig.1. Heat loss for insulated and non-insulated conditions

3.1. Ground source heat pump application

To do heat insulation in accordance with TS 825 standard and to provide the annual building heating and cooling requirements which are reduced to minimum in virtue of passive methods applied, vertical type ground source heat pump application has been approved.

Energy requirement for the building has been calculated in accordance with TS 825 as mentioned above and distributions by months have been determined. As this distribution is reviewed it is seen that in January at the value of 20.497.178 kJ (7,9 kW) maximum energy requirement is occurred. Heat pump with 14,6 k W heating and 2,4 kW (EER=5,1) cooling capacity has been selected according to heating load. By calculating the cooling load of the building, solar collector has not been applied because in the system designed to be used both in heating and cooling seasons the heat pump will provide the required energy for both heating and cooling water usage. Analysis results for this design are presented in Table 1. Payback period for the planned system has been calculated as 11 years and 11 months.

When geological structure in Lake Mogan surrounding in Ankara-Gölbaşı region has been investigated, it has been understood that after a significant boring depth underground water is reachable [1]. Accordingly, specific thermal contraction capacity of stratas with underground water has been determined as 70-90 W/m [2]. It has been seen that 102 m borehole is required as a r esult of calculations below based on the peak load a h eat contraction capacity. Investment cost (device, pipe, boring and labor cost included) for this system is determined as 8472 TL. Fuel requirement is removed the heat pump will completely provide the energy needed for heating the house and generating hot water.

3.1.1. Economic analysis of active systems

Investment calculations, fuel savings and other additional cost (electricity consumption) belong to above mentioned active systems have been calculated and economically reviewed. Interest rate for the economic analysis has been considered 10% and "payback period" of the system has been calculated also considering the time value of Money.

The results obtained are presented below on Table 1. By considering interest rate as i = 10% and also considering the time value of Money, it has been seen that the system will return to profitability in 11 years and 11 months.

Table 1. Energy audit of the new investment and monetary values

	Heating (m^3 N.Gas)	Domestic Hot Water (m^3 N.Gas)	Cooling (kW)	Cooling (TL)	Investment (TL)	Saving (TL)	Additional Cost (TL)
Current situation	7647	340	12,3	1004			
Insulation	-4592				13722	2572	
Heat pump (heating)	-3395				10500	1901	-1356
Heat Pump (cooling)			-12,4	-393			+611
PV					1090		
TOTAL	0		0	+611	25312		-745
						Net Utility (NU) =	3728

Payback period (PP) is calculated according the equation below:

$$PP = \frac{\ln\left(\dfrac{\text{NetUtility}}{\text{NetUtility} - i * \text{Investment}}\right)}{\ln(1+i)} \quad (1)$$

$$PP = \frac{\ln\left(\dfrac{3728}{3728 - 0.10 * 25312}\right)}{\ln(1+0.10)} = 11 \text{ years } 11 \text{ months}$$

3.2. Heat storage in greenhouse, water wall and bedrock

Thermal storage is significant in direct solar energy recovery systems. Thermal masses allow storage and later usage of solar energy.

3.2.1. Greenhouse application

As one of passive heating systems greenhouse application has been applied on the building (Fig.1, Fig.2). Greenhouse is a structure which is on the South frontage, adjacent to the building. It has one-way inclined roof and its all areas are consisted of glass. Roof pitch is designed as 50° in accordance with incidence angle of sun beams for Ankara in winter. Therefore heat gain occurs in the areas next to the greenhouse. Glass used on greenhouse is a Standard insulation glass with a U value of 2,6 W/m^2K. By using this glass sun radiation has been utilized more effectively. At the same time heat loss from the glass has been tried to minimize. In virtue of the vents that positioned on the upside and underside of the greenhouse, it has been targeted to reduce the negative contribution to cooling load of the greenhouse by providing an air stream in hot summer days. Also with the help of shadowing components (jalousie) that will be placed on glass surface of the greenhouse and deciduous trees, it has been provided to reduce sun radiation that affect the greenhouse surface. As a result of thermal analysis of the design the total heat gain provided from the greenhouse has been calculated as 17,444 kW.

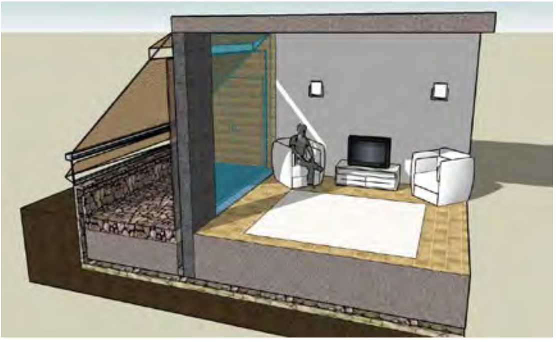

Fig. 1. Greenhouse, summer application (jalousie closed, went open)

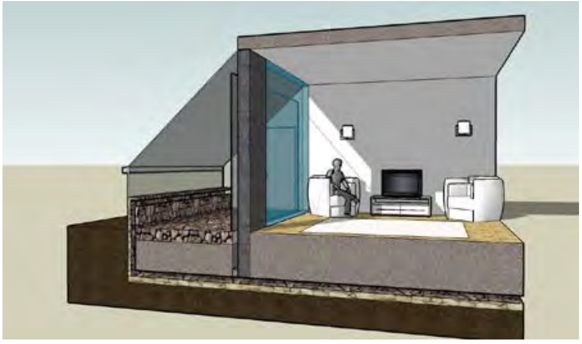

Fig. 2. Greenhouse, winter application (jalousie open, went closed)

3.2.2. Water wall application

Both to store thermal energy and to reduce light transmittance the wall that separates the greenhouse from the site has been transformed to a thermal mass by using two plane plexiglas board. In this application, by using water, which is a supply that has one of the highest thermal capacity (4160.103 kJ/m^{3}K), more heat has been stored and also it has been provided to increase the amount of sun beams entering the site because of the transparent surface [3]. With this thermal mass that is placed on south frontage sun radiation affecting the surface will be stored to able to be used in hours that we can not utilize the sun enough or none.

3.2.3. Heat storage application on bedrock

Bedrock has been formed as a thermal mass on the greenhouse or house floor to support passive heating of the house. It has been anticipated that by means of this thermal mass storing of excess heat accumulates in the greenhouse during the insulation and utilizing this energy when insulation is not enough [4,5,6].

It is provided to transform heat to rocks by sending the hot air which is drafted from between the water columns with a glass panel placed on front side of water columns, by means of the fan that is placed on the intersection point of the greenhouse floor and water columns. In virtue of two sensors, one is placed inside the greenhouse and the other on rock surface, fan only will work when the temperature in greenhouse is higher than rock heat. By this means, it is provided to prevent this cool air to reduce the heat of the bedrock. It has been targeted to rise apparent ambient temperature in virtue of the heat stored on r ocks which cause a temperature rise on floor heat.

3.3. Other passive system applications

Window spaces on the south frontage of the building have been increased to utilize incident rays in winter. Window space increase has been provided at the rate of 62% on south frontage and a total of 45%.

To prevent living spaces from extreme heating in summer because of new windows which have been placed to utilize the sun beams more effectively in winter, window shades in specific sizes have been placed on top of the windows. These components let the light in which comes with oblique angle in winter but reflect the light out which comes with right angle in summer.

Two lines forestation has been done on north to protect the building from north winds. No forestation has been done on South frontage of the building.

Natural air conditioning – vents have been place on North frontage to provide natural air conditioning in the building. These vents have been placed on stairs column, penthouse bedroom and living room walls. Pressure difference required for these vents to work will be occurred when the Windows on South frontage are open and by that air circulation will be provided.

Light shelf systems – Light shelf is a component which is designed to prevent the sun light entering and direct it to the ceiling and placed horizontal or almost horizontal on inner surface or exterior surface of the window. These components will be added to top sides of the windows afterwards.

Two-leaf glass frontage application – Glass frontage cladding has been applied on first floor bedroom and first floor living room to utilize the sun beams on south frontage and two vents are used on the walls. These vents have been placed on top corners and bottom corners of the wall as enter and exit.

Power generation with Photovoltaic panels (PV) – It has been seen that payback period for the system will be too long as a result of feasibility study on whether all energy requirement of the building that becomes independent on heating and providing hot water can be provided with renewable energy or not. In that case, it has been designed to provide electricity requirement for fire exit way illumination and smoke sensors with PV panels instead of entire energy requirement of the house. For this purpose a package unit that consists of 180 W solar battery, 1 charge regulator and control unit, 1 solar accumulator and 4 light bulbs (11 W, 12 V) has been selected to be placed on roof. Investment cost for this unit is 1090 TL and it is presented in economical analysis tables mentioned above.

Heat insulated garden roof terrace – Besides looking beautiful, roof gardening, which is very common in western Europe, also provides substantial economical and ecological benefits if it is applied with a safe water insulation and well planning [7,8,9]. Considering the draught in Ankara, water has become significant and roof gardening application has been decided.
Water saving and recycling – To reduce the utility water usage in the house it has been suggested to use type-A water saving sinks and double stage reservoir in bathrooms and to store the rain water handled in gutter and roof gardening to use in both toilet flush tank and watering the garden.

Chimney flue – No change has been made in the chimney which is on the North side of the current house. It has been thought that using the chimney in winter will provide heat gain on the colder north side of the house and also to utilize flue gas heat. Discharge shaft has been designed as a heat transformer to do that. In that design, by placing a second layer on flue gas brick it is targeted to heat the flowing air in between and return it to the environment. Therefore reduced heat requirement for the environment has been provided.

Phototubes (Cold light in hot day) – Sun light has the top quality light among lighting devices. Day light for first floor North bathroom, garage, mechanical room and the penthouse which has been made by roof gardening application has been provided by this system. Therefore there will be electricity saving at the rate of 30%-70%.

4. Conclusion

It is a fact that a significant part of energy consumption is occurred at our living environments, houses and working places. Therefore designing and configuring the living environments to provide energy saving and efficient energy use is a necessity.

In this study in virtue of heat insulation, active and passive methods applied to the building both energy saving and economical benefits has been provided. Energy generated, transmissioned and commercialized in our country has been used without squandering. When the applied methods are considered as a whole, 7987 m^3 natural gas and 10320 kg CO_2 release saving has been provided. In the second system that also the cooling load of the building is considered as well as the heating requirement 7987 m^3 natural gas saving and reduced electricity consumption has been provided. In that case CO_2 release saving has been 11847 kg.

Current building has been transformed into an “Energy Efficient Building” by applying heat insulation as well as other several active and passive systems and its ecological footprint has been reduced.

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