

Research Article

Energy Performance Analysis of Buildings in Terms of Alternative Reinforced Concrete Structural Systems

Hakan TUTUMLU^{1,*}, Berkay AYDOĞDU² and Mustafa İNALLI³

¹ Mechanical Engineering Department/Faculty of Engineering / Firat University, Turkey, Orcid ID: 0000-0003-3884-7015, htutumlu@firat.edu.tr

² Mechanical Engineering Department/Faculty of Engineering / Firat University, Turkey, Orcid ID: 0000-0002-5117-5412

³ Mechanical Engineering Department/Faculty of Engineering / Firat University, Turkey, Orcid ID: 0000-0002-6260-4948, minalli@firat.edu.tr

* Correspondence: htutumlu@firat.edu.tr

(First received March 18, 2022 and in final form June 04, 2022)

Reference: Tutumlu, H., Aydoğdu, B. ., & İnallı, M. . Energy Performance Analysis of Buildings in Terms of Alternative Reinforced Concrete Structural Systems. *The European Journal of Research and Development*, 2(2), 241–268.

Abstract

In this study, the thermal energy performances and environmental effects of two different reinforced concrete structures, Pure Shear Wall (PSW) Building and Shear Wall-Frame (SWF) Building, were investigated in the climatic conditions of Elazığ province. Thermal performance analysis for both buildings; was carried out with the TS 825 program. First of all, through this program, monthly and annual heating loads were determined for 11 different alternative building component scenarios of two different buildings. Subsequently, efficiency alternatives were created in accordance with the climatic conditions of the region and TS 825. Efficiency alternatives designed for both buildings have been analyzed together with their completely uninsulated and current states. Finally, buildings with reinforced concrete carrier systems, energy analysis methods and efficiency alternatives were compared and evaluated based on the results of the analysis. As a result, it has been observed that the building with the PSW system consumes more energy than the building with the SWF system when it is uninsulated and in its current condition.

Keywords: Pure Shear Wall, Shear Wall-Frame, TS825, Performance Analysis and Insulation

1. Introduction

In today's societies, which are a reflection of the global order, the need for energy is increasing day by day. The increase in energy demand and the use of non-renewable energy sources cause significant environmental and economic problems. Contrary to these problems, energy policies should be implemented in order to ensure sustainability

and improve the level of energy efficiency. In this context, buildings, which are responsible for approximately 40% of energy consumption and approximately 30% of greenhouse gas emissions in the world, are seen as one of the main components in the execution of energy policies. In order to improve energy efficiency levels in buildings, energy consumption should be minimized, energy efficiency should be increased, carbon emissions should be reduced, in other words, the energy and environmental performance of buildings should be evaluated and improved [1].

In this study, it is aimed to reveal the thermal performance and environmental effects of buildings by making energy analysis in terms of different reinforced concrete carrier systems. The steps regarding the methods followed for this purpose are presented below in articles. The items in question are:

- 1) Identification of the building with the “Shear Wall-Frame” carrier system and the building with “Only Shear Wall” carrier system to be applied and obtaining the architectural data of the buildings,
- 2) Analyzing the effect on monthly heating energy consumption by performing an energy analysis with “TS 825” for the current situation of buildings with Shear Wall-Frame carrier system and buildings with Pure Shear Wall carrier system,
- 3) Bringing efficiency suggestions for the building with Shear Wall-Frame carrier system and the building with Pure Shear Wall carrier system in terms of both heating energy consumption and improving carbon emission,
- 4) It is to determine and evaluate the energy consumption and carbon emission differences of the building with Shear Wall-Frame carrier system and the building with Pure Shear Wall carrier system, resulting from carrier systems, energy analysis methods and efficiency alternatives.

Some of the studies in the literature related to this study are as follows;

Mangan and Oral [1] evaluated the life cycle energy and environmental performances of a residential building built by Directorate of Mass Housing and Public Partnership Administration (TOKİ, in Turkish) according to three different climate zones. It is assumed that there are residential buildings in the cities of Istanbul, Ankara and Diyarbakır, which represent three different climate zones. They provided improvement suggestions for residential building life cycle energy consumption and carbon emissions for three cities and simulated these recommendations with the help of the ICE database, DesignBuilder and EnergyPlus programs. As a result, it has been revealed that with the improvement suggestions of the residential building, which is considered for three different climate zones, a reduction in life cycle energy consumption and carbon emissions is achieved.

Yaman and Gökçen [2] determined the energy performance of a university administrative building in İzmir with dynamic and static methods and made a comparative evaluation with real measurements. They used TS 825 method as static

method and Ecotect and EnergyPlus programs as dynamic method. According to the heating energy consumption results, the EnergyPlus program gave the closest result to the actual measurement, and the TS 825 method gave the farthest result.

Süt [3] has positioned a TOKİ building in different degree-day zones in Turkey and evaluated the energy performance and environmental impacts of the building with energy efficient strategy proposals in each zone. As a result, energy consumption in different degree-day regions decreased by 19.3% - 35.7%.

Ferdos et al. [4] calculated the operational energy consumption of a primary school building in Istanbul with the help of DesignBuilder and EnergyPlus simulation programs. Then, by applying different energy efficiency suggestions, they evaluated the primary school building in terms of life cycle energy analysis and carbon emissions. According to the results, they stated that different efficiency proposals will provide an improvement of around 25-27% in life cycle energy consumption and life cycle carbon emissions.

Akalp [5] calculated and compared the effects of design elements such as direction and shading on heating-cooling loads of buildings in a TOKİ site in Diyarbakır with the help of the DesignBuilder program. As a result of the study, they determined that the ideal direction is the south direction in the north-south direction. In addition, they determined that the shadow effect created in the north-south direction did not make a significant contribution to the heating-cooling load.

Gazioglu et al. [6] calculated the heating energy consumption of a building located in a mass housing complex in Istanbul with DesignBuilder and EnergyPlus programs and examined the effect of passive efficiency alternatives on building heating performance. According to this study, they found that passive efficiency alternatives provide an improvement in heating energy consumption up to 20%.

Çetintaş and Yılmaz [7], assuming that a TOKİ residential building is located in cold (Erzurum), hot humid (İzmir) and moderately humid (Istanbul) climate zones, life cycle energy consumption and life cycle of thermal insulation material and thickness alternatives for each of the different climate zones. examined their effects on carbon emissions and suggested optimum alternatives. As a result, they determined that 5 cm XPS for Istanbul, 3 cm glass wool for Izmir, and 9 cm stone wool for Erzurum will contribute optimally.

Gümüş [8] calculated the energy performance of the blocks in a mass housing in Istanbul Ataşehir with the help of the DesignBuilder program and offered improvement suggestions in terms of energy efficiency. As a result, they determined that approximately 49% of energy savings were achieved with improvement suggestions such as improvement in the opaque and transparent component, glazing of the balcony and application of hipped roof.

Ünsal [9] calculated the heating and cooling energy loads of a TOKİ residential building through the DesignBuilder and EnergyPlus program and developed some alternatives in terms of energy efficiency for different climate regions. In the study, the energy consumptions were calculated separately for the provinces of Istanbul, İzmir, Diyarbakır, Ankara and Erzurum, and they found that they provide energy savings in every climate zone with alternatives such as low-e glass, aerated concrete shell, increasing the transparency rate, and solar control.

Kobalas [10] calculated the energy consumption of a detached residential building belonging to the Tarımköy project built by TOKİ in Afyon with the help of the DesignBuilder program and evaluated the energy efficiency of the detached building with alternative packages derived from different building components and passive solar systems. According to the results, adding 10 cm EPS to the existing wall is the most efficient alternative package, consisting of electronic reflective argon gas filled double glass (6 mm/13 mm), external blinds system on all facades and a completely transparent storage wall + winter garden. They found that the package reduced the total energy load by approximately 25%.

The energy efficiency of these buildings is of great importance for the country's economy. In this paper, all research and development studies that have been done or will be done, and solution proposals related to the sustainability of energy efficiency will seriously benefit the literature. Researching the energy analysis of different architectural structures is of great importance in this context.

2. Materials and Methods

TS825 package program, prepared by the Heat, Water, Sound and Fire Insulators Association (HWSFA), makes calculations based on the meteorological data of the last 20 years in Turkey and in accordance with the TS825 standard. Through the HWSFA TS825 program, the values found with the calculations for the specific heat loss are compared with the limit values, and the compliance of the building to be designed with the legal regulations regarding energy efficiency is examined. With this package program, the thickness of the insulation and building materials to be used in buildings should be taken in accordance with the limit values described in the relevant standard. In the TS825 program, the net heating need is determined by subtracting the heat gains from the heat losses, provided that the total area and gross volume of the building are taken into account [11].

In this program, first the address and information of the region related to the project should be entered, followed by data in the floor, ceiling, wall, door, window and solar energy gain tabs. A screenshot of the project information is given in Figure 1. In Figure 2, a sample screenshot of the material data is shared.

Proje Bilgileri

Sahibi: []
Bina Tipi: [Korollar] []
Kat Adedi: []

İz Yalıtım Projesi Yapılan

Adı Soyadı: []
Unvanı: []
Sicil No: []
Kuruluşu: []

Arzanan

İz: [İLAZİ] []
Dışarı: [VERMEZ] []
Hafifliği: []
Sıkılığı: []
Yalıtı: []
Ağırlık: []
Pervaz: []
İnce: []

Hesaplama Bilgileri

R_{t1} : [1.0] R_{t2} : []
 R_{t3} : [] R_{t4} : []
 R_{t5} : [] R_{t6} : []
 R_{t7} : [] R_{t8} : []
 R_{t9} : [] R_{t10} : []

Net Dış Yüksekliği [] m
Hesaplanacak İz [] m

İzlek Katmanları (İzlek Katmanları)

☒ Normal (Korollar, korollar ve korollarla korunan binalar vb.)
☐ Yüksek (Yüksek katmanlar, aydınlatma katmanları, korollar vb.)

Figure 1. Project information entry screen

Hesaplanacak Katmanlar

No	İz (m)	Malzeme Cinsi veya Bilgisi	İz İhtiyacı Hesap	p
1	0,02	4.1. Kireç harcı, kireç çimento harcı	1	15
2	0,3	7.4.4.4. Kireç harcı, kireç çimento harcı	0,32	5
3	0,055	10.5.1 Mineral ve bitümlü lifli iz yalıtım malzemesi (Cam yünü, T)	0,055	1
4	0,025	4.1. Kireç harcı, kireç çimento harcı	1	15

Malzemeler

Malzeme veya Bilgisi	Sıra No	İz İhtiyacı Hesap	p
1. Duğal Taşlar	1	1	15
2. Duğal Zeminler (Duğal Zeminler)	2	1,40	15
3. Dökme Malzemeler (Dökme Malzemeler, İzletme durumu)	3	1,40	15
4. Sıvalar, Sıvalar ve Diğer Harç Tabakaları	4	1,40	15
4.1. Kireç harcı, kireç çimento harcı	1800	1	15
4.2. Çimento harcı	2000	1,40	15
4.3. Alçı harcı, kireçli alçı harcı	1400	0,70	15
4.4. Yalıtım alçı kumları (agregat) yapılmış sıva	1200	0,51	15
4.5. Alçı harcı gips	2000	1,40	15
4.6. Çimento harcı gips	2000	1,40	15
4.7. Dökme sıvalı kaplama	2100	0,70	15
4.8. Anonim sıvalı hafif agregatlı yapılmış sıva harcı	2100	0,70	15
4.9. Sıvaların sıvalı agregatlı yapılmış sıvalar ve harç tabakaları	2100	0,70	15
4.10. Sıvaların sıvalı agregatlı yapılmış sıvalar ve harç tabakaları	2100	0,70	15

Tavsiye Edilen İ İz Değerleri

İz Değeri	İz Değeri	İz Değeri	İz Değeri
1. İz Değeri	0,7	0,40	0,7
2. İz Değeri	0,4	0,4	0,4
3. İz Değeri	0,3	0,3	0,40
4. İz Değeri	0,4	0,30	0,4

Alan: [3333] İz Değeri: [0,37]

Değer (Değer Açık)

Konut Görünümü

Figure 2. Material data entry screen

2.1.TS 825 Standards Calculation Method

TS 825 standards aim to determine the annual heating energy in order to increase the energy performance of all buildings in Turkey. According to this standard, a thermal insulation project should be prepared at the design stage. In the calculation method, the entire building is considered a single zone. Annual heating energy for a single zone is calculated using Equation 1 and Equation 2.

$$Q_{year} = \sum Q_{month} \quad (1)$$

$$Q_{month} = [H(T_{i,month} - T_{d,month}) - \eta_{month}(\varphi_{i,month} + \varphi_{g,month})] \cdot t \quad (2)$$

Here, Q_{year} represents the annual heating energy (J). Q_{month} , H , $T_{i,month}$ and $T_{d,month}$ represent monthly heating energy (J), specific heat loss (W/K), monthly average internal temperature (°C) and monthly external average temperature (°C), respectively. η_{month} , $\varphi_{i,month}$, $\varphi_{g,month}$ and t represent the monthly average usage factor, monthly internal heat gain (W), monthly solar energy gain (W) and time (s) for heat gains, respectively. The specific heat loss (H) of the building is obtained by summing the heat loss due to conduction (H_i) and the heat loss due to ventilation (H_h). The specific heat loss is calculated using Equation 3.

$$H = H_i + H_h \quad (3)$$

The specific heat loss due to conduction is calculated using Equation 4.

$$H_i = \sum AU + I \cdot U_i \quad (4)$$

Here, $\sum AU$, I and U_i denote the total heat loss (W/K), thermal bridge length (m) and linear permeability of the thermal bridge (W/mK) by convection and conduction, respectively. The total heat loss due to conduction and convection is calculated using Equation 5.

$$\sum AU = U_D A_D + U_P A_P + 0.8 U_T A_T + 0.5 U_t A_t + U_d A_d + 0.5 U_{dsic} A_{dsic} \quad (5)$$

Here, U_D , U_P and U_T denote the thermal transmittance coefficient of the outer wall (W/m²K), the thermal transmittance coefficient of the window (W/m²K) and the thermal transmittance coefficient of the ceiling (W/m²K), respectively. U_t , U_d and A_d respectively represent the thermal conductivity coefficient of the sole sitting on the floor (W/m²K), the thermal conductivity coefficient of the sole in contact with the outside air (W/m²K) and the thermal conductivity coefficient of the building components in contact with the low temperature indoor environments (W/m²K). A_D , A_P and A_T denote the exterior wall area (m²), window area (m²) and ceiling area (m²), respectively. A_t , A_d and A_{dsic} represent the floor area (m²) resting on the ground (m²), the floor area in contact with the outside air (m²) and the area of the building components (m²) in contact with low-temperature

indoor environments, respectively. The heat permeability coefficients take different values according to the regions. Table 1 contains the recommended thermal conductivity coefficient values for building components [12].

Table 1. Recommended thermal conductivity coefficient values for building components according to regions [12]

Regions	U _{wall}	U _{ceiling}	U _{base}	U _{window}
1. Region	0,7	0,45	0,7	2,4
2. Region	0,6	0,4	0,6	2,4
3. Region	0,5	0,3	0,45	2,4
4. Region	0,4	0,25	0,4	2,4

The specific heat loss due to ventilation is calculated using Equation 6.

$$H_h = \rho \cdot c \cdot V' = \rho \cdot c \cdot n_h \cdot V_h = 0.33 n_h \cdot V_h \quad (6)$$

Here, ρ , c and V' represent the density of the air (kg/m³), the specific heat of the air (J/kgK) and the volumetric flow rate of the air (m³/h), respectively.

Internal heat gains; It can be caused by electrical devices, people, lighting, hot water and cooking processes. In buildings used for residential, office and educational purposes, a maximum value of 5 W/m² per unit floor area is taken in terms of internal gains, and 10 W/m² is taken in buildings where electrical appliances and industrial devices that give heat to their surroundings are used intensively.

The monthly average solar gain is calculated using Equation 7.

$$\varphi_{g,month} = \sum r_{i,month} \cdot g_{i,month} \cdot I_{i,month} \cdot A_i \quad (7)$$

Here, $r_{i, month}$, $g_{i, month}$, $I_{i, month}$ and A_i are the shading factor average of the transparent surfaces, the solar energy transmission factor of the transparent elements, the intensity of the solar radiation in contact with the vertical surfaces (W/m²), respectively. represents the total area of the windows (m²).

The monthly average gain factor is calculated using Equation 8.

$$\eta_{month} = 1 - e^{\left(-\frac{1}{KKO_{month}}\right)} \quad (8)$$

Here, KKO_{month} represents the ratio of heat gains to heat losses. KKO_{month} is calculated using Equation 9.

$$KKO_{month} = (\varphi_{i,month} + \varphi_{g,month})/H(T_{i,month} - T_{d,month}) \quad (9)$$

Here, $\varphi_{i,month}$, $\varphi_{g,month}$, $T_{i,month}$ and $T_{d,month}$ represent the monthly internal gains (W), the monthly solar energy average (W), the monthly average indoor temperature, respectively. (°C) and the average of the monthly outdoor temperature (°C). If the KKO_{month} ratio is at least 2.5, it is accepted that there is no heat loss for that month [12].

2.2. Alternative Reinforced Concrete Support Systems

Shear Wall-Frame (traditional formwork) and sheer Shear Wall (tunnel formwork) systems are frequently used as reinforced concrete carrier system in multi-storey building and mass housing production in Turkey. The details of the shear-frame and shear-wall systems, which fall within the scope of alternative reinforced concrete carrier systems, are shown under two subheadings.

2.2.1. Shear Wall-Frame Building Carrier Systems

Shear Wall-Frame Building (SWFB) carrier systems; It is called carrier systems made of columns, beams and shear wall that can be built with traditional formwork systems. The frame building system consists of columns and beams. However, when the storey height increases, the columns and beams are insufficient to meet some loads. For this reason, shear walls are added in addition to columns and beams. Thus, the carrier system consists of both a shear walls and a frame system. The said carrier system is used in high-rise buildings with at least 10-15 floors. It is one of the systems frequently used in the world and in our country. An example building model with Shear Wall-frame carrier system is shown in Figure 3.

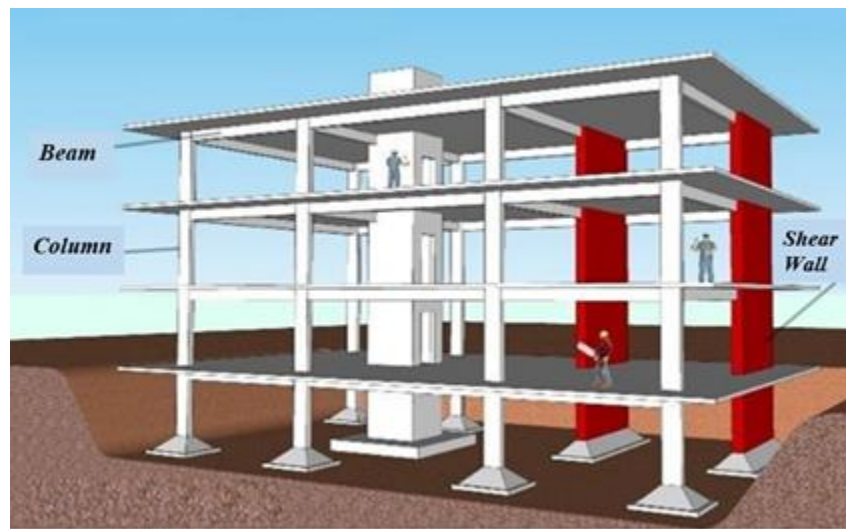


Figure 3. An exemplary frame building model with a shear wall-frame structural system

2.2.2. Pure Shear Wall Building Carrier Systems

Pure Shear Wall -only carrier systems; It is called carrier systems that can be built with tunnel formwork and consist entirely of shear walls. The tunnel formwork system is a tunnel-shaped, smooth-surfaced steel formwork system that allows the floor and shear walls to be concreted in place in one go. In the tunnel formwork system, the load-bearing (shear) walls can be concreted in a single operation, so the carrier system is purely curtailed. Based on this, an example building with a shear wall system is shown in Figure 4. In particular, in many mass housing constructions such as TOKİ, only pure shear wall carrier system is used depending on the tunnel formwork. There are some benefits that the tunnel formwork system can provide in building production. These benefits are:

- The building is earthquake resistant.
- Compared to the traditional formwork system, the production rate of the building made with the Tunnel formwork system is higher.
- Since the tunnel formwork system is not a complex technology, it is possible to facilitate the application.



Figure 4. An example building with Pure Shear Wall carrier system [13]

2.3. Description and Project Information of the Application Building with Shear Wall-Frame Carrier System

Within the scope of this study, application is made on two different reinforced concrete carrier systems. As the first application, the building in the context of the Shear Wall - Frame carrier system is discussed. The building in question is located on a site consisting of three apartment blocks and two shop blocks in Elazig, which is in a moderate-dry climate zone. C block was chosen as the reference building among them. The site plan and satellite image of the application building within the site are shown in Figure 5 and Figure 6, respectively. The (a) exemplary front view [14] and (b) the rear view of the buildings in the site are shown in Figure 7.

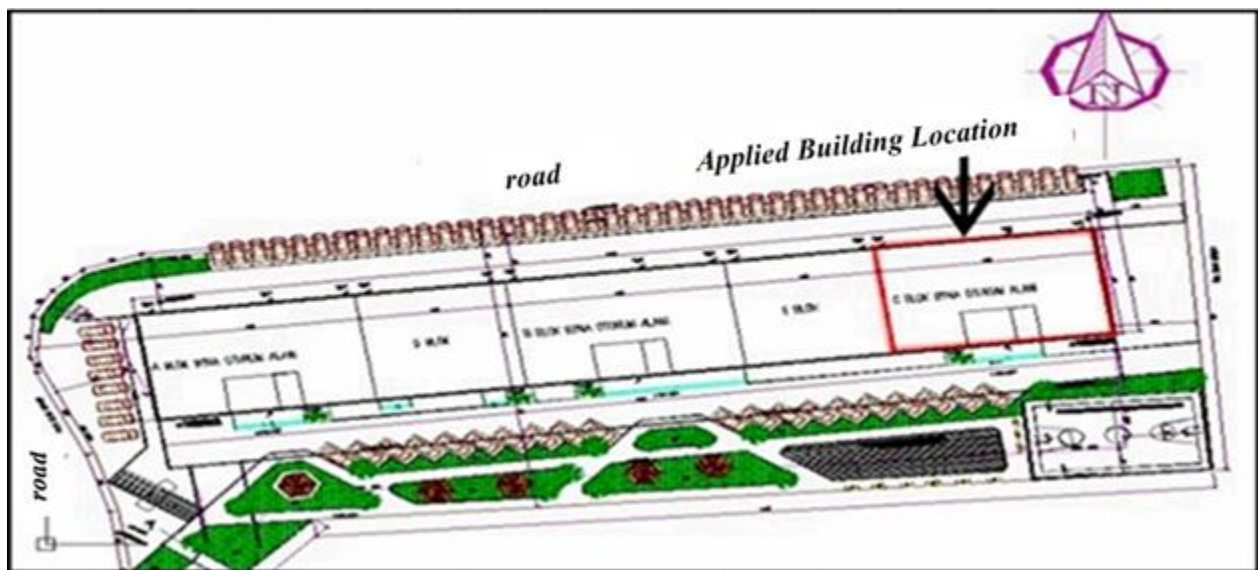


Figure 5. Situation plan of the site and the application building with the Shear Wall-Frame carrier system in the site



Figure 6. Satellite image of the site and the application building with the Shear Wall-Frame carrier system in the site

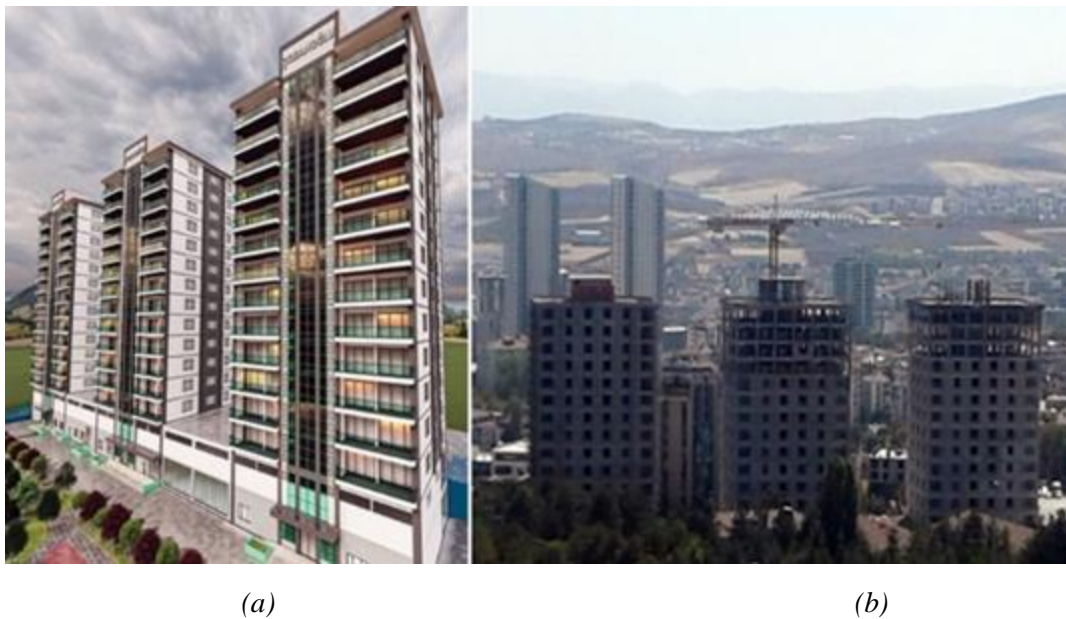


Figure 7. Buildings in the site; (a) diagonal views from the sample model [14] and (b) rear views under construction

The general characteristics of the application building with the Curtain-Frame carrier system are given in Table 2. The normal floor plan and various views of the building in question are shown in Figure 8 and Figure 9, respectively. The cross-sectional views of the application building with the Shear Wall-Frame carrier system are shown in Figure 10.

Table 2. General characteristics of the application building with Shear Wall-Frame carrier system

Situation	Properties
City	Elazig
Reinforced Concrete Carrier System	Shear Wall + Frame
Building Purpose	Residential + Shop
Number of Storey	16 (13 normal storey+ 1 ground storey + 2 basement storey)
Number of Flat	26
Location	K 38.67503, D 39.17524
Building Width	26.40 m
Building Depth	19.25 m
Building height	53.45 m (including basement storey)
Storey Height	3.15 m (Normal Storey), 4.50 m (Ground Storey), 4 m (Basement Storey)
Exterior Column Dimensions	30 cm x 120 cm
Outdoor Beam Dimensions	30 cm x 60 cm
Shear Wall Dimensions	280 cm x 35 cm
Flooring Thickness	20 cm

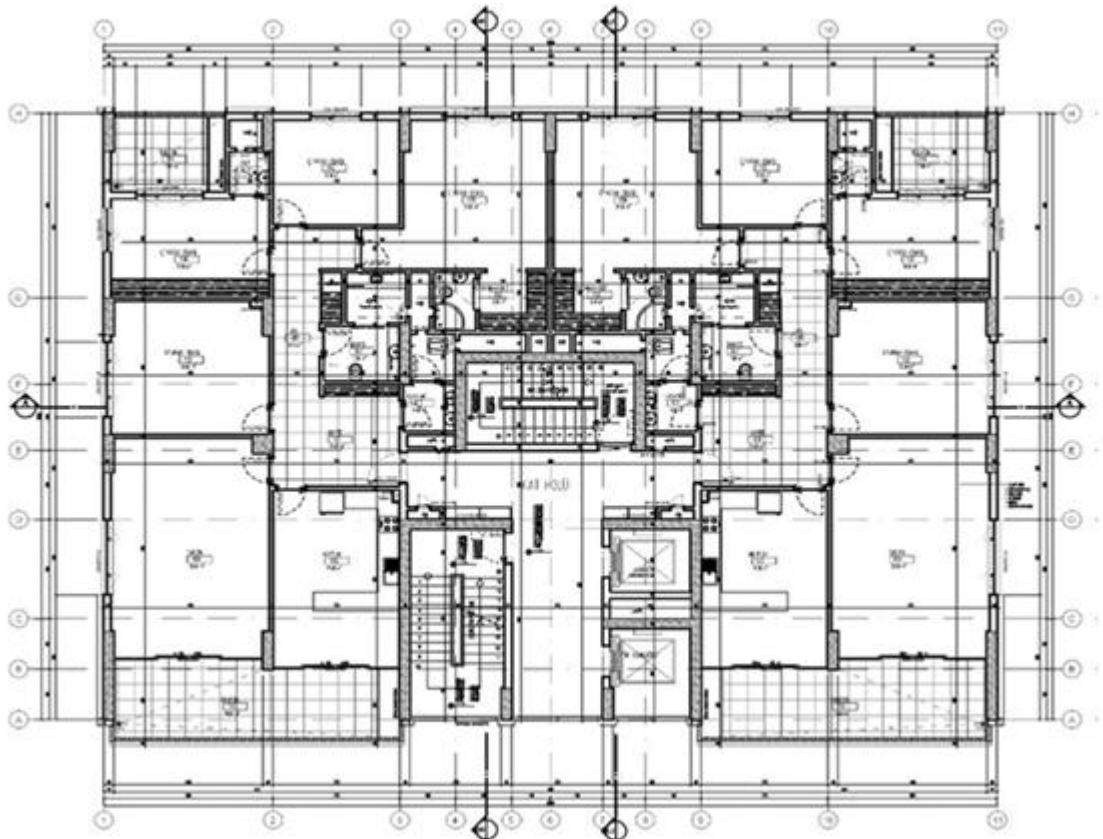


Figure 8. Normal Storey plan of the application building with Shear Wall-Frame carrier system



Figure 9. Various views of the application building with the Shear Wall-Frame carrier system during the construction phase

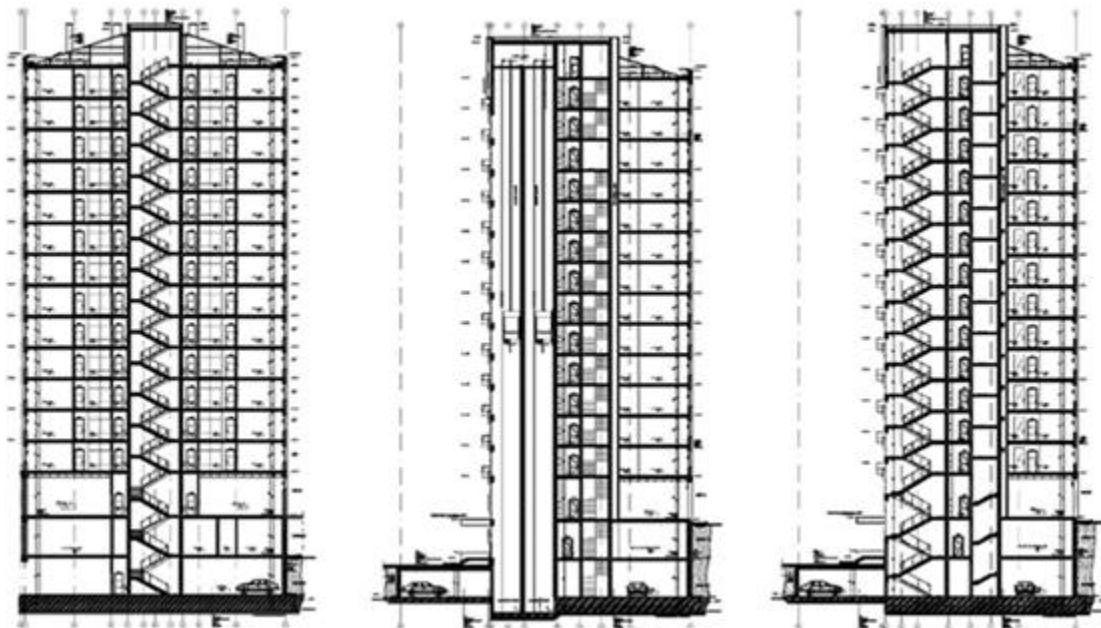


Figure 10. Sectional views of the application building with the Shear Wall-Frame carrier system

2.4. Description and Project Information of the Application Building with Pure Shear Wall Carrier System

The second application, the building in the context of the Pure Shear Wall carrier system, is located in the 4th Stage TOKI Site in the Abdullahpaşa Neighborhood of the Central District of Elazığ. C21-22-23-24-25 blocks are some of the blocks in the site. These blocks, which are equivalent to each other, were made with the tunnel formwork system. C25 block was chosen as the reference building among them. The area where the blocks are located and the site plan and satellite image of the application building in this area are shown in Figure 11 and Figure 12, respectively. The general features of the building are shown in Table 3. TOKI Site construction start area is shown in Figure 13.

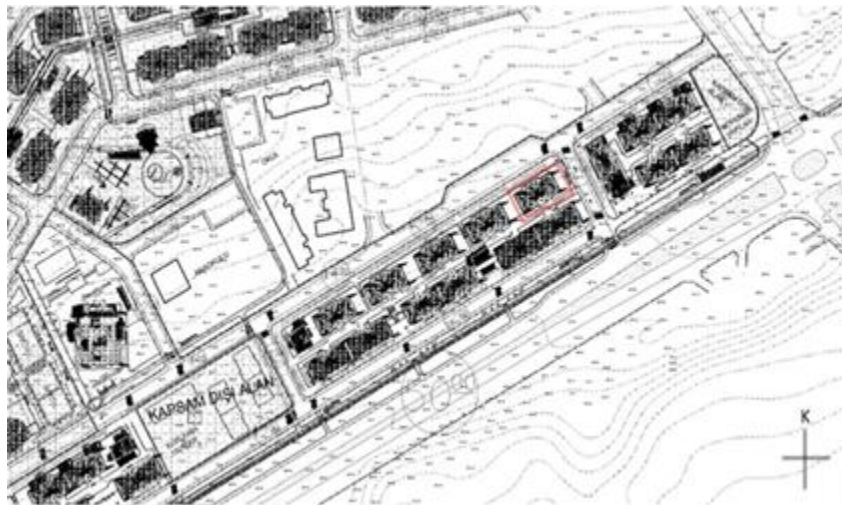


Figure 11. Layout plan of the application building with Pure Shear Wall carrier system



Figure 12. Satellite image of the application building with Pure Shear Wall carrier system

Table 3. General properties of the application building with Pure Shear Wall carrier system

Situation		Properties
City		Elazığ
Reinforced Concrete Carrier System		Pure Shear Wall
Building Purpose		Residential
Number of Storey		7 (5 normal storey+ 1 ground storey + 1 basement storey)
Number of Flat		18
Location		K 38.65895, D 39.15887
Building Width		30.30 m
Building Depth		15.60 m
Building height		20.37 m (Basement included)
Storey Height		2.91 m
Exterior Column Dimensions		15 cm



Figure 13. TOKI Site construction start area

Some views of Abdullahpaşa Neighborhood 4th Stage TOKİ Site are given in Figure 14. a) rear and b) side views of the C25 block under construction are given in Figure 15. The front views of the C23-C24-C25 equivalent blocks are shown in Figure 16. The normal storey plan and sectional views of the C25 block, which is the application building with pure shear wall carrier system, are shown in Figures 17 and 18, respectively.



Figure 14. Some views from Abdullahpaşa 4th Stage TOKİ Site [15]



Figure 15. C25 block under construction a) Rear b) Side views



Figure 16. Front views of blocks C23-C24-C25 [13]

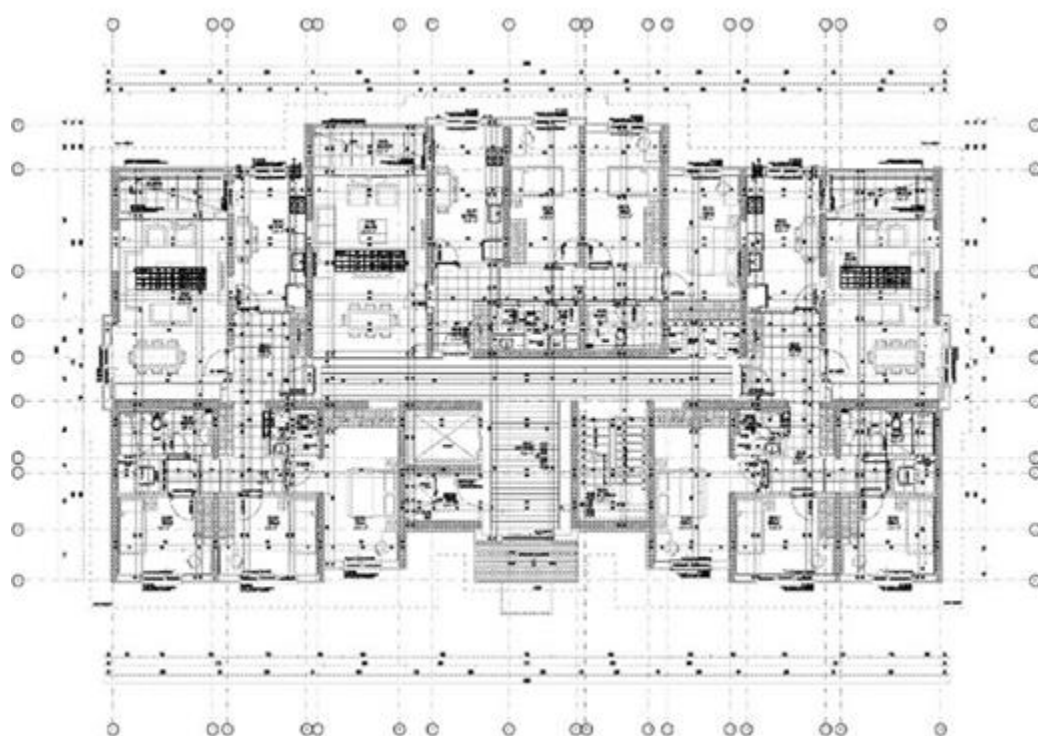


Figure 17. The session plan of blocks C23-C24-C25 [13]

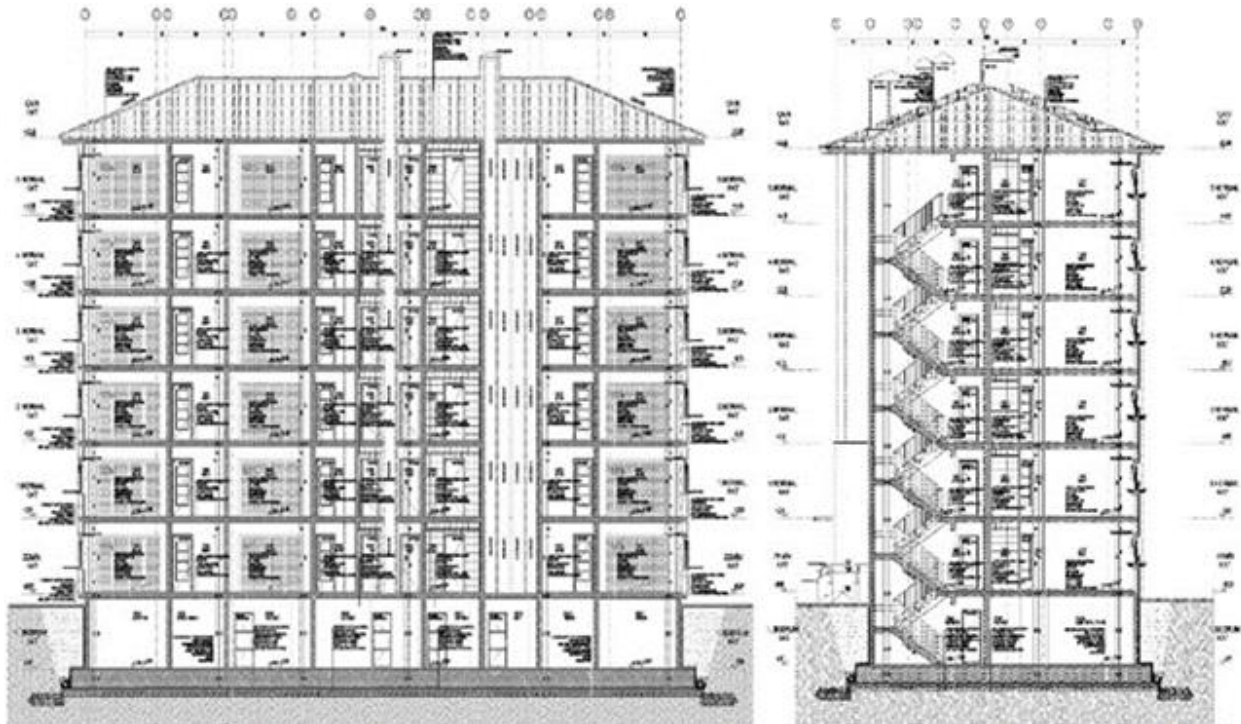


Figure 18. Sectional views of the application building with Pure Shear Wall carrier system

3. Discussion and Conclusion

In this section, data, findings and results that evaluate the energy analysis of a building with a shear wall-frame carrier system and a building with a pure shear wall carrier system in Elazig climatic conditions with the TS825 Program and various efficiency variations are presented.

3.1. Climate Data

Elazig is located in a moderate-dry climate zone and has 3 degree-day climatic conditions according to TS 825 rules. The summers are hot and dry, and the winters are cold and rainy. This situation shows that Elazig climate has a transition feature between continental and Mediterranean climate conditions. In the measurements made by the General Directorate of Meteorology between 1938 and 2020, the hottest day was 42.2°C in July and August, and the coldest day was -22.6°C in December and January. The average annual total precipitation amount is 416.1 mm. The average annual sunshine duration is 7.1 hours. The average number of rainy days is 98.6 days per year. The average outdoor temperatures of the province of Elazig are shown in Figure 19 [16].

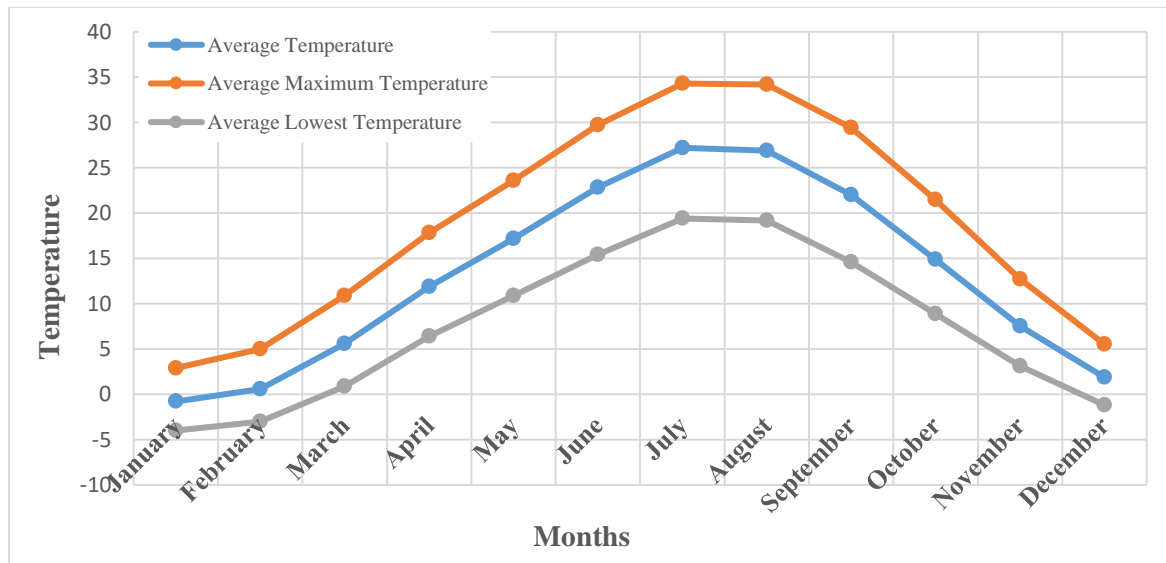


Figure 19. Average outside temperatures of Elazig province [16]

3.2. Thermo-Physical Properties of Building Structural Elements

The presumptions regarding the thermo-physical properties of the building with Pure Shear Wall carrier system and the building with Shear Wall-Frame carrier system are as follows: The average transparency rate of the building with Pure Shear Wall carrier system is calculated as 20%, and the average transparency rate of the building with shear wall-frame carrier system is calculated as 35%. The Solar Energy Gain Coefficient (SEGC) of the transparent components in both buildings is 60%. The thermal permeability of the inner walls was calculated as 1,923 W/m²K. The overall heat transfer coefficients of the building components are given in Table 4 and Table 5.

Table 4. Overall heat transfer coefficients of the building components of the existing pure shear wall structural system building

Building Structural Elements	Layer Detail (Inside to Outside)	U Values (W/m ² K)
Reinforced Concrete Wall Surfaces	0.02 m Lime mortar, lime-cement mortar	0,498
	0.2 m Reinforced	
	0.02 m Cement mortar	
	0.06 m Rock wool	
	0.01 m Gypsum mortar, calcareous gypsum mortar	
Total Contact Ground- Wall Surfaces	0.02 m Lime mortar, lime-cement mortar	3,702
	0.2 m Reinforced	
	0.006 m Bituminous cover	

Ceiling	0.02 m Lime mortar, lime-cement mortar 0.2 m Reinforced 0.1 m Rock wool 0.02 m Gypsum mortar, calcareous gypsum mortar	0,354
Base	0.02 m Granite flooring 0.03 m Cement mortar screed 0.7 m Reinforced 0.05 m Unreinforced 0.003 m Bituminous cover 0.1 m Unreinforced 0.1 m of Gravel	1,373
Window	4+16+4 aluminum joinery low-e insulated glass	2,1
Door	heat insulated door	4

Table 5. Overall heat transfer coefficients of the building components of the building with the existing Shear Wall-Frame carrier system

Building Structural Elements	Layer Detail (Inside to Outside)	U Values (W/m ² K)
Infill Wall Surfaces	0.03 m Lime mortar, lime-cement mortar 0.2 m Pumice Wall 0.06 m Rock wool 0.03 m Lime mortar, lime-cement mortar	0,366
Reinforced Concrete Wall Surfaces	0.03 m Lime mortar, lime-cement mortar 0.2 m Reinforced 0.06 m Rock wool 0.03 m Lime mortar, calcareous gypsum mortar	0,541
Total Contact Ground-Wall Surfaces	0.03 m Lime mortar, lime-cement mortar 0.3 m Reinforced 0.006 m Bituminous cardboard 0.06 m Rock wool 0.15 m Soil	0,536
Ceiling (Unused with Roof)	0.02 m Lime mortar, lime-cement mortar 0.2 m Reinforced 0.006 m Bituminous cardboard	0,35
Ceiling (Without Roof)	0.1 m Rock wool 0.02 m Unreinforced	0,355
Base	0.2 m Unreinforced 1.7 m Reinforced 0.2 m Reinforced 0.006 m Bituminous carbon 0.1 m Unreinforced 0.1 m of Gravel	0,941

Window	4+16+4 aluminum joinery low-e insulated glass	2,1
Door	Heat insulated door	4

3.3. Establishment of Efficiency Alternatives for Existing Building Structural Elements

Various efficiency scenarios and thermal permeability coefficients of the building components calculated depending on the scenarios of the building with Pure Shear Wall structural system and the building with Shear Wall-Frame structural system are presented in Table 6 and Table 7, respectively. The different structural components of the buildings in question were examined in detail in a total of 11 different scenarios with and without insulation.

Table 6. Overall heat transfer coefficients of the building components calculated based on the efficiency scenarios for the building with Pure Shear Wall structural system

Alternative Number	Clarification	U _{ow1}	U _{ow2}	U _{td}	U _c	U _b	U _w	U _d
A1	Non-isolated Condition	0,822	3,419	3,702	3,401	1,373	2,8	5,5
A2	The current situation	0,368	0,558	3,702	0,354	1,373	2,1	4
A3	A2 Alternative + Improvement of building components other than the outer wall that do not comply with TS 825	0,368	0,558	0,44	0,28	0,367	2,1	4
A4	6 cm for Exterior Walls XPS + Improvement of building components other than exterior walls that do not comply with TS 825	0,311	0,436	0,44	0,28	0,367	2,1	4
A5	6 cm EPS for Exterior Walls + Improvement of building components other than exterior walls that do not comply with TS 825	0,341	0,498	0,44	0,28	0,367	2,1	4
A6	8 cm rock wool for Exterior Walls + Improvement of building components other than exterior walls that do not comply with TS 825	0,311	0,436	0,44	0,28	0,367	2,1	4
A7	8 cm for Exterior Walls XPS + Improvement of building components other than exterior walls that do not comply with TS 825	0,258	0,338	0,44	0,28	0,367	2,1	4

A8	8 cm EPS+ for Exterior Walls Improvement of building components other than exterior walls that do not comply with TS 825	0,286	0,388	0,44	0,28	0,367	2,1	4
A9	10 cm rock wool for Exterior Walls + Improvement of building components other than exterior walls that do not comply with TS 825	0,269	0,358	0,44	0,28	0,367	2,1	4
A10	10 cm for Exterior Walls XPS+ Improvement of building components other than exterior walls that do not comply with TS 825	0,22	0,276	0,44	0,28	0,367	2,1	4
A11	10 cm EPS for Exterior Walls + Improvement of building components other than exterior walls that do not comply with TS 825	0,245	0,317	0,44	0,28	0,367	2,1	4

Table 7. Overall heat transfer coefficients of the building components calculated depending on the efficiency scenarios for the building with the Shear Wall-Frame carrier system

Alternative Number	Clarification	U_{ow1}	U_{ow2}	U_{td}	U_{c1}	U_{c2}	U_b	U_w	U_d
A1	Non-isolated Condition	0,813	2,857	2,74	2,775	3,122	0,941	2,8	5,5
A2	The current situation	0,366	0,541	0,536	0,35	0,355	0,941	2,1	4
A3	A2 Alternative + Improvement of building components other than the outer wall that do not comply with TS 825	0,366	0,541	0,481	0,277	0,28	0,327	2,1	4
A4	6 cm for Exterior Walls XPS + Improvement of building components other than exterior walls that do not comply with TS 825	0,31	0,426	0,481	0,277	0,28	0,327	2,1	4
A5	6 cm EPS for Exterior Walls + Improvement of building components other than exterior walls that do not comply with TS 825	0,34	0,484	0,481	0,277	0,28	0,327	2,1	4
A6	8 cm rock wool for Exterior Walls + Improvement of building components other	0,31	0,426	0,481	0,277	0,28	0,327	2,1	4

	than exterior walls that do not comply with TS 825								
A7	8 cm for Exterior Walls XPS + Improvement of building components other than exterior walls that do not comply with TS 825	0,257	0,331	0,481	0,277	0,28	0,327	2,1	4
A8	8 cm EPS+ for Exterior Walls Improvement of building components other than exterior walls that do not comply with TS 825	0,284	0,379	0,481	0,277	0,28	0,327	2,1	4
A9	10 cm rock wool for Exterior Walls + Improvement of building components other than exterior walls that do not comply with TS 825	0,268	0,351	0,481	0,277	0,28	0,327	2,1	4
A10	10 cm for Exterior Walls XPS+ Improvement of building components other than exterior walls that do not comply with TS 825	0,219	0,271	0,481	0,277	0,28	0,327	2,1	4
A11	10 cm EPS for Exterior Walls + Improvement of building components other than exterior walls that do not comply with TS 825	0,245	0,312	0,481	0,277	0,28	0,327	2,1	4

Here; U_{ow1} and U_{ow2} represent the overall heat transfer coefficients of the infill wall and the thermal permeability of the reinforced concrete wall, respectively. U_{ttd} , U_c , U_b , U_d and U_w represent the thermal transmittance value of the ground contact wall, ceiling, floor, door and window, respectively. It is accepted that 6 cm XPS is used on the floor and soil contacted wall and 13 cm rock wool is used on the ceiling in the option of improving the building components other than the outer wall, which do not comply with TS 825.

3.3. Energy Performance Evaluation Results of Buildings

Figure 20 shows the monthly heating energy consumption per square meter depending on TS825 energy analysis methods in the current (A2 alt.) position of the building with Pure shear wall structural system and the building with Shear Wall-Frame carrier system, respectively. As seen in Figure 20, it is seen that the heating energy need in the Pure Shear Wall carrier system is higher on a monthly basis.

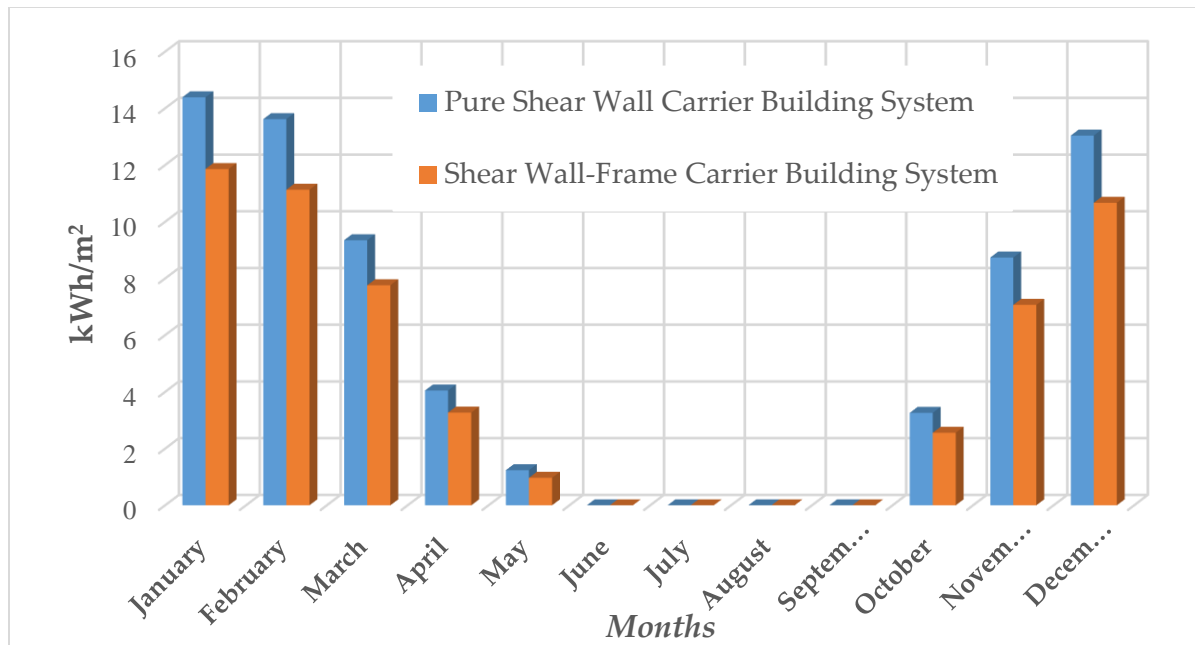


Figure 20. Monthly Change of Heating Energy of Buildings with Pure Shear Wall Carrier and Shear Wall-Frame Carrier System According to TS825 Program

When the energy consumption is examined in the TS825 program, the required heating load is 14.39 kWh/m² energy requirement in the shear wall structural building system, while it is calculated as 11.86 kWh/m² in the Shear Wall-Frame carrier system. When the energy loads are examined according to the TS825 energy analysis method and the current state of two different buildings, it is seen that the thermal energy loads are the lowest in the summer season and the highest in the winter season. Therefore, the heating season is usually in October-April.

The annual heating energy balances of buildings with Pure Shear Wall carrier and Shear Wall-Frame carrier systems are given in Figure 21. There is a difference of 44.56 kWh/m².year between the heating energy between pure curtain wall and curtain frame carrier system buildings.

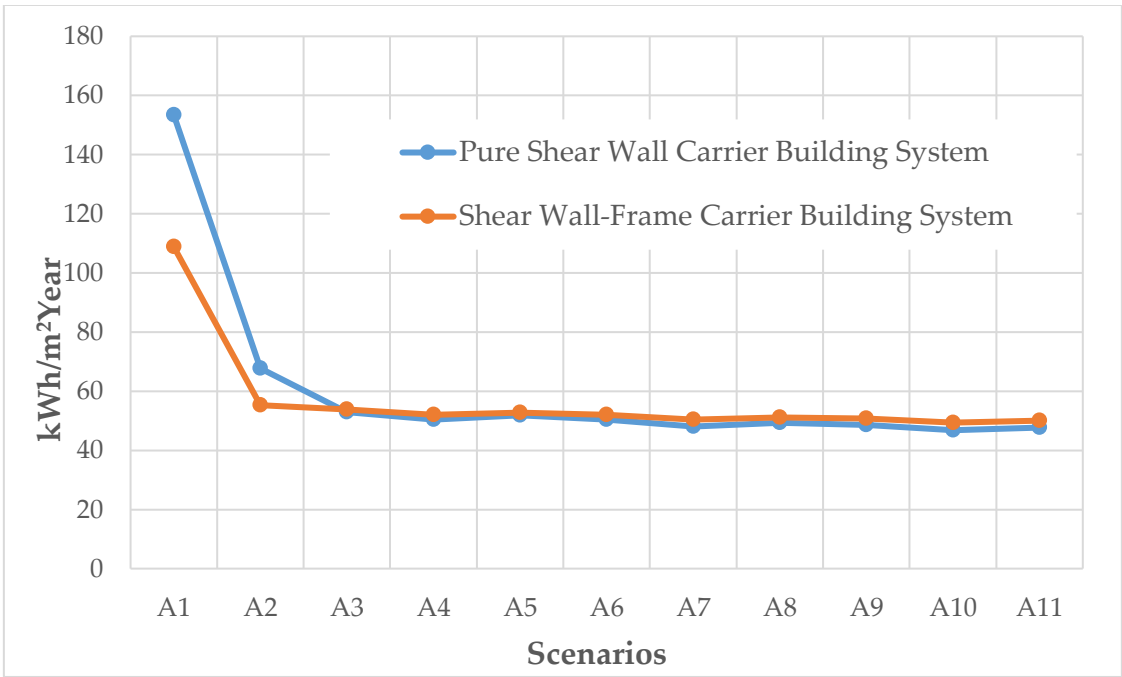


Figure 21. Annual Change of Heating Energy of Buildings with Pure Shear Wall Carrier and Shear Wall-Frame Carrier System According to TS825 Program for 11 Different Scenarios

The percentage change in energy consumption for the scenarios created with the alternative building components of the building with the Shear Wall-Frame carrier system compared to the building with the Pure Shear Wall carrier system is given in Figure 22.

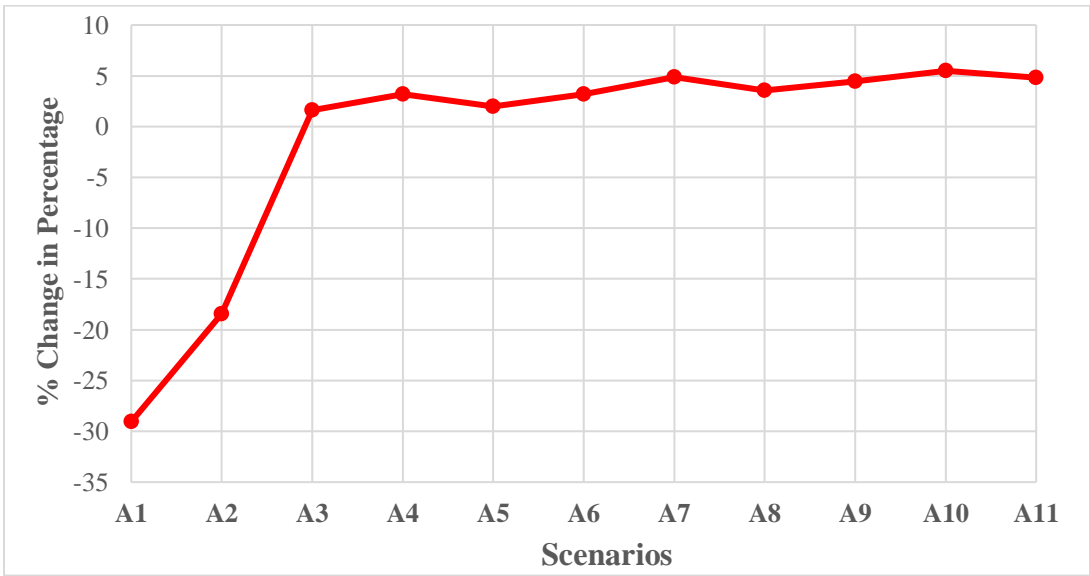


Figure 22. Percentage change of energy consumption of the building with Shear Wall -Frame carrier system compared to the building with Pure Shear Wall carrier system

In the energy analysis made according to the TS825 program, in the A1 alternative, the building with Shear Wall-Frame carrier system consumed 29.06% less energy than the building with Pure Shear Wall carrier system. In the A2 alternative, the building with Shear Wall-Frame carrier system consumed 18.45% less energy than the building with Pure Shear Wall carrier system. However, in the A10 alternative, which reveals the lowest energy consumption, the building with Shear Wall-Frame carrier system consumed 5.49% more energy than the building with Pure Shear Wall carrier system. Due to the heavy weight of the concrete, which has a very high thermal permeability in an uninsulated building, the building with Pure Shear Wall carrier system consumes more energy than the building with Shear Wall-Frame carrier system. In other alternatives, which are generally optimized in terms of insulation, the building with Shear Wall-Frame carrier system consumes up to 5.49% more energy than the building with Pure Shear Wall carrier system. The reason for this is that the transparency ratio of the building with Shear Wall-Frame carrier system is higher than the building with Pure Shear Wall carrier system.

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