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Effect of phase change materials on building heating and cooling load considering different wall combinations

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Abstract

In this study, energy analyzes were carried out on a sample building for wall types where 3 main materials (brick, concrete block, aerated concrete) and 3 different insulation materials were used in different combinations, taking into account the situations with and without PCM. Building heating and cooling loads for 39 different scenarios derived in this way were determined by taking into account the coldest and hottest days of the year and also as the total energy need during the year. Analyzes were made with the Design Builder program and the results are presented with tables and graphs. By comparing and classifying the total energy loads of wall samples created for 39 different scenarios during the year, wall types that gave more positive results were determined. Three different PCM types with melting temperatures of 21 °C, 23 °C and 29 °C were used in the analyses. Based on the main material of the wall, three walls with the best performance among their main materials were initially determined. Then, among the wall types consisting of these 3 main materials (brick, concrete block, aerated concrete), the walls that showed the best performance were determined among the combinations created with the addition of insulation material and PCM. The best results with PCM were obtained for XPS as insulation material and aerated concrete as wall type. According to the results of the simulations, 25% energy savings were achieved when only insulation materials (XPS, EPS, Rock Wool) were used in the building envelope, and 9% energy savings were achieved when only PCM was used. By using PCM and insulation materials (XPS, EPS, Rock Wool) together, 30% energy savings were achieved.PCM, which is used in addition to the insulation materials used in the building envelope to reduce the energy load of the building, has led to a decrease in the annual energy need of the building. The combined use of PCM and insulation material can be recommended for regions where the heating load is high. It will be more effective to use PCMs with low melting points in cold climate regions, and PCMs with high melting points to be used in temperate and hot climate regions. It has been advised using PCM with two melting temperatures instead of using PCM with a single melting temperature in the building envelope as a more advantageous solution.

Keywords: phase change material, design builder, cooling load analysis, heating load analysis, energy analysis, building envelope, simulation

1. Introduction

Energy has become an indispensable requirement that continues to increase in the amount of need from past to present. Today, increasing population and technological developments have led to the depletion of energy resources and the issue of energy to become important. Unconscious and excessive consumption of energy resources used to meet this energy need has led to environmental problems (Yılmaz,2006).

In Turkey, 30% of the energy is used in buildings and a large part of the buildings are made up of residences. The increase in population and building stock causes an increase in energy demands in direct proportion. The use of renewable energy sources, the popularity of which is increasing day by day due to the decreasing energy resources in the world, and in parallel with this, energy efficiency has become an important subject today. This plays a major role in reducing the cost of energy and contributes to the reduction of greenhouse gas emissions, air and environmental

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pollution (Turkish Grand National Assembly 11th Development Plan). In addition to the use of renewable energy sources, thermal storage systems, techniques and materials used to increase energy efficiency are also important and necessary (Narin & Akdemir, 2006).

Heat storage, which is the cornerstone of energy efficiency, reduces energy losses and energy savings. Today, thermal storage can be offered as a solution in order to use energy more efficiently and to save money (Aydın & Okutan, 2010). Apparent heat storage is the most common method used in thermal energy storage. Apparent heat storage occurs due to an increase in temperature. Latent heat storage which is an another method may be evaluated as a better and more effective method than apparent heat storage. The material used changes phase (gas-liquid, liquid-solid, gas-solid) at a certain temperature, takes a large amount of heat energy from the environment or performs heat exchange by giving it to the environment. Since there is no change in temperature when this heat exchange takes place, it is called latent heat storage. The oldest examples are the example of preserving the heat of the environment by using ice and snow (Prakash et al., 1985).

Phase Change Materials (PCM) which have the ability of latent heat storage are generally applied on building envelopes which has an intensive heat exchange. They generally play role as an area of storage in order to protect the heat. PCM can be defined as a modern “ thermal mass” which absorbs the heat, store in it, delaying the effects of external climate elements and reducing their amplitudes, transferring them to the interior space and thus preventing the overheating that may occur in the interior. The performance of PCM changes due to climatic regions while they also decrease cooling energy load in summer beside heating energy load in winter times (Konuklu & Paksoy, 2009). PCM is a material suitable for use in light and high heat mass building envelope applications (Kosny, 2015). It also helps to minimize the negative effects between buildings, which can occur with mutual shading and reflections in urban environments, as they increase building inertia while reducing indoor temperature fluctuations (Han & Taylor,2015). On the other hand, if the PCM mass is overestimated, the time required for heat release indoors may be greater than the discharge time and the solidification process cannot be completed. This results in insufficient latent heat storage (Soares et al,2013).

The effect of phase change materials on energy consumption has been the subject of many studies. Kuznık and Virgona (2009), experimentally investigated the thermal performance of a PCM copolymer composite wallboard in a full-scale test room. The test cell is fully controlled (temperature and solar irradiance flux) so that a typical day can be replicated. The effects of PCM were investigated for three conditions by comparing results with and without composite wall sheets: a summer day, a winter day, and a mid-season day. The results showed that for all cases tested, the reduction factor ranged from 0.73 to 0.78. In a study by Kissock et al. (1998), the results were observed by impregnating the walls with 30% commercial PCM paraffin (K18). During 14 days, solar radiation, outdoor temperature were recorded by measuring the temperature values between the tested walls with and without PCM. As a result, it was observed that the region with PCM was 10 °C less than the region without PCM. In a study commissioned by Rubitherm, PCMs were placed on the ground to provide building insulation. When the system used is compared with conventional heating systems, it has been determined that it provides 35% reduction in energy consumption.

Alawadhi (2008) applied the PCM material to the brick and performed thermal analyzes for hot climate zones. As a result of the research, when PCM was included in the brick, a decrease in heat gain and a positive effect were observed when the amount of PCM was increased. In a study by Shukla et al. (2009), the performance of PCM in solar water heaters was investigated. They wanted to take advantage of the thermal storage feature of PCM. As a result of the study, it was seen that it was necessary to use PCM for high latent heat and heat transfer to the large surface in order to provide a higher performance from the water heater. Konuklu and Paksoy (2011), investigated whether there is a reducing effect on the energy consumed in the building by using PCM material in the building envelope. In the research conducted on an area of 4 m², it was observed that PCM affected the heating and cooling load. In addition, a better result was obtained in the building envelope in which insulation materials were used together with PCM, than in the building envelope in which only PCM was used. In the study, it was concluded that the melting temperatures of PCMs used in summer should be higher to give better results, while PCMs used in winter should have lower melting temperatures. It was deemed appropriate to use PCM with two different melting temperatures in order to save energy in the building in summer and winter. Tomlinson and Heberle (1990) investigated the effect of PCM used in gypsum panels in interior spaces on building energy saving. According to the results obtained, it was determined that the cost spent on PCM was paid by the energy savings it provided. It has also been observed that PCM affects energy saving. Castellón et al. (2006) conducted an experimental study to investigate the effect of PCM material on energy saving by applying it to conventional concrete. In the experiment conducted in Spain, the positive effect of concrete using PCM on energy saving was determined. It has also been observed that PCM melts during the day and freezes at night. According to the results obtained, it was stated that night freezing of PCM was considered as an advantage. Izquierdo-Barrientos et al. (2012) conducted a study to examine the effect of PCM on the external wall. The study also concluded the study by producing various scenarios such as increasing or decreasing the melting temperature of PCM and changing the orientation of the building. As a result of the study, it was seen that PCM reduces the heat fluidity passing through the wall and reduces the amount of heat lost in winter. It was determined that PCM increased the thermal load during the day and decreased it at night. In a study conducted by Izquierdo-Barrientos et al. (2013) to examine the behavior of a fluidized tank filled using PCM, it was determined that PCM is a material that can be used in fluid systems to increase heat storage efficiency.

Energy consumption is also increasing due to the increasing human population and the resulting increasing building stock. Achieving energy savings in buildings depends primarily on making the right decisions regarding the variables affecting heating and cooling energy loads. The building envelope separates the indoor and outdoor environments and plays a major role in heat transfer control; It is one of the most important parameters affecting energy consumption with its optical and thermophysical properties. In order to solve this problem, many studies have been carried out with the help of programs that perform energy analysis in buildings. In studies using PCM material, comparisons were generally made by taking advantage of climatic differences.

In this study, analysis studies were carried out on a sample building in Elazığ, based on the hypothesis that PCM reduces the energy load in the building by taking advantage of its thermal storage feature. Due to its various properties, PCM is expected to provide better results in terms of energy saving than insulation materials. In the study, a series of analyzes were carried out to compare the heating and cooling load values obtained by using insulation material in the building envelope of the sample building and the heating and cooling load values obtained by using PCM with insulation material in the building envelope. Analyzes were also made for PCM types with different melting temperatures. Thus, the effect of Phase Change Materials (PCM) on heating and cooling load was also analyzed for different insulation materials and different melting temperatures of PCM. Many programs are available to examine the effect of using different building materials on heating and cooling in the building envelope system. Among these programs, Design Builder was used because it can work in harmony with many programs and is more reliable than other programs related to energy simulations of the building. In the first stage of the study, the building was modeled with Design Builder. In the later stages, the heating and cooling loads obtained by using PCM material in the building envelope in the modeled building were compared and examined. In addition, in this study, the effect of PCM on the energy loads of the structure where it was used only by taking advantage of its thermal storage feature was examined.

2. Methods and Materials

In this study, energy analyzes were carried out on a sample building for wall types where 3 main materials (brick, concrete block, aerated concrete) and 3 different insulation materials were used in different combinations, taking into account the situations with and without PCM. Building heating and cooling loads for 39 different scenarios derived in this way were determined by taking into account the coldest and hottest days of the year and also as the total energy need during the year. Analyzes were made with the Design Builder program and the results are presented with tables and graphs. By comparing and classifying the total energy loads of wall samples created for 39 different scenarios during the year, wall types that give more positive results were determined. Based on the main material of the wall, three walls with the best performance among their main materials were initially determined. Then, among the wall types consisting of these 3 main materials (brick, concrete block, aerated concrete), the walls that showed the best performance were determined among the combinations created with the addition of insulation material and PCM.

Accordingly, the framework determined in the study is briefly presented below:

- In the study, wall types made of brick, concrete block and aerated concrete were among the scenarios created and were included in the analyzes without insulation.
- In the wall types created, PCM was used close to the outer surface of the wall.
- In the created scenarios, the insulation materials used with PCM were used before PCM and placed closer to the core of the building envelope.
- Generally, PCM thickness is in the range of 1-5 cm, and in order to analyze the relationship between thickness and efficiency, simulations were made for 3 different thicknesses of PCM as 1cm, 5cm, 10cm.
- Considering the climate data of Elazığ province, PCM with 3 types of melting temperatures (21 °C, 23 °C, 29 °C) was used to measure how PCM behaves in the specified province (Rubitherm, 2003).
- As a result of the determined scenarios, the cooling and heating load amounts required on the coldest and hottest days of the year were compared, taking into account the climate data of the building. At the same time, comparisons were made based on the total loads during the year.
- Heating, cooling and total loads are expressed in kWh units.
- The layer details and the properties and locations of the materials specified in the created walls were applied exactly in the simulations.
- Elazığ climate data is from 2002 due to the Design Builder program.
- When determining the indoor temperature, the days when the climatic conditions are most extreme are taken as basis.
- Since the PCM was used in the study, Finite Difference algorithm was used among the existing algorithms.

2.1. Building Specifications

For the study, a single-volume building with only the ground floor, with dimensions of 4m x 4m x 3m, was designed in the climate zone of Elazığ province. There are no elements that will create a shadow in the area where the building is located. The area where it is located is slopeless. A flat roof was used in the building. The slab sits on the floor. In order to benefit from more solar energy in the mass, a window with a height of 0,8 m from the ground, dimensions of 2,8 m x 1,5 m and a transparency rate of 30% and was placed on the south facade. 10 mm double glass was used in the window and 16 mm Argon gas was compressed between it. A door was placed on the north facade. Mechanical ventilation in the structure is excluded. Artificial lighting was used in the building. It is assumed that equipment was used in the building to ensure human life. The 3D visual of the structure is given in Figure 1 while the plan of the square-shaped structure is shown in Figure 2.

Figure 1 3D visual of the structure of the building

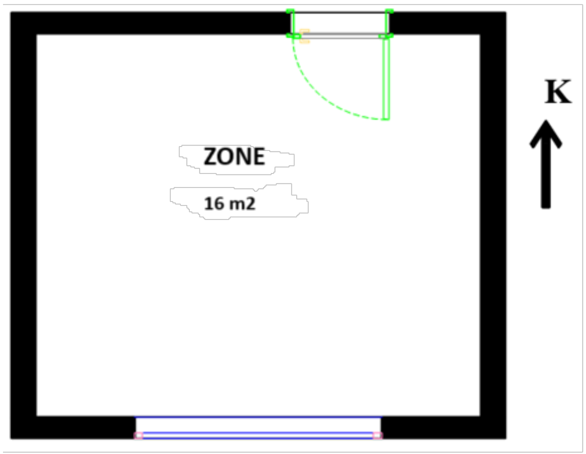


Figure 2 The plan of the square-shaped structure

Elazığ province is located in the 3rd degree day zone (Aksoy & Ekici, 2013). Insulation materials have been added to the elements of the created structure in order to reach the U value standards specified in TS 825 (Thermal Insulation Rules in Buildings). U values of structural elements are given in Table 1 for slab and roof elements while the U value for window and door accepted as 2.484 W/m²K and 2.283 W/m²K respectively.

Table 1 U Values of Structural Elements (Slab and Roof) d: Thickness k: Heat Transfer Coefficient (Yüksek & Sıvacılar, 2017)

Slab	d (m)	k (W/mK)	Roof	d (m)	k (W/mK)
Wood Floorıng Cover.	0,018	0,14	**Drywall**	0.0125	0.25
Enhancement Concrete	0,03	1,14	**Leveling Concrete**	0.05	1.14
Polyethylene	0,004	0,33	**Concrete Floors**	0.12	2.5
Polystyrene	0,07	0,034	**Bitumen**	0.003	0.23
Cement Screed	0,05	1,14	**Pcm**	0.05	0.20
Concrete Floors	0.10	1.13	**Xps**	0.16	0.034
			Geotextile Felt	0.01	0.30
			Aggregate	0.05	2
U (W/m²K)	**0,389**		**U (W/m²K) 0,188**		

2.2. Validation

In order to prove the accuracy of the results obtained as a result of the simulations made with the V7.0.2.006 version of the Design Builder program, another energy analysis program, CARRIER Hourly Analysis Program (HAP), was used, and the results obtained with Design Builder were compared by calculating the heating and cooling load of the building with HAP version 4.90. In this comparison process, all internal and external conditions were kept constant.

Hourly Analysis Program (HAP) was chosen for the validation study because the program is part of E20-II. E20-II which is an HVAC design program. HAP has a versatile structure that is often used for HVAC design in commercial buildings. The HAP program allows HVAC designs to be versatile and building simulations easier. The most important feature of the HAP program is that it analyzes 8760 hours a year, taking into account the climate data, human density, and the heat emitted by the equipment in the building to the environment. The ASHRAE Transfer Function Method is used to create these analyzes (ASHARE Standars and Guidelines). Creating hourly analysis ensures that the results obtained are closer to real data.

The energy loads of the building with the effect of the building components (roof, floor, wall, door, floor) that most affect the heating and cooling load of the building are given in the Table 2. Energy analysis was carried out for 1 space in the building. As a result of building analysis, the heating load was determined as 2839 W for Design Builder and 2947 W for HAP. In cooling load, values of 6146 W for Design Builder and 6261 W for HAP were obtained. A convergence of 4% and 2% was achieved between the two programs for heating and cooling loads, respectively.

Table 2 Comparison of Design Builder and HAP Results

	DESIGN BUILDER	HAP
Cooling Load	6146 W	6261 W
Difference	%2	
Heating Load	2839 W	2947 W
Difference	%4	

2.3. Simulation Details

Simulations were made with the Design Builder program for 39 scenarios created based on the building prototype determined in the study, and the results were analyzed. The process started with 3D modeling of the structure and continued with entering and editing the data required to complete the simulations accurately. Accordingly, firstly, the ratio between the number of people and the area in 1 zone defined in the activity tab of the Design Builder program was determined as 8. The number of people was determined as 2. The temperature range determined for the heating system in the building to operate was applied as -10 °C and 19°C. The temperature range determined for the cooling system in the building to operate was 26-50 °C. In order to meet the needs of the people living in the building, the equipment in the building was activated and allowed to radiate heat by working in a certain program. In this way, it is aimed to have a realistic value for the calculated heating and cooling load of the building. The HVAC system is selected as simple and the ideal loads tab is activated. When the HVAC system was active, the operative temperature values of the climate in which the building was located were checked. The HVAC system is assumed to operate at 100% efficiency without energy loss. The operating hours of the systems in the building are considered active between 07:00-24:00 and passive between 00:00-07:00.

2.4. Studied Scenarios

In order to measure the effect of PCM on the annual heating and cooling load, various scenarios were produced using insulation materials (XPS, EPS, Rock Wool) and PCMs on 3 main wall cores (Brick, Concrete Block, Aerated Concrete). Scenarios were created using examples such as uninsulated wall, wall with PCM, wall with insulation, wall with PCM + insulation material. Figure 3 presents the detailed definiton of codes for scenarios. For example the code of BW-XPS-5-21 reptresents a Brick Wall insulated with XPS and PCM which is 5 mm thick and has a melting point of 21 ^{0}C. Figure 4 also presents the detailed wall sections of main core of studied models in this work. Wall thickness accepted as 20 cm for all structural cores while the insulation thickness used as 5 cm for all insulation materials. The thickness of inner and outer plasters accepted as 2 and 3 cm respectively. Termophysical properties of structural and insulation materials used in the study are presented in Table 3.

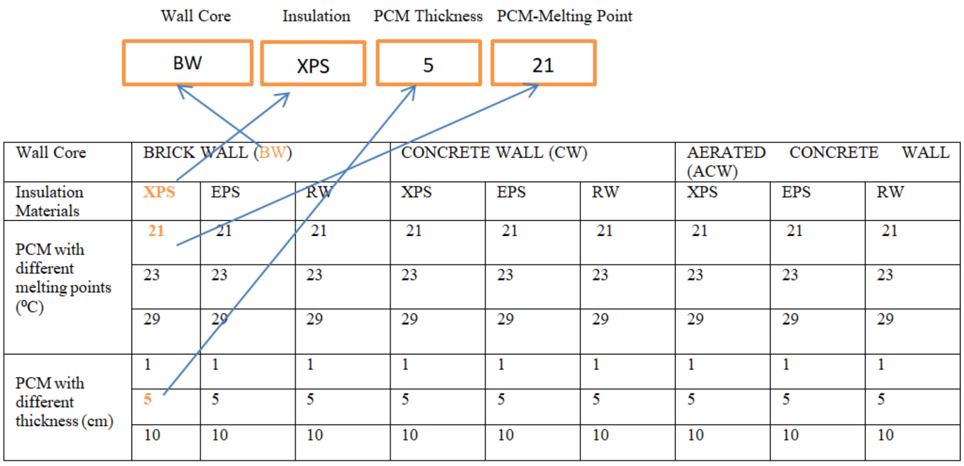


Figure 3 Detailed definiton of codes for scenarios

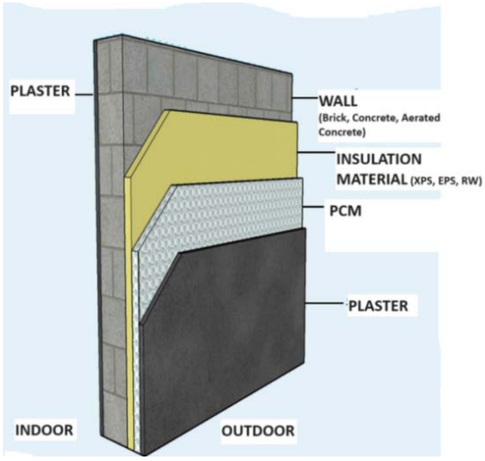


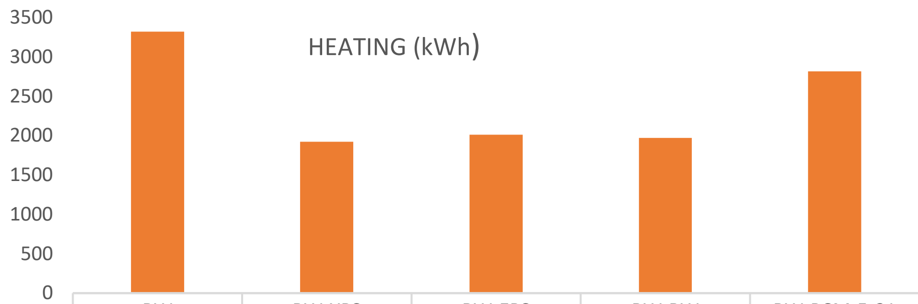
Figure 4 Detailed wall sections of main core of studied models

Table 3 Thermal Conductivity Coefficient (k (W/mK)) of Materials Used in the Scenarios

	d (m)	k (W/mK)
Structural Core		
Brick	0,20	0,30
Concrete Block		0,19
Aerated Concrete		0,14
Insulation		
XPS	0,05	0,034
EPS		0,040
Rock Wool		0,037

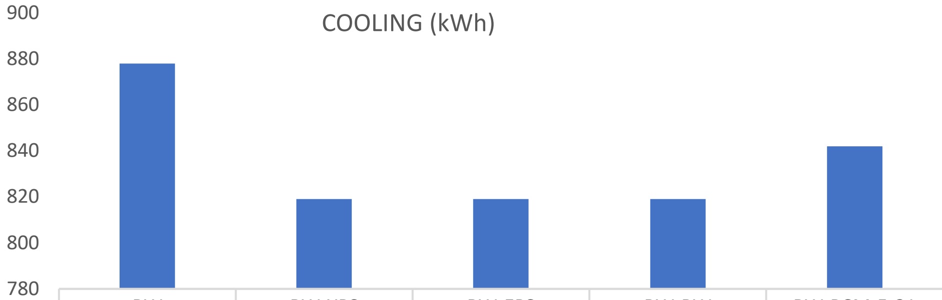
3. Results and Findings

In the study, 3 types of wall types (brick, concrete block, aerated concrete) with different main cores were used in the envelope of the building created in Elazığ province with Design Builder. Certain scenarios were selected and compared among 39 different scenarios created using these wall types. It is aimed to reveal the effect of PCM on heating and cooling load and also to investigate the effect of PCM on heating and cooling load when used with other building elements. Figure 5 and Figure 6 present the heating and cooling loads for different scenarios for brick wall respectively.



	BW	BW-XPS	BW-EPS	BW-RW	BW-PCM-5-21
HEATING (KWH)	3322	1923	2015	1971	2818

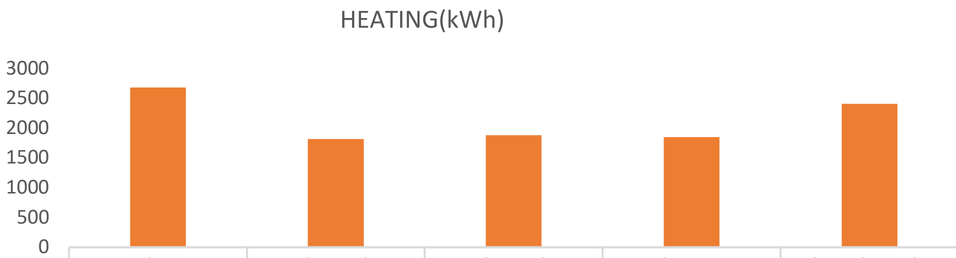
Figure 5 Heating loads for different scenarious on BW



	BW	BW-XPS	BW-EPS	BW-RW	BW-PCM-5-21
COOLING (kWh)	878	819	819	819	842

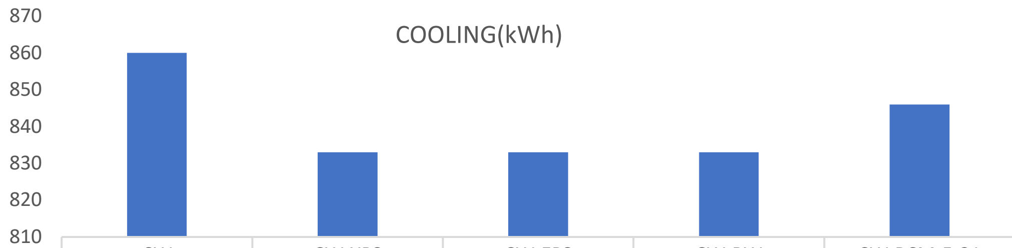
Figure 6 Cooling loads for different scenarious on BW

Heating load values of the created scenarios vary between 3322-1923 kWh. As a result of the simulations, the highest heating load requirement was observed in the BW wall type and the lowest heating load requirement was observed in the BW-XPS wall type. When the cooling load values stated in Figure 6 are examined, the maximum cooling load requirement is 878 kWh for BW wall. The cooling load value for BW-XPS, BW-EPS, BW-RW wall types is calculated as 819 kWh. Total heating and cooling loads of the walls, the main material of the building envelope of which is concrete block, during the year are shown in Figure 7 and Figure 8.



	CW	CW-XPS	CW-EPS	CW-RW	CW-PCM-5-21
HEATING(KWH)	2680	1814	1881	1849	2403

Figure 7 Heating loads for different scenarious on CW



	CW	CW-XPS	CW-EPS	CW-RW	CW-PCM-5-21
COOLING(KWH)	860	833	833	833	846

Figure 8 Cooling loads for different scenarious on CW

The wall types with the highest and lowest heating load requirements for the concrete block are CW and CW-XPS, with values of 2680-1814 kWh, respectively. The maximum cooling load requirement was obtained for the CW wall type with a value of 860 kWh. For CW-XPS, CW-EPS, CW-RW wall types, the cooling load requirement is determined as 833 kWh.

Total heating and cooling loads of the walls of which the main material of the building envelope is aerated concrete during the year are shown in Figure 9 and Figure 10 respectively.

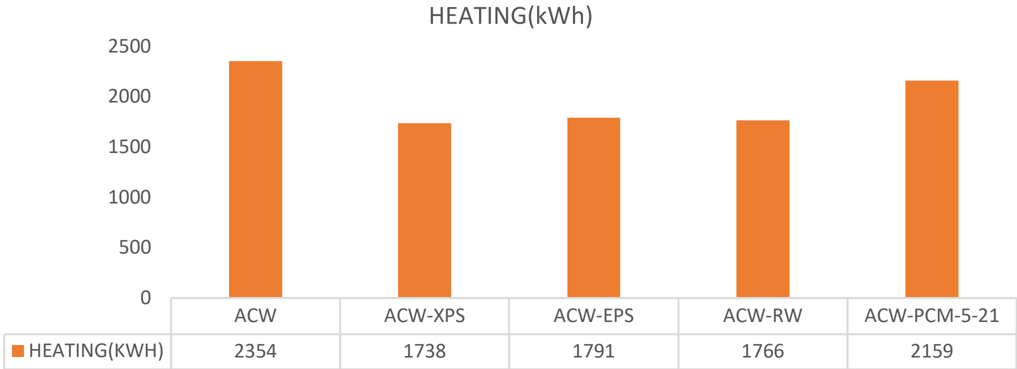


Figure 9 Heating loads for different scenarious on ACW

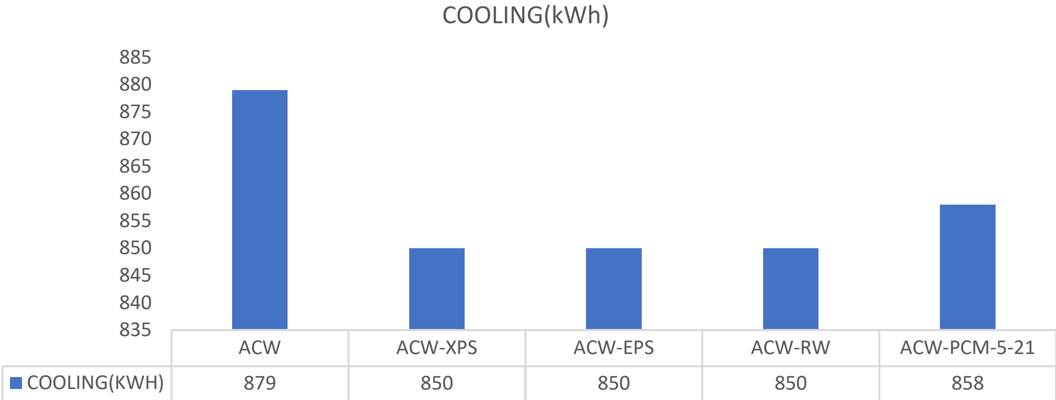


Figure 10 Cooling loads for different scenarious on ACW

When the heating and cooling load graphs of aerated concrete are examined, it is the ACW-XPS wall type with a value of 1738 kWh that gives better results in heating load compared to other wall types. In addition, the wall type with the highest heating load requirement is the ACW wall type with a value of 2354 kWh, without the use of insulation materials and PCM. The value of wall type ACW, which has the highest cooling load as well as heating load, is 879 kWh. The value of the 3 wall types that give the best results (ACW-XPS, ACW-EPS, ACW-RW walls) is 850 kWh. Figure 11 and Figure 12 presents the effect of PCM on the total heating and cooling load in the building, taking into account the melting temperatures. In these scenarios created on the brick wall, 3 different melting temperatures of PCM were applied as 21, 23, 29 °C.

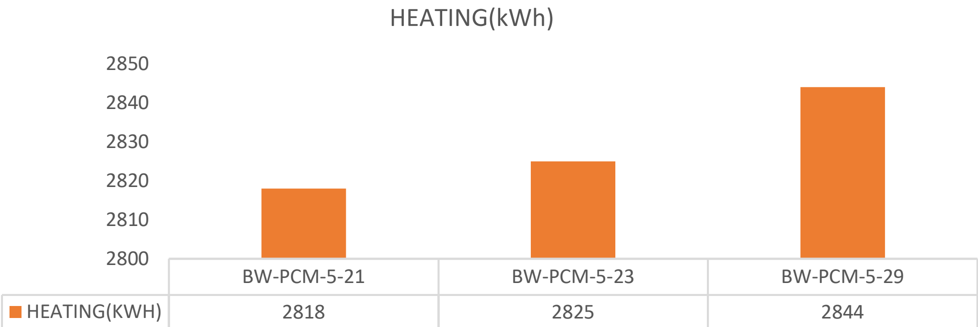


Figure 11 Effect of PCM with different melting points on total heating load

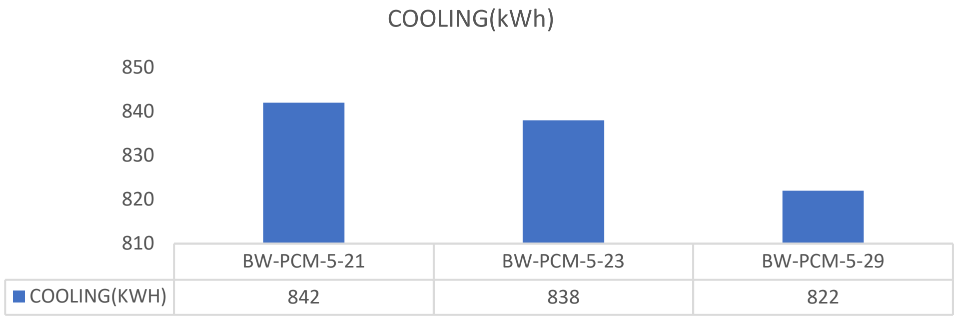


Figure 12 Effect of PCM with different melting points on total cooling load

It has been determined that when PCMs with different melting temperatures are used in the structure, it has an effect on the heating and cooling load of the structure. When the heating loads specified in Figure 11 are examined, the wall type with a value of 2818 kWh, in which PCM with a low melting temperature is used, is determined as BW-PCM-5-21. The wall type that has the least effect on the heating load is the wall type BW-PCM-5-23 with a value of 2844 kWh. When the cooling load is examined, unlike the heating loads, the wall type with the least load is BW-PCM-5-29 wall type with a value of 822 kWh. The wall type with the highest cooling load requirement is the BW-PCM-5-21 wall type with a value of 842 kWh.

During the summer period, the average air temperature in Elazığ is generally higher than 23°C. For this reason, PCMs with a melting temperature of 21 °C and 23 °C used in the building did not have much effect on the cooling load since they were generally in liquid form. However, it was determined that the energy performance of PCM at a melting temperature of 29 °C was better than the others. In winter, since the outdoor temperature remains below 29°C and this type of PCM is in solid state, its effect on the heating load of the building is less than the other two types of PCM with melting temperatures (21°C, 23°C). Effect of PCM thickness on energy loads in the building envelope is given in Figure 13 and Figure 14. Scenarios were created using 3 different thicknesses as 1, 5, 10 cm.

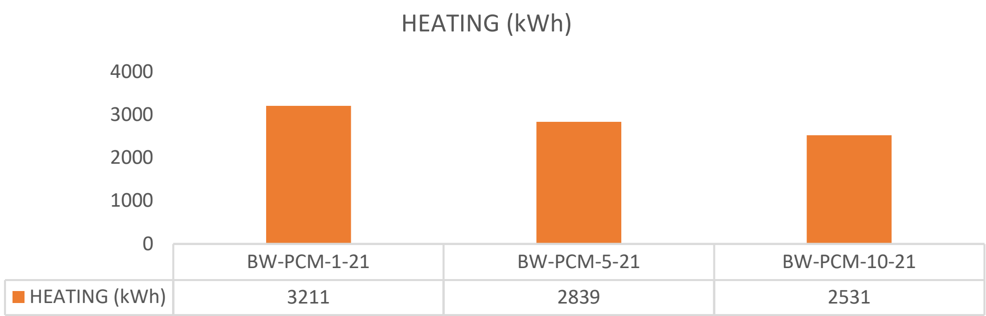


Figure 13 Effect of PCM thickness on heating loads

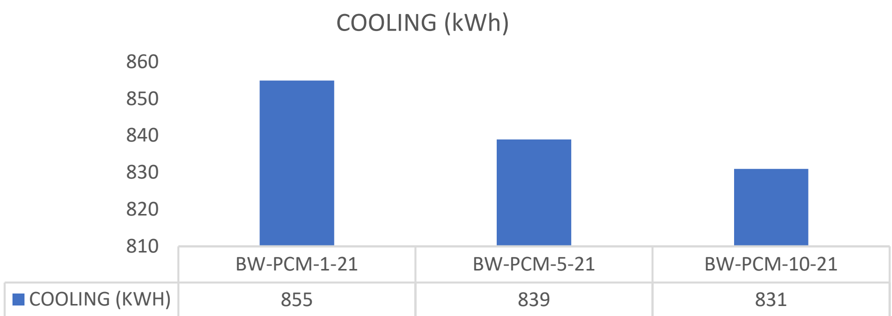


Figure 14 Effect of PCM thickness on cooling loads

Accordingly, it can be seen that when the thickness of the PCMs used in the structure increases, their effect on both cooling and heating loads is the same. When the graphics of cooling and heating loads are examined, the wall type with the least load requirement in both graphics is the BW-PCM-10-21 wall. The heating and cooling load requirement of wall BW-PCM-10-21 is 2531 and 831 kWh, respectively. The wall type with the highest load requirement is the BW-PCM-1-21 wall. The heating load of this wall is 3211 kWh and the cooling load is 855 kWh. The efficiency of PCM is directly proportional to the thickness for heating load. As the thickness increases, energy efficiency also increases. Since melting temparature is also a decisive parameter and used as 21 ^{o}C for this part, the effect of thickness for the cooling load is lower.

The effect of the use of XPS, EPS, Rock Wool materials and PCM used in brick walls on the heating and cooling load of the building are given in Figure 15 and Figure 16.

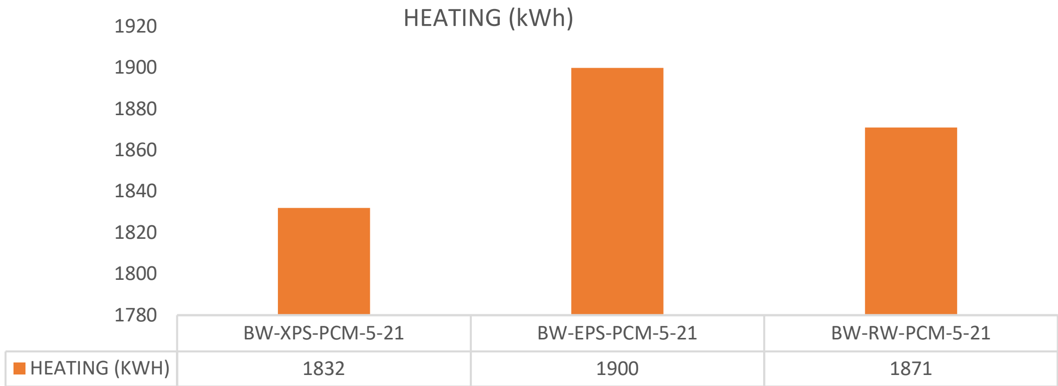


Figure 15 Effect of insulation materials and PCM 21^{o}C on heating load on brick wall

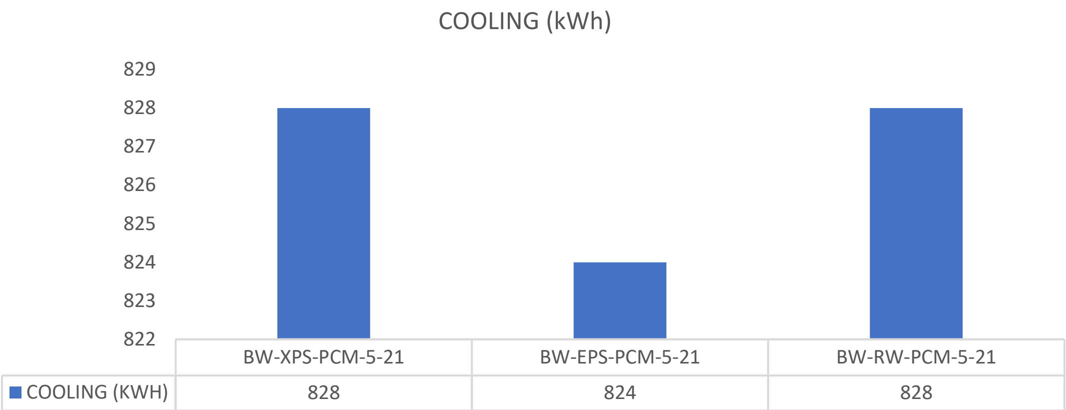


Figure 16 Effect of insulation materials and PCM 21^{o}C on cooling load on brick wall

When the heating and cooling load requirement graphs of the wall types where insulation materials and PCM are used on brick walls are examined, the wall type with a higher heating load requirement compared to other wall types is BW-EPS-PCM-5-21 with a value of 1900 kWh. The wall type with the lowest heating load requirement was BW-XPS-PCM-5-21 with 1832 kWh. In terms of cooling load requirement, BW-XPS-PCM-5-21 and BW-RW-PCM-5-21 walls with 828 kWh are followed by BW-EPS-PCM-5-21 wall type with 824 kWh.

The effect of using XPS, EPS, RW materials and PCM together in concrete block on the heating and cooling load of the building are given in Figures 17 and 18.

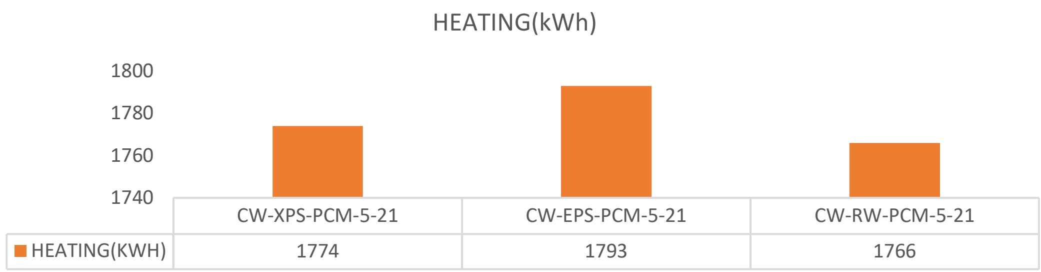


Figure 17 Effect of insulation materials and PCM 21°C on heating load in concrete block

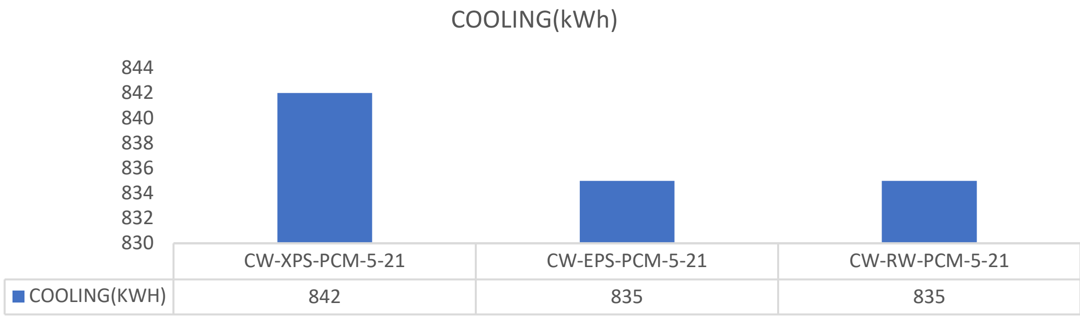


Figure 18 Effect of insulation materials and PCM 21°C on cooling load in concrete block

When the graph in Figure 17 is examined for the heating load requirement, the wall with the lowest load requirement is the CW-XPS-PCM-5-21 wall with a value of 1774 kWh. The wall type with the highest load requirement is the CW-EPS-PCM-5-21 wall with a value of 1793. Additionally, in Figure 18 the types of walls with lowest load requirement are CW-EPS-PCM-5-21 and CW-RW-PCM-5-21 walls with a value of 835 kWh. The wall with the highest load requirement is the CW-XPS-PCM-5-21 wall type with a value of 842 kWh.

The effect of the use of XPS, EPS, Rock Wool materials and PCM used in aerated concrete on the heating and cooling load of the building is given in Figures 19 and 20.

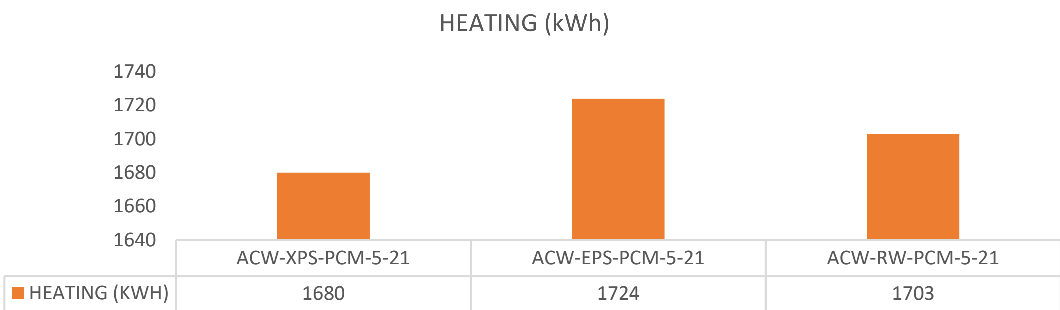


Figure 19 Heating load of PCM 21°C with insulation materials in aerated concrete

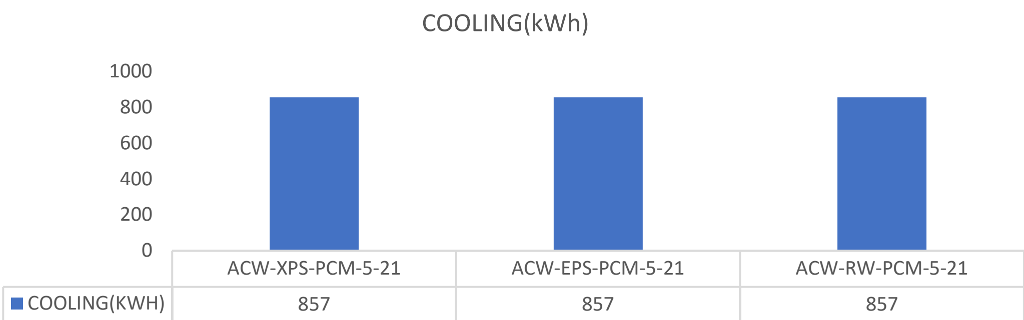


Figure 20 Effect of insulation materials and PCM 21°C on cooling load in aerated concrete

When the scenario results of aerated concrete are examined, the wall type that gives the best results for the heating load is the ACW-XPS-PCM-5-21 wall, which has a value of 1680 kWh. The wall type with the highest load requirement is the ACW-RW-PCM-5-21 wall with a value of 1703. When the cooling load requirement is examined, the cooling load requirement for the 3 wall types has a value of 857 kWh.

For heating load XPS with PCM presented better results for all Wall types while it is obligated for EPS with PCM when cooling load is the case. For heating load XPS which has a lower heat transfer coefficient provides better heat resistance and cause a decrease for the heating load. On the other hand melting point of PCM is again a decisive parameter for cooling load and it gives better result with EPS for all wall types.

4. Conclusion

In this study, the effect of phase change materials (PCM) on energy efficiency was investigated based on the Elazığ climate region. In the structure designed for the region, 3 wall cores (brick, concrete block, aerated concrete) were determined. In the analysis studies where the heating and cooling load values of the building were calculated, 39 scenarios were produced as a result of different combinations of uninsulated walls, PCM walls and insulation materials (XPS, EPS, Rock Wool). Scenarios are classified as use of insulation and PCM on the external wall, use of only insulation material, use of only PCM and use of PCM + insulation material. In addition, various scenarios were produced using different melting temperatures (21°C, 23°C, 29°C) and thicknesses (1cm, 5cm, 10cm) of PCM. As a result of the simulations made in the Design Builder program for all scenarios created, the total annual heating and cooling loads of the building were determined. In general, among the scenarios created on 3 types of wall cores, AEW-XPS-PCM-5-21, AEW-RW-PCM-5-21 and AEW-EPS-PCM-5-21 scenarios were determined to have the best performance in their groups.

In conclusion based on the uninsulated wall, it was determined that the use of PCM alone in all 3 wall types had an effect on both heating and cooling load. In wall types, the heating and cooling load required as a result of using only insulation material is lower than the energy required as a result of using only PCM. This shows that the effect of the insulation material on the heating and cooling load is better than PCM. This result was also supported by Konuklu and Paksoy (2011) previously as she studied the effect of PCM on building heating and cooling load for a 4m2 dwelling.

The effect of insulation materials on heating load gives different results in all 3 wall types. However, the cooling load values within each group were the same for all 3 insulation materials. It is seen that PCM has a positive effect on the annual heating load as a result of increasing its thickness in all 3 wall types as it was also determined by Alawadhi (2008). However, the energy savings provided in the cooling load did not continue in direct proportion to the thickness of the PCM, as in the heating load.

PCM with various melting temperatures (21°C, 23°C, 29°C) used in the building envelope has been decisive on the thermal energy efficiency of the building. Since PCMs with a melting temperature of 21 °C and 23 °C are generally in liquid form, they did not have much effect on the cooling load. However, it was determined that the energy performance of PCM at a melting temperature of 29 °C was better than the others. Konuklu and Paksoy (2011) also had concluded that the melting temperatures of PCMs used in summer should be higher to give better results.

Among the scenarios created, the wall scenarios with the best energy performance among the 3 wall types were the scenarios in which PCM and insulation material were used together as concluded by Castellón et al. (2006) and Konuklu and Paksoy (2011). The insulation material that gives the best results when used with PCM was determined to be XPS while in scenarios where PCM was used, its use with aerated concrete wall type gave the best results in terms of energy performance.

In general scenarios, 9% energy savings were achieved when PCM was used alone on an uninsulated wall, 25% when insulation material was used alone, and 30% when PCM and insulation material were used together.

As a result, PCM, which is used in addition to the insulation materials used in the building envelope to reduce the energy load of the building, has led to a decrease in the annual energy need of the building. The combined use of PCM and insulation material can be recommended for regions where the heating load is high.

According to the results obtained, it will be more effective to use PCMs with low melting points in cold climate regions, and PCMs with high melting points to be used in temperate and hot climate regions. In order to ensure the energy efficiency of the building both in summer and winter, using PCM with two melting temperatures instead of using PCM with a single melting temperature in the building envelope can be recommended as a more advantageous solution. Thus, the energy needs of the building can be reduced both in summer and winter.

The use of PCM, which is a different and innovative material from insulation materials, is increasing day by day due to its features such as its long life and its effect on heating and cooling load according to ambient conditions. Although it is expected that the use of PCM will increase further in the coming years, it is important to investigate the economic aspect of PCM and include it in studies in order to provide optimum benefit both in terms of energy and economy.

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Resume

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