Thermal Performance Assessment of Existing Buildings: A Case Study From Turkey

Egemen Kaymaz [a] , Filiz Senkal Sezer [b]
[a,b] Department of Architecture, Faculty of Architecture,
Uludag University, Institute of Science and Technology Bursa, Turkey
[a,b] Corresponding author: filizss@gmail.com, egemensaritabak@gmail.com

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Abstract: This paper focuses on the thermal performance assessment of building envelope systems based on heat loss and heat gain through external walls, skeleton structural frame, wall openings, roof and ground floor using a national energy calculation program. An inspection case of an educational building, the external envelope of which is analyzed in terms of energy efficiency and U-values of components, is presented. Findings of thermal comfort survey which were drawn from the users of studied building are also briefly explained. The study consists of four main parts: i) literature review ii) evaluation of user satisfaction survey, iii) thermal performance assessment of building envelope by an insulation calculator software, and iv) a discussion of a proposed model focusing on a thermally improved external envelope. The findings of this study consist of attempts to develop a more robust external envelope in terms of prevention of thermal bridges, sufficient and proper insulation application, and improved enclosure protection against environmental factors. The calculation results show that it is possible to increase the thermal performance of building's envelope and reduce high heating energy demand with minor changes to facade design. This improved performance also creates a more comfortable environment for occupants by upgrading the living standards.

***Keywords**:* Computer based evaluation, Energy efficiency, Existing Building, Thermal performance

Introduction

The amount of energy consumption and its environmental effects throughout the life-cycle of buildings is gaining greater importance due to go green act. As the leading contributor of the socio-economic development in the world countries, the construction industry plays a significant role in energy consumption and energy-related environmental issues and pollution. Buildings appear to be one of the major contributors to restricted nonrenewable energy sources. Today, numerous investigations are carried out worldwide to determine the thermal performance of existing buildings' envelopes, as well as to improve users' comfort conditions. As part of literature review, case studies particularly investigating thermal performance assessment methods and the optimal conditions of comfort inspections are reviewed.

When analyzing the design and comfort conditions of the education buildings, Conceição & Lúcio (2008), Filippín (2005), Kwok & Chun (2003) and Baker (1982) have studied on related subjects with thermal comfort conditions. [1,2,3,4]. We have seen that such research papers conducted either with computer modelling and simulation or experimental analysis and measurements of buildings in-situ also took into account of energy preservation and consumption while providing thermal comfort conditions [5,6,7,8,9]. The authors dealing with subjects like the quality of interior air quality and ventilation are reviewed as; Clements-Croome, Awbi, Bakó-Biró, Kochhar and Williams (2008), Tippayawong, Khuntong, Nitatwichit, Khunatorn and Tantakitti (2008), Sohn, Yang, Kim, Son and Park (2008), Becker, Goldberger and Paciuk (2007), Khedari, Boonsri and Hirunlabh (2000) [10,11,12,13,14].
There are also research papers about environmental comfort conditions. On the other hand, Collet da Graça, Kowaltowski and Diego Petreche (2007) have aimed to evaluate indoor comfort conditions with different techniques [15] whereas Krüger and Dorig (2008) have focused on the importance of daylight and natural illumination in creating the optimal conditions of comfort in education buildings design [16]. There are certain sources in which planning and academic achievement in education buildings are studied through specific cases such as Narucki (2008) Chan (2001), Sleegers, van den Berg and Geijsel (2000), Cooper (1982), Maitreya (1979), and Ghaswala (1968) [17,18,19,20,21,22].

When aiming to reduce the negative impact of buildings on their occupants and nature, energy regulations and environmental policies play a crucial role in the life cycle effects of design, construction and operation stages. According to the EU's Construction Products Directive [23] and the Energy Performance of Buildings Directive [24], building and its parts must be energy efficient and fulfill performance requirements over an economically reasonable working life. With respect to heat losses and gains through building envelope, heating and cooling energy expenditure is required to be low as a primary building performance today. As a result, greater emphasis is given to use clean and renewable sources, integration of active-passive systems in buildings, energy efficiency of service systems and building shell.

Since thermal performance of buildings is now a major concern, architectural studies focusing on optimal performing solutions have gained momentum in new building projects. As part of the sustainable development strategy in the EU integration process, national legislation and regulations such as Energy Efficiency Law [25], Turkish Thermal Insulation Requirements for Buildings (TS 825), first published in 1981 and revised in 2008, [26], Directive on the Energy Performance of Buildings (BEP-TR) [27], and Energy Identity Certificate (EKB) are introduced or adapted to relevant EU directives to improve the energy efficiency of buildings in Turkey. Furthermore, Turkish Green Building Council (CEDBİK) is trying to develop a sustainable building assessment model based on local standards and solutions [28].

Though designing with the environmental performance criteria produces good results and buildings are rated and certified by various sustainability assessment tools, limited data exists regarding the thermal performance of building stock in Turkey in terms of energy efficiency and other ecological aspects. New buildings are required to possess at least a "C Class" Energy Certificate to obtain a Municipally Approved Architectural Project and Building License, demonstrated in Figure 1. On the other hand, no such restriction is currently in effect for existing buildings aside from being rated until 2017. According to BEP-TR, annual energy consumption of the building is calculated and rated within a scale "A to G", considering CO_2 emissions, thermal insulation properties, heating/cooling, hot water, illumination and ventilation system efficiency.

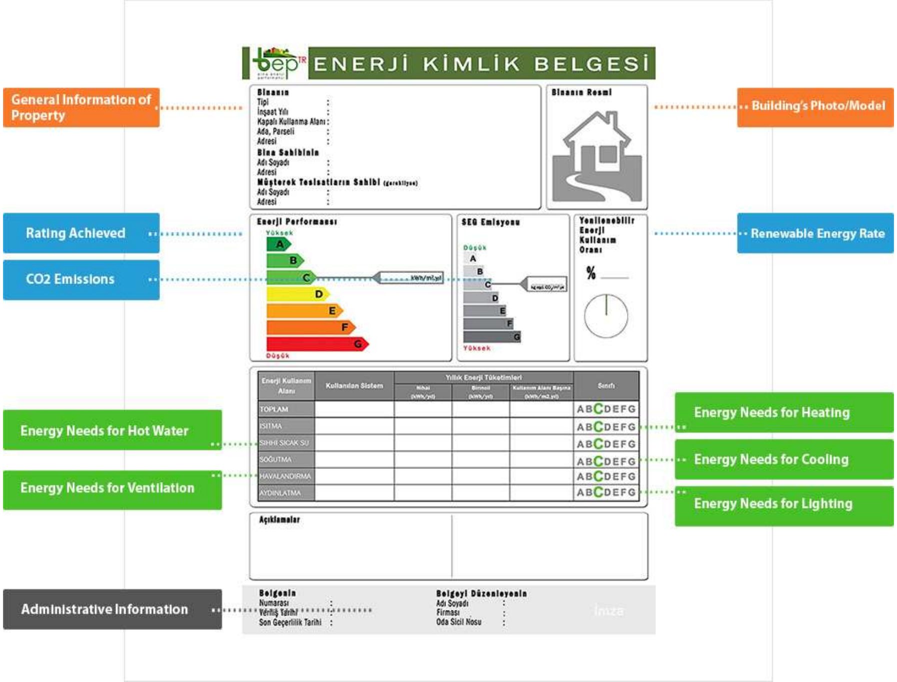


Figure 1: Energy Identity Certificate (EKB) in Turkey [27]

Existing building stock should be renovated to comply with the latest energy standards. TS 825 Insulation Standard specifies limited energy consumption and the acceptable U-values of building assemblies for different climate zones in Turkey. The new regulations have generally been quite effective on newly developed building zones; however in most part of the nation, the energy consumption of existing buildings is above the desired limits.

Research shows with heat insulation, % 20-50 heat saving can be achieved depending on the condition of the building. Considering the building stock consists of nearly 8 million buildings in Turkey, only 4% percent has Energy Identity Certificate (EKB), thus involving a potential for significant energy saving [27,29]. Investing in insulation of building envelope is therefore a sustainable way of rising comfort and air quality for users while reducing our reliance on fossil based energy.

Thermal performance of building envelope

As energy conservation is the leading issue of our time, thermal comfort is a primary aspect in almost all types of buildings. Heat energy flows through the building enclosure via opaque and transparent components by conduction, convection and radiation. Research maintains that the main energy losses through building envelope occur at external walls, roofs and windows [30]. To raise overall thermal resistance of the entire building envelope, heat transfer and temperature distribution through buildings elements and assemblies should be controlled by applying insulation as well as thermal bridges, unconditioned air leaks, moisture and dampness. Thermal performance properties expected from a building envelope can be regarded as: i) lower heat loss during heating period, ii) lower heat gain during cooling period, iii) capability of heat storage, iv) lack of air infiltration, v) keeping inner surface temperatures of required levels, and last but not least vi) lack of thermal bridges [26,31].

Energy efficiency, comfort and indoor air quality issues are mainly associated with thermal performance of building envelope is in terms of user requirements. According to American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Standards [32], thermal comfort is defined as "The state of mind which expresses satisfaction with the thermal environment". The comfort temperature is a result of the interaction between the users and the built environment they are occupying. The clothing level, type of activity and environmental variables such as air temperature, humidity, air velocity and radiation affect thermal sensation and satisfaction of occupants [33].

According to national Guidelines for Heat Insulation in Buildings Standard (TS 825), thermal comfort is defined as the least energy of the human body uses to adapt himself to the environmental conditions [26]. Indoor temperature of 19-22 °C and relative humidity of 55-65% are defined as necessary conditions to maintain optimal comfort. In addition to constant indoor ambient temperature, the temperature difference between exposed surfaces and indoor air is required to be no greater than ±3°C and maintain homogeneous throughout the year. The highest heat transfer coefficient (U-value) for the external building elements have been limited by the building regulations in Turkey, further discussed in detail.

Materials and methods

The computer-based design tools offering user-friendly graphical interfaces including three-dimensional visuals and animations have become a part of today's architectural design. Over the past 50 years, a variety of energy simulation technologies have been developed contributing to design and implementation stages of construction projects as well as improvements to do in the use stage. A comprehensive range of simulation data such as; heat transmission through building envelope, heating, cooling, ventilation and air-conditioning (HVAC) loads, fuel use, CO_2 emissions and energy consumption of lighting systems can be obtained using these energy simulation programs. Energy simulation tools worldwide used can be counted as Energy Plus, Design Builder, Radiance, Trnsys, Relux and Ecotect [34].

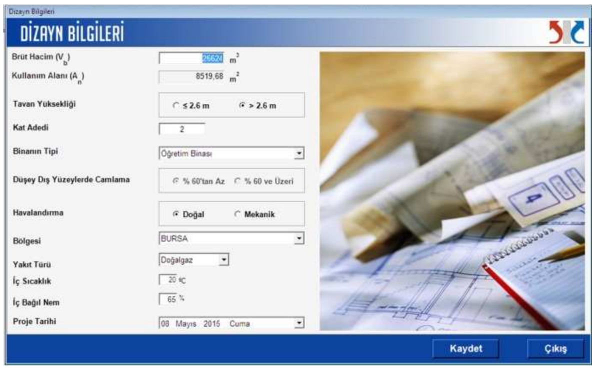
The aim of this study is to calculate an estimate and limited value of heating energy demand of an uninsulated building and to suggest savings alternatives without substantially altering the building's structure. In the present study, established software of Turkish Autoclaved Aerated Concrete Association (TGUB) was used to generate data applying the national Guidelines for Heat Insulation in Buildings standard, TS 825 [35]. The building is illustrated with Google Sketch-up Pro. 2015 3d virtual modelling program and thermal calculations are performed by TGUB v.4.0 software. Findings from thermal comfort and user satisfaction survey are also presented in this paper.

TGUB assesses the thermal performance of the building shell taking into account its orientation and assemblies. It is possible to make a quantitative assessment of building envelope via TGUB which comprises a calculation of heat gain and loss through the envelope, current and restricted heating energy consumption and the amount of condensed water in architectural components. Thermal loads and energy needs for heating can be derived for most building types and all climate regions in Turkey; however, the program does not include total energy needs such as cooling loads, electricity used for appliances and lighting as well as CO_2 emissions and cost of fuel etc.

The considered input parameters are illustrated in Figure 2 has been:

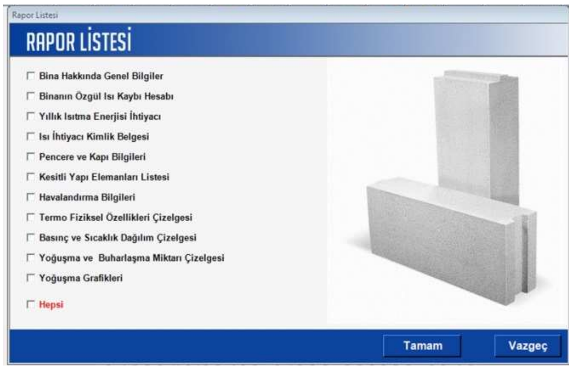
- the location and function of the building
- total floor surface area
- the net volume
- the height of the building
- the percentage of transparent surfaces on opaque surfaces
- geometrical data regarding to surfaces exposed to outdoor conditions and ground,
- the operative temperature and relative humidity set points
- fuel type

The required physical properties of architectural components can be determined either using software database based on TS825 standard or by adopting default values. Output data is shown on a monthly basis for one year period and lists of results are presented in MS Excel spreadsheets, shown in Figure 3.



Brüt Hacim (V_b) 25624 m^3
Kullanım Alanı (A_n) 8519,68 m^2
Tavan Yüksekliği ○ ≤ 2.6 m ● > 2.6 m
Kat Adedi 2
Binanın Tipi Öğretim Binası
Düşey Dış Yüzeylerde Camlama ● % 60'tan Az ○ % 60 ve Üzeri
Havalandırma ● Doğal ○ Mekanik
Bölgesi BURSA
Yakıt Türü Doğalgaz
İç Sıcaklık 20 °C
İç Bağıl Nem 65 %
Proje Tarihi 08 Mayıs 2015 Cuma

Figure 2: Building Design Data Input Interface of TGUB Thermal Calculation Program



☐ Bina Hakkında Genel Bilgiler
☐ Binanın Özgül Isı Kaybı Hesabı
☐ Yıllık Isıtma Enerjisi İhtiyacı
☐ Isı İhtiyacı Kimlik Belgesi
☐ Pencere ve Kapı Bilgileri
☐ Kesitli Yapı Elemanları Listesi
☐ Havalandırma Bilgileri
☐ Termo Fiziksel Özellikleri Çizelgesi
☐ Basınç ve Sıcaklık Dağılım Çizelgesi
☐ Yoğuşma ve Buharlaşma Miktarı Çizelgesi
☐ Yoğuşma Grafikleri
☐ Hepsi

Figure 3: List of Output Thermal Reports

Case Study

Bursa, the 4th biggest city, is located in the northwest of Turkey and the south-east cost of the Marmara Sea, in Marmara region. TS 825 standard divides Turkey into four climatic zones depending on average temperature degree-days of heating. Bursa locates in the second zone and the city's temperate climate is characterized with warm summers and mild winters. The weather is influenced by places' proximity to the Sea of Marmara. The prevailing winds are northeaster and southwester.

Uludag University with a campus area of 16 million m² was established 20 km away from the city center in 1975. Campus area in Figure 4 is surrounded by newly developed dwelling zone, Nilufer residential district, on west and eastside, bordered to north by pinewoods and south by main highway. Student access from city center to campus is primarily by public bus and light railway system that runs above ground.

For the case study, an existing three-storey detached block, the Faculty of Industrial Engineering Building is selected. The subjected building is located in the northeast side of the campus and completed in 2006. As seen in Figure 5, the rectangular floor plan of the building is placed on northwest – southeast axis. The total area is approximately 8520m². There exist 12 classrooms, 4 laboratories, 2 workshop studios, 1 cafeteria, 1 lecture hall, 1 library, 14 lecturers' offices, administration and dean's office in building's architectural program. Image in Figure 8 demonstrates the open courtyard of the building, situated in the center of its layout where students gather mostly for free time. Regarding 2015, the user population of the faculty is about 500 people, including 20 teaching and administrative staff, 350 undergraduate and 125 graduate students.

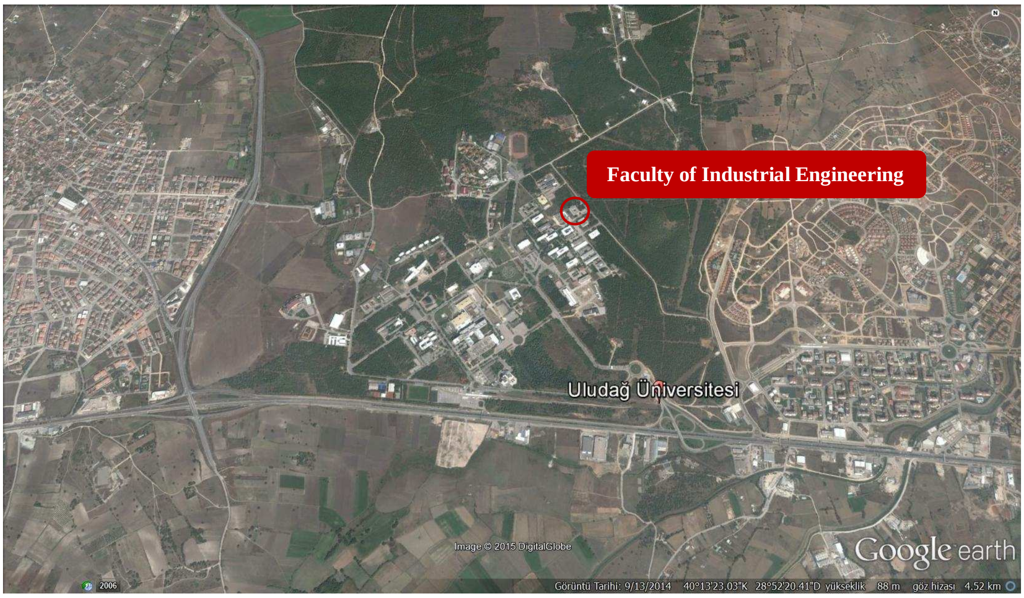
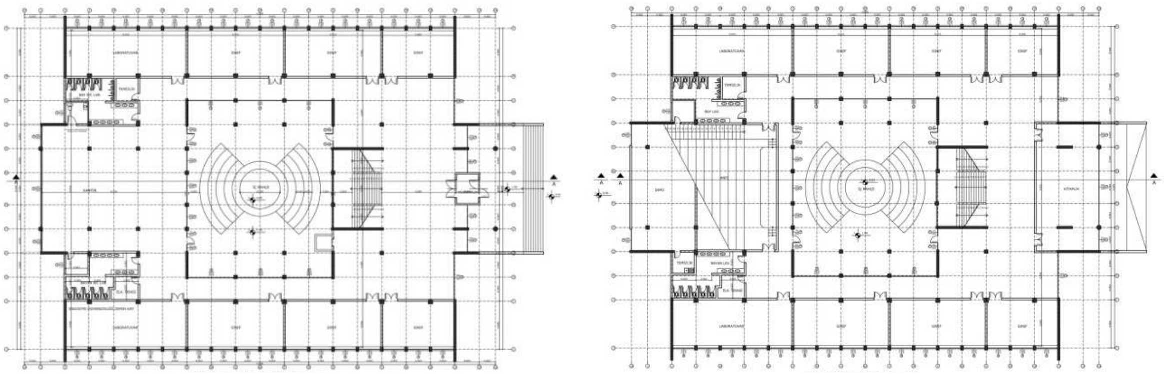
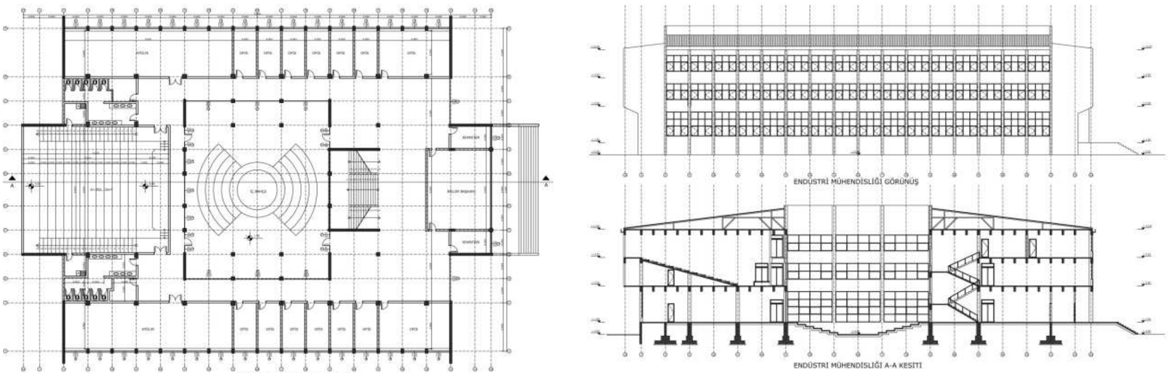


Figure 4: Aerial Photograph of Uludag University Campus Area [36]



Ground Floor Plan First Floor Plan



Second Floor Plan Side View and A-A Section View of the Faculty

Figure 5: Floor Plans, Side View and section view of the Faculty

Technical data regarding the detailed information on application project is obtained from Uludag University Construction and Maintenance Department. According to the existing drawings, the building does not have a basement. Entrance floor is lifted 1.5 m above the ground level to form a surrounding plinth wall. Ground floor measures 58 m by 43 m and has 4.5 m ceiling height. First and second floors form a 3 m outer cantilever facing to SE and NW and are 3.5m high. Shallow column footings are used for the foundation as seen in A-A section view in Figure 5. Window range on each facade is open up to allow breeze through classes and offices in conjunction with the windows on atrium wall, seen in Figure 8. Courtyard also provides natural light for long indoor hallways.

The school is designed to operate using nonrenewable energy sources. Space heating is supplied by gas driven central boiler. Classrooms and offices are naturally ventilated; yet, some units have their own air conditioning (AC) system optionally installed. Main entrance door is made of metal frame and single-pane glass. Double doors and covered entrance serves as a wind break between the classrooms and outside in Figure 6.

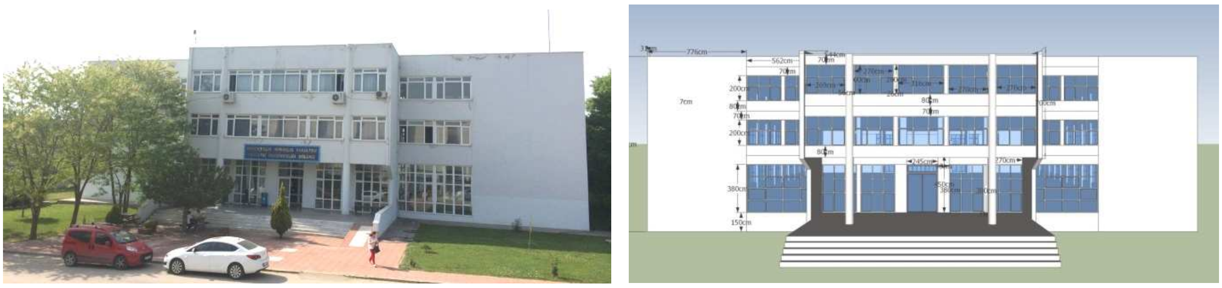


Figure 6: The main entrance of Industrial Engineering Faculty, Photo and 3d Virtual Model of SW Façade

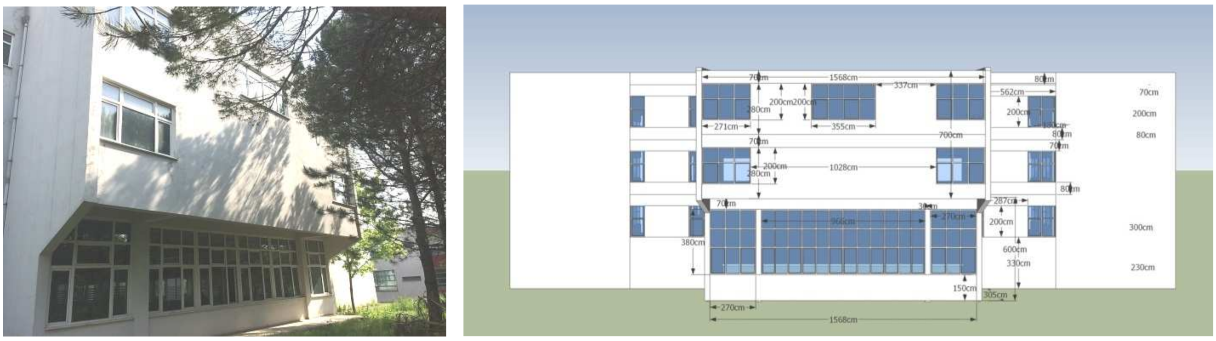


Figure 7: Photo and 3d Virtual Model of Industrial Engineering Faculty's NE Façade

Figure8: SE Facade of Industrial Engineering Faculty and Open Courtyard

The orientation of the building facade is important in terms of solar gain, exposure of prevailing wind and the severity of driving rain. For this case, the transparency ratio increase light penetration to the classrooms facing to NW and SE. On the other hand, uncontrolled solar exposure and uninsulated external walls lead to overheating problems in summer and net losses in winter. The facades comprise of several polyvinyl chlorides (PVC) window frames with fixed and operable sashes, double glazing and marble sills with a drip edge on the exterior side. All windows have manually operated blinds and curtains. No external shading device is used to avoid glare. On the other hand, evergreen trees situated on the northeast and southwest site that obstruct strong winds and provide shade for the sun. However trees are measured to be oriented at a distance of 5 m from the investigated facades. They reduce receiving solar gain in winter time (Figure 7).

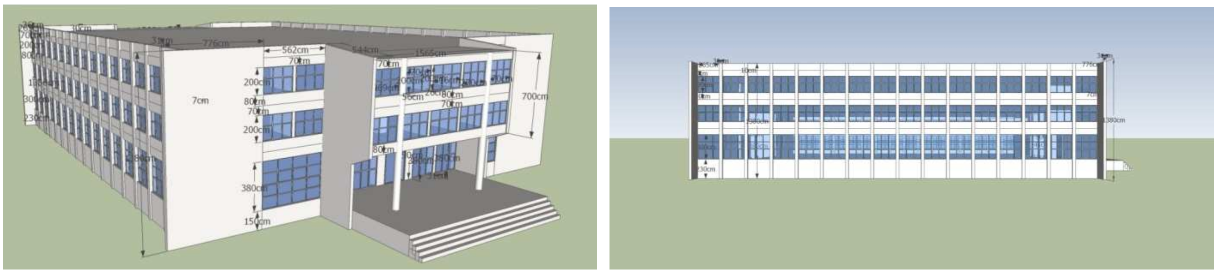


Figure 9: 3d Virtual Perspective of NW and SE Façade of Industrial Engineering Faculty

One way ribbed slab is commonly used floor type of the building. The main body of the external walls has built with conventional hollow fired clay bricks within the RC skeleton frame. No additional thermal insulation was applied either on the external or on the internal side of the masonry walls. The infill brick walls have been applied to align with the center of RC columns. As a result half size of the columns lining up along the wall is exposed to outdoor conditions. Neither those columns, nor inclined shear walls on the right and left side of the cantilevers are insulated. Silicon based paint has applied on cement rendering for finishing of external walls. The roof is constructed with trapezoidal metal sheeting with a slope of 12%. Metal gutter system has used to drain water away from the building. Mineral wool supplies thermal resistance between the roof panels. Table 1 below consists of geometrical input data of building envelope measured through drawings.

Table 1: Area and Volume Size of the Subjected Building

Total Floor Area (m²)	8519,68
Total Gross Volume (m³)	26624
Total Area of Exposed RC Skeleton Structural Frame (WW1) (m²)	1461,1
Total Area of Exposed Masonry Wall (WW2) (m²)	545
Total Area of Exposed Pitched Roof (WR1) (m²)	2110
Total Area of Ground Floor Against Earth (GF1) (m²)	1940
Total Area of Exposed Cantilevered Floor (WF1) (m²)	170,6
Total Window Area (m²)	909
Total Door Area (m²)	9,3

Results and discussion

When assessing the thermal performance of building enclosure system, a series of field analyses were conducted using different scales. In this context, external envelope system which mainly comprise of thermal bridges through skeleton structural frame and infill masonry walls together with thermal comfort conditions survey are presented in this part.

Thermal performance of buildings is critical considering energy saver design approach. Energy efficiency of building envelope can be improved depending on the thermo-physical properties of construction materials and components. The numerical analysis has been carried out in terms of annual heating energy consumption, heat loss and heat gain through envelope considering R and U-values of building elements and components. The R-value is a measure of resistance to heat flow through a given thickness of material. So the higher the R-value, the more thermal resistance the material has and therefore the better its insulating properties.

U-value is referred to building assembly's capacity to resist heat transfer by conduction, convection and radiation. Technically it is a measure of the rate of heat conduction through 1 m³ of a material with a 1ºC temperature difference across the two opposite faces [26]. U-value is the basic data describing patterns of heat gain and loss in building envelope. In addition to calculate thermal properties of individual materials, U value is used in a way of predicting the composite behavior of building elements and entire assemblies. Table 2 illustrates the limited and calculated U-values for the main components of the building’s enclosure in temperate climate conditions. When current and limited U-values are compared, results indicate that infill masonry brick wall is unable to provide the required level of thermal resistance according to national thermal standards, TS 825. That means the external walls lose a considerable amount of heat and decrease the energy efficiency of the building.

Table 2: Limited and Calculated U-values of External Envelope for Temperate Climate Region inTurkey

Temperate Climate	Wall -1 Infill Masonry (W/m²K)	Wall-2 Thermal Bridge (W/m²K)	Roof (W/m²K)	Floor (W/m²K)	Glazing (W/m²K)
Limited by TS 825	0,60	0,60	0,40	0,60	2,4
Calculated	**1,15**	**2,28**	0,25	0,61	2,4

For obtaining comfort from building envelope, variants are calculated assuming a set point of 21°C indoor interior air temperature, 60% the relative humidity, 0,8 h^{-1} air change rate for indoor conditions. Total heat loss through subjected building elements is calculated according to their unit mass (kg/m³) and thermal conductivity value (W/mK) based on specifications in TS825. Table 3 illustrates the impact of R and U-value by giving the net heat gain and losses.

Table 3: Thermo-physical properties of exposed elements and calculated heat loss through the building envelope in existing state

Building Envelope Elements	Thickness l (m)	Resistivity R (m²K/W)	Overall Heat Transfer Coefficient U (W/m²K)	Heat transfer surface area A (m²)	Heat Loss A x U (W/K)
RC Column, Beam and Shear walls	0,30	0,32	3,151	1461	4603,61
Masonry Brick Wall	0.24	0,75	1,342	545	731,39
Low Pitch Metal Roof, Insulated	0.23	3,96	0,2016	2110	425,38
Ground Floor Slab against earth	2,75	1,57	0,319	1940	618,86
Cantilevered RC Floor Slab		0,32	3,204	170,6	546,6
Windows			2,4	909	2181,6
Doors			5,5	9,3	51,15

Thermal performance of enclosure is determined by the characteristics of components such as opaque element's thermal resistivity and thicknesses as well as transparent element's thermal transmittance and weather tightness. Columns, beams and shear walls have higher thermal conductance factor than the rest of the opaque wall components due to high thermal conductivity of concrete. Since resistance to heat transfer R is the reciprocal of the total U-value, the thermal effectiveness of the wall is diminished by RC structural elements, contributing to the highest heat loss through wall (4603,61 W/K), called "thermal bridge". Floor slabs are the other structural elements that form a major thermal bridge depending on the total surface area on facade.

19 cm exterior brick wall and wall finish have a low heat storage capacity and do not provide a satisfying degree of thermal mass; therefore, excessive energy is used to maintain surface and indoor air temperature fluctuations stable during heating and cooling period. Additionally, surface degradation problems are inspected in some parts of the building envelope most likely originating from lack of insulation. Exterior wall, particularly locating towards the direction of prevailing wind on the NE and NW facade is subjected to moisture accumulation. Image taken from the NW facade in Figure 10 demonstrates visible deterioration in corner sections of wall, window casement and marble sill joints.

Figure 10: Wall Deteriorations Most Likely Originating From on Lack of Insulation and Moisture Ingress

Heat loss and gain through the building envelope basically depends on form, orientation, internal and solar gain, ambient indoor and outdoor temperature, insulation level and thermal properties of elements. An allowance is added for infiltration through leaks including badly fitting doors, windows, damaged structures surface etc. The overall heat loss from a building can be calculated as follows [26];

$$H = Ht + Hv + Hi \qquad (1)$$

Where;
H = overall heat loss (W)
Ht = heat loss due to transmission through walls, windows, doors, floors and ceiling etc. (W)
Hv = heat loss caused by ventilation (W)
Hi = heat loss caused by infiltration (W)

The overall heat loss H is calculated as 16187.33 W/K.

Annual energy need for heating refers to space heating energy; domestic water heating is not included. Benefits from solar and internal heat gain have taken into account. Heating demand occurs for seven months and central heating is switched off for five months of the year. Annual heat demand Q_y is equal to the sum of monthly heating energy demand Q_m.

$$Q_y = \sum Q_m = 567.768 \text{ kWh} \qquad (2)$$

$$Q = 567.768/26624 = 21.33 \text{ kWh/m}^3 \qquad (3)$$

Where;
Q_y = annual heating energy demand (kWh)
Q_m = heating energy demand per month (kWh)
Q = actual annual heating energy demand per m³ (kWh/m³)
Q' = limited annual heating energy demand per m³ due to TS 825 (kWh/m³)

Calculation results for the existing building shell indicate that:

- Actual heating energy demand per m³ is calculated as Q = 21.33 kWh/m³.
- Limited heating energy demand per m³ is calculated as Q'= 13.81 kWh/m³ due to TS 825.
- Actual fuel consumption per m³ is calculated as 2.49 $kg.m^3$
- Q > Q', means that the actual energy consumption (Q) is above the maximum limits (Q') of TS 825.
- The indoor surface temperature of exposed external walls differ more than 3ºC from the (indoor) ambient air temperature."
- Building envelope fails to comply with the TS 825 standard.

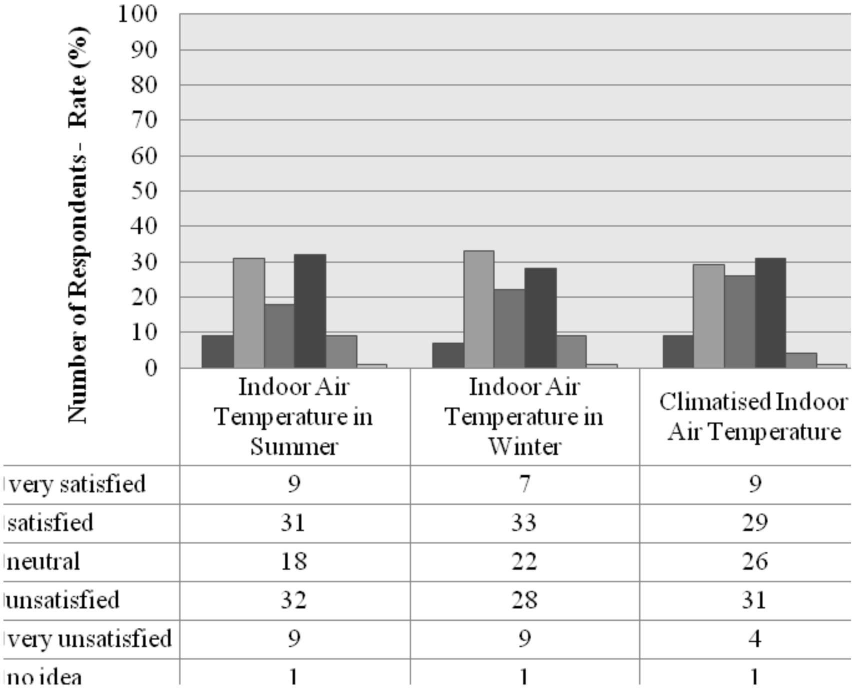
User Satisfaction Survey On Indoor Thermal Comfort

Thermal comfort is an important aspect when evaluating the users’ satisfaction. In this context, a survey was conducted to receive users’ view on optimal thermal comfort conditions in academic institutions. Industrial Engineering Faculty has been climatized (heating) at the time of the survey and 100 people including students and staff joined as respondents. They were asked to indicate their appreciation of indoor environment in terms of heating, cooling, natural ventilation and air-conditioning level of spaces and rate the building on a scale ranging from "very satisfied" to "very unsatisfied". Details were collected about their clothing, working activity and the use of climate controls such as windows, air conditioning, fans and radiators. The answers have statically analyzed in terms of percentages and and the attained results were presented with a graph of in Table 4.

The users were asked about the air quality conditions in terms of how they feel and what they do to provide thermal comfort during winter and summer. Of all the users, 37% complained about the low heating level in winter, while %41 complained about over-heating in summer. Similar results were found regarding the use of mechanical systems individually. 38% of the users were content with comfort conditions of their unit whereas 35% expressed discomfort for indoor environment when AC operates.

During the heating season the comfort temperature is automatically controlled by the central heating system instead of occupants. Building envelope is found to lower acceptable indoor air quality for each classroom due to the fact that the users take actions such as opening the window, switching on a fan or using AC to make them comfortable. The building does not have a mechanical ventilation system so windows are opened as the temperature rises; however solar exposure and glare affects visual comfort especially for the classrooms on SE facade.

Table 4: User Reviews on Thermal Comfort Level of Industrial Engineering Faculty



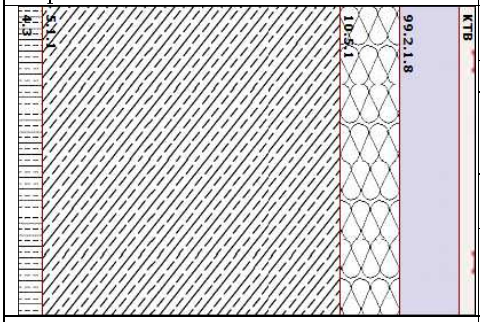
	Indoor Air Temperature in Summer	Indoor Air Temperature in Winter	Climatised Indoor Air Temperature
very satisfied	9	7	9
satisfied	31	33	29
neutral	18	22	26
unsatisfied	32	28	31
very unsatisfied	9	9	4
no idea	1	1	1

Improvements For Energy Effıcıency In The Exıstıng Building Envelope

Thermal performance of building envelope is mainly associated with energy efficiency and environmental sustainability in terms of long-term performance, service life prediction and durability of buildings and its parts, in addition to thermal comfort and indoor air quality issues. In this respect, thermal insulation of external envelope is critical considering climate-sensitive, sustainable design approach. Besides, ensuring energy conservation and thermal insulation is a legal requirement.

According to thermal insulation standard, heat transfer characteristics of glazing should give a U-value of 2.4 W/m²K or less. Existing double glazed PVC framed windows with 20 mm air gap and thermal breaks achieve the limited level and considered to be adequate as well as the insulated roof of the building. In this case, the majority of the heat loss occurs at exposed structural frame; therefore, a layering model is presented to improve thermal performance of RC parts of the external wall In Table 5.

Table 5: Proposed wall layering model for RC structural frame

BUILDING ENVELOPE COMPONENTS		**Thickness**	**Thermal conductivity**	**Resistivity**	**Heat Transfer Coefficient**
		l	**λ**	**R**	**U**
		(m)	**(W/mK)**	**(m²K/W)**	**(W/m²K)**
RC Skeleton Frame Exposed to Outdoor Conditions	Internal Surface Resistance, $1/\alpha_i$			0,13	
	Calcium silicate gypsum plaster	0,02	0,70	0,03	
	RC column	0,25	2,5	0,1	
	Rock wool Thermal Insulation	0,05	0,035	1,43	
	Weatherboard Composite Panel	0,015	0,4	0,04	
	External Surface Resistance, $1/\alpha_d$			0,08	
TOTAL				**1,81**	**0,554**

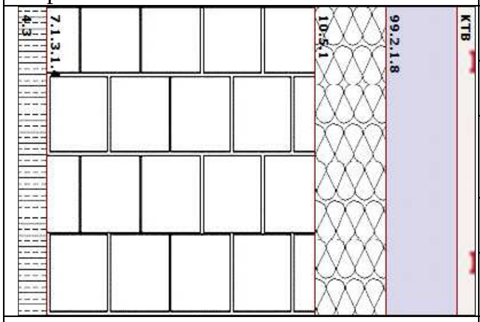
The existing building enclosure has no thermal insulation regulating the transfer of heat by conduction. Thermal bridges through the wall construction especially through beams, columns, lintels and cantilever floor slabs are determined to be dealt with as a leading issue. Infill masonry wall has applied behind the columns; as a result, half sizes of the columns are directly exposed to weathering. Plus, RC structural frame has the highest exposed surface area among all enclosure elements.

For the external walls, rock wool is chosen as a common inorganic mineral-based insulate alternative to synthetic insulates. It is vapors and air permeable material offering certain important properties like resistance to fire and avoidance of ozone depleting chemicals [37]. The calculation results show that with 50mm rock wool insulation, it is possible to lower the existing U–value from 3,151 W/m²K to 0,554 W/m²K for RC wall fabric.

The infill masonry brick wall facing with 50 mm of rock wool thermal insulation is protected by external cladding, demonstrated in Table 6. The existing brick wall gives a U value of 1,342W/m²K. External insulation upgrades the main body of external walls and achieves a U-value of 0.448 W/m²K.

Continued next page

Table 6: Proposed wall layering model for infill masonry wall

BUILDING ENVELOPE COMPONENTS		**Thick ness**	**Thermal conductivity**	**Resistivity**	**Heat Transfer Coefficient**
		l	**λ**	**R**	**U**
		(m)	**(W/mK)**	**(m^{2}K/W)**	**(W/m^{2}K)**
External Infill Masonry (Brick) Wall Exposed to Outdoor Conditions	Internal Surface Resistance, 1/α_i			0,13	
	Calcium silicate gypsum plaster	0,02	0,70	0,03	
	Fired Clay Brick Masonry Wall	0,19	0,36	0,53	
	Rock wool Thermal Insulation	0,05	0,035	1,43	
	Weatherboard Composite Panel	0,015	0,4	0,04	
	External Surface Resistance, 1/α_d			0,08	
TOTAL				**2,24**	**0,448**

The building external walls were inspected to have surface degradation caused by moisture accumulation so there is no problem as regards changing the appearance of facades by over cladding. The application includes stainless steel rigid wall ties and 50 mm cavity in between insulation and weatherboard composite panel wall cladding. The air gap positioned between insulation and cladding provides ventilation and reduces the risk of condensation in insulant. Table 7 illustrates the limited and calculated U-values for the assemblies of the external envelope before and after insulation.

Table 7: U-values for Limited, Existing and Insulated Envelope Elements, Exposed to Outdoor Conditions

Temperate Climate	External Infill Masonry Wall (W/m^{2}K)	RC Columns, Beams, Shear Walls (W/m^{2}K)	Wall-1 Infill Masonry (W/m^{2}K)	Wall-2 Thermal Bridge (W/m^{2}K)
Limited by TS 825			0,60	0,60
Existing	1,342	3,151	1,15	2,28
Insulated	0,448	0,554	0,43	0,53

Annual energy consumption of the building is calculated one more time, considering rock wool insulation applied from the outside of wall. Calculation results for the layers of proposed wall assembly indicate that:

- The overall heat loss H is reduced from 16187.33 W/K to 10547.39 W/K.
- Actual heating energy demand per m^3 is calculated as Q = 10.9 kWh/m^3.
- Q' > Q, means that the energy consumption (Q) is below the specified limits (Q')
- Actual fuel consumption per m^3 is calculated as 1.27 kg.m^3
- Q/Q'< 0.80, the building is classified within a scale defined as "A" due to TS 825 standard.
- The indoor surface temperature of exposed external walls differ less than 3°C from the (indoor) ambient air temperature, which stays within the acceptable limits.
- The proposed insulated envelope complies with the TS 825 standard.

Conclusions

This paper presents results from heating loads and energy demand analysis along with a user satisfaction survey for an existing building. The selected case is a university building built before TS 825 (2008) and is representative of uninsulated educational building stock in temperate climate region of Turkey. Calculation data is prepared by TGUB insulation calculator software which provides users with key thermal performance indicators such as resistivity and overall heat transfer coefficient of exposed building partitions. Computed results are given together with an envelope layering alternative. This way, the study offers a solution through which the existing envelope's thermal performance is compared with a proposed model that meets thermal insulation regulations and reveals the difference in annual heating energy demand. By the implementation of the current standard, it is possible to upgrade existing building's thermal performance and comfort levels of occupants in the use stage. In addition, environmental pollution can be decreased due to considerably reduced fuel consumption.

Buildings play a crucial role in CO_2 emissions, global warming and depletion of resources and this problem is, in part, in the responsibility of architects and engineers. One of the most difficult challenges ahead is to determine how to improve existing structures since the majority of these energy consuming buildings will be too expensive to function in the near future. An additional layer of thermal insulation is one of the most common ways that has been tried to influence by national authorities since 1980'ies. By applying low-density and lightweight organic or inorganic insulants on the external side of the enclosure, transfer of conducted heat can be regulated [38].
Briefly, insulating our buildings;

- Reduces space heating and cooling demand and operational costs
- Reduces energy consumption, CO_2 emissions and the use of natural resources
- Diminishes temperature fluctuations between exposed surfaces and indoor air
- Maintains steady and comfortable internal environment for users
- Protects the building enclose from weathering, ensuring a longer life.

In Uludag University campus area, most of the buildings constructed prior to 2008 have not been energy-consciously designed. Existing buildings are arranged similar to a campus plan and researches show that approximately 25% percent of buildings have "adequate" insulation in the walls according to TS 825 standards. Unfortunately the figure is disconcerting; yet, investing in thermal performance of existing buildings could result in major energy savings. Therefore, converting existing buildings enclosure appears to be a more sustainable and logical alternative than tearing down the whole stock and rebuilding it in short term.

This study aims to provide guidance not only on renovation of existing uninsulated buildings but also in the early stage of design and planning process for the future projects. For further evaluation of such cases, comprehensive dynamic simulation engines could be used that enables detailed modelling options related to building envelope and daily and hourly interval of fuel use, HVAC and lighting system savings for multiple zones. Along with the computer simulations, existing buildings need to be inspected in the field to assess the actual thermal performance of building envelope. Such performance issues of a building may have different characteristics than what was planned on paper and applied in the construction process, and this may have been particularly changed in the long-term by the effects of environmental factors.

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About the authors:

Name: Egemen KAYMAZ
Research Assistant in Uludag University, Department of Architecture, Faculty of Architecture
Mailing address: Uludağ Universitesi Görükle Kampüsü, Mimarlık Fakültesi No:118 Görükle/Nilüfer Bursa
Tel: +90 553 306 3264
Fax: +90 224 2942 128
e-mail : egemensaritabak@gmail.com

Name: Filiz Şenkal SEZER
Associate Professor in Uludag University, Department of Architecture, Faculty of Architecture
Mailing address: Uludağ Universitesi Görükle Kampüsü, Mimarlık Fakültesi Görükle/Nilüfer Bursa
Tel: +90 542 345 3525
ax: +90 224 2942 128
e-mail : filizss@gmail.com