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Yalova Üniversitesi Mühendislik Fakültesi Binasının Yeşil Perde ile Gölgelendirilmesi ve Sağlanacak Soğutma Tasarrufunun Değerlendirilmesi

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Anahtar Kelimeler

Yeşil kalkan, Pasif tasarım, Gölgeleme, Soğutma yükü, Yeşil bina

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Amaç

Bu çalışmada Yalova Üniversitesi Mühendislik Fakültesi binasında enerji tasarrufu sağlayacak, yenilikçi ve doğa ile bütünleşik yeşil kalkan tasarımı değerlendirilmiştir. Bu tasarım ile binanın gölgelenmesi simüle edilmiş ve sağlanabilecek soğutma yüküne bağlı enerji tasarrufu ortaya koyulmuştur.

Metot

Yeşil kalkan, binanın güney ve doğu cephelerini ısı kazançlarından koruyan sarmaşıktan bir perdedir. Yaz sezonunda yaprakları yeşeren bu bitkisel yapının, güneşten gelen ısı kazançlarını soğurması; kış döneminde ise yaprak döküp ısı kazancına engel olmaması amaçlanmıştır. Çalışma kapsamında binanın Design Builder programı üzerinde modellemesi oluşturulmuş ve soğutma yükü simüle edilmiştir. Simülasyondan bağımsız olarak MMO Klima Tesisatı Kitabı'nda yer alan ısı kazançları hesap metodu ile soğutma yükü hesaplanmıştır. Elde edilen simülasyon sonucu ve hesaplama sonuçları birbiriyle kıyaslanıp, doğrulanmıştır. Akabinde Design Builder üzerindeki yapı modeline yeşil kalkan tasarımı eklenmiş ve soğutma yükü tekrar simüle edilmiştir.

Sonuçlar

Sonuç olarak, soğutmaya bağlı yıllık enerji tüketiminde %22'lik azalma ve buna bağlı yıllık 26.6 tonCO2e salımının önlenmesini sağlayan doğal bir tasarım modeli sunulmuştur. Uygulamayla gerçekleşebilecek bu tasarruf; ülke ekonomisine, enerji güvenliğine ve çevre sağlığına katkıda bulunmayı hedefler. Bu ve benzeri doğa dostu tasarımların yaygınlaşması; sağlıklı ve sürdürülebilir bir geleceğin inşası için önem taşır.

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Shading of Yalova University Faculty of Engineering Building with Green Shield and Evaluation of Savings on Cooling Load

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ABSTRACT

Buildings are a major part of human life, as well as global energy consumption and carbon emissions. In today's world, passive strategies like green shield, which is a plant curtain that protects the facades of a building from heat gain, are of great importance for energy efficiency and conservation in buildings. In this study, the shading of the Yalova University Faculty of Engineering Building with the green shield was simulated and the potential savings from cooling consumption were evaluated. The green shield is a plant curtain that protects the southern and eastern facades of the building from heat gain. The simulation of the green shield was created in the Design-builder software, and the results were compared with the current energy consumption. As a result, within this study, a natural design model has been presented which provides 22% annual reduction in energy consumption from cooling and prevent 26.6 tons of CO_2e emissions.

Keywords: Green shield, Passive design, Shading, Cooling load, Green building

NOMENCLATURE

ABBREVIATION	DESCRIPTION	UNIT
CO_2e	Carbon Dioxide Equal Emission	(kg or tonne)
COP	Coefficient of Performance	(kW / kW)
Q	Cooling Load	(W)
U	Heat Transfer Coefficient	(W / m^2.K)
R	Thermal Resistance Coefficient	(m^2.K / W)
A	Area	(m^2)
CLTD	Cooling Load Temperature Difference	(K)
SC	Shading Coefficient	Dimensionless
SCL	Solar Cooling Load	(W / m^2)

1. INTRODUCTION

Today, environmental problems and climate crisis are on the agenda of all countries of the world [1, 2]. Many countries are actively working on initiatives and policies to address these issues and have made commitments to implement solution-oriented practices [3, 4]. The main reason for the environmental crises is greenhouse gas emissions due to fossil fuels consumptions [5, 6]. Global warming is thought to be at the level of 1.1 °C compared to the period before the industrial revolution and this warming is becoming increasingly dangerous for the future of the planet [3, 7]. The development of technology increases the amount of energy demand we need every day and this increment causes another increase in fossil fuel consumption [8-10]. Currently, all countries and stakeholders of these problems are searching for a solution.

1.1.The Importance of Energy Efficiency

For 2021, approximately 50.7 billion dollars' worth of energy imports were realized in Turkey and approximately 40% of this energy is consumed in buildings [11, 12]. It is claimed that approximately 80% of the buildings in Turkey consume energy in a low efficient way, which results in energy waste equivalent to 10 billion dollars in 2021 due to inefficient usage [13]. For Turkey, which is in the position of an energy-importing country, saving on this high cost through proper consumption methods is of great importance for the national economy [14].

The production of the energy that is being wasted leads to greenhouse gas emissions, which is currently recognized as one of the main causes of the climate crisis [15]. The emission reduction that will be achieved through efficient energy usage provides a great step forward in ensuring the carbon neutrality policies that countries have made commitments to, while displaying an environmentally friendly attitude [16]. In addition, energy efficiency in buildings is also included in the scope of the Climate Action target within the Sustainable Development Goals published by the United Nations [17].

1.2.Net Zero Energy Buildings

Approximately 87% of the average human life is spent in buildings [18]. Buildings are responsible for 36% of global energy consumption and 37% of CO_2 emissions [19]. In many countries around the world, practices for effective energy use in buildings are developed and encouraged, and there are various organizations that serve this purpose [20]. These structures, which can be located in all kinds of geography and climate conditions, provide energy savings thanks to the correct planning to be conducted especially at the design stage. Energy savings reduces carbon emissions and provide a great reduction in energy bills. This economic advantage is a great opportunity both for the building users and for the countries that are dependent on outsourced energy [20].

Today, net-zero energy buildings are shown as the solution to this problem. These buildings have high energy efficiency performance and provide 70% to 90% less energy consumption than a standard building [12]. Zero-energy buildings generate as much energy as they consume. This is a very effective solution to reduce carbon emissions and contribute to decrease environmental problems [21].

1.3.Purpose and Scope of the Study

In this study, a green shield for Yalova University Engineering Faculty Building is modeled. The purpose of the green shield is to make a summer shield from the leaves of the plants which prevent solar radiation during summer. In the wintertime, the shield allows solar radiation, thanks to defoliation. The shield decreases the energy consumption of the building and ensuring a vital precondition for becoming a net zero energy building. In the study, the east and south facades of the building are covered with ivy vegetation and provide shading, while the roof is covered with green roof concept to provide insulation. This completely natural structure can maintain its own operation with no automation or heavy maintenance and repair, and it has the quality of an ecological and original design.

Figure 1 – Yalova University Engineering Faculty Building

2. MATERIAL and METHOD

2.1.Climatic Conditions

Yalova is in the Marmara Region–Turkey and has an average annual temperature of 14.6 °C. The summer seasons are dry and hot, while the winter seasons are warm and abundant rain. However, the average temperature of the coldest month is 6.6 °C, while the average temperature of the hottest month is 23.7 °C [22].

The climate type in the city, according to the Köppen Climate Classification method, is CSA. This classification indicates a climate characterized by mild winters, hot and dry summers (Mediterranean Climate) [23].

2.2.Engineering Faculty Building

Yalova University Engineering Faculty Building, photographed in Figure 1, comprises 5 floors. Its dimensions are 53 meters width, 53 meters length and 27.8 meters height and a total indoor area of 11176 m^2 [24, 25].

2.2.1. Building Simulation

Design-builder–EnergyPlus program was used for the cooling load simulation of the building. The program provides three-dimensional modeling of the building in computer aided design (CAD) file type, various technical data entries on a single platform, and provides various analysis results and technical reports because of these inputs [26].

In the building modeling phase, the building's architectural drawings and floor plans which provided by Yalova University Rectorate Department of

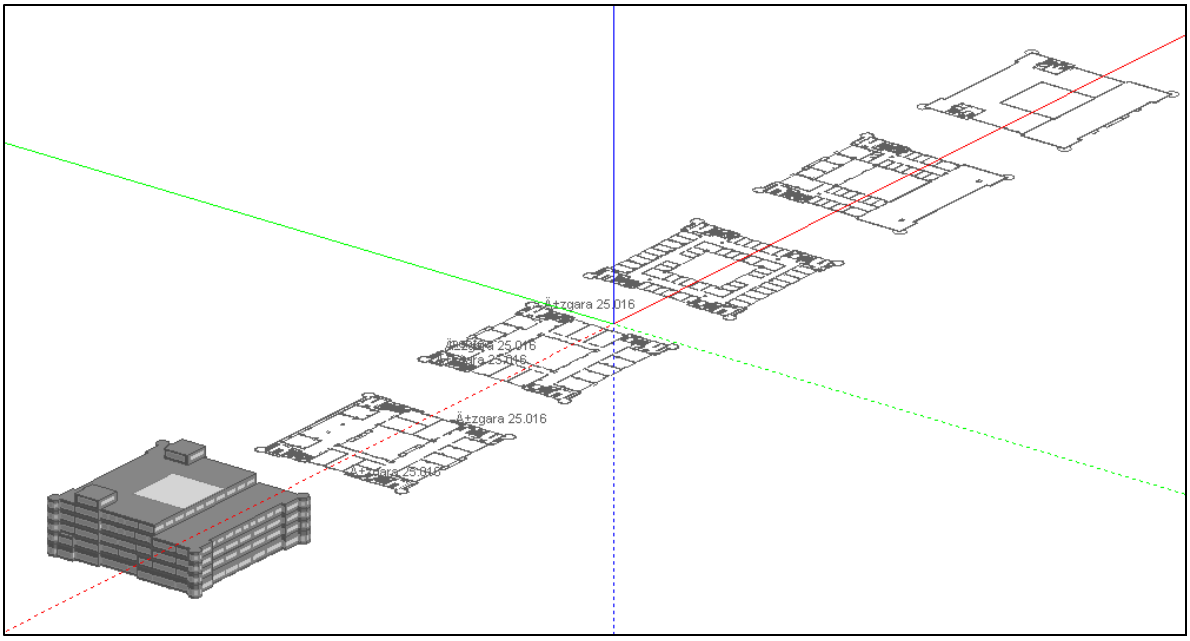

Figure 2 – Architectural Drawings Imported into Design-Builder

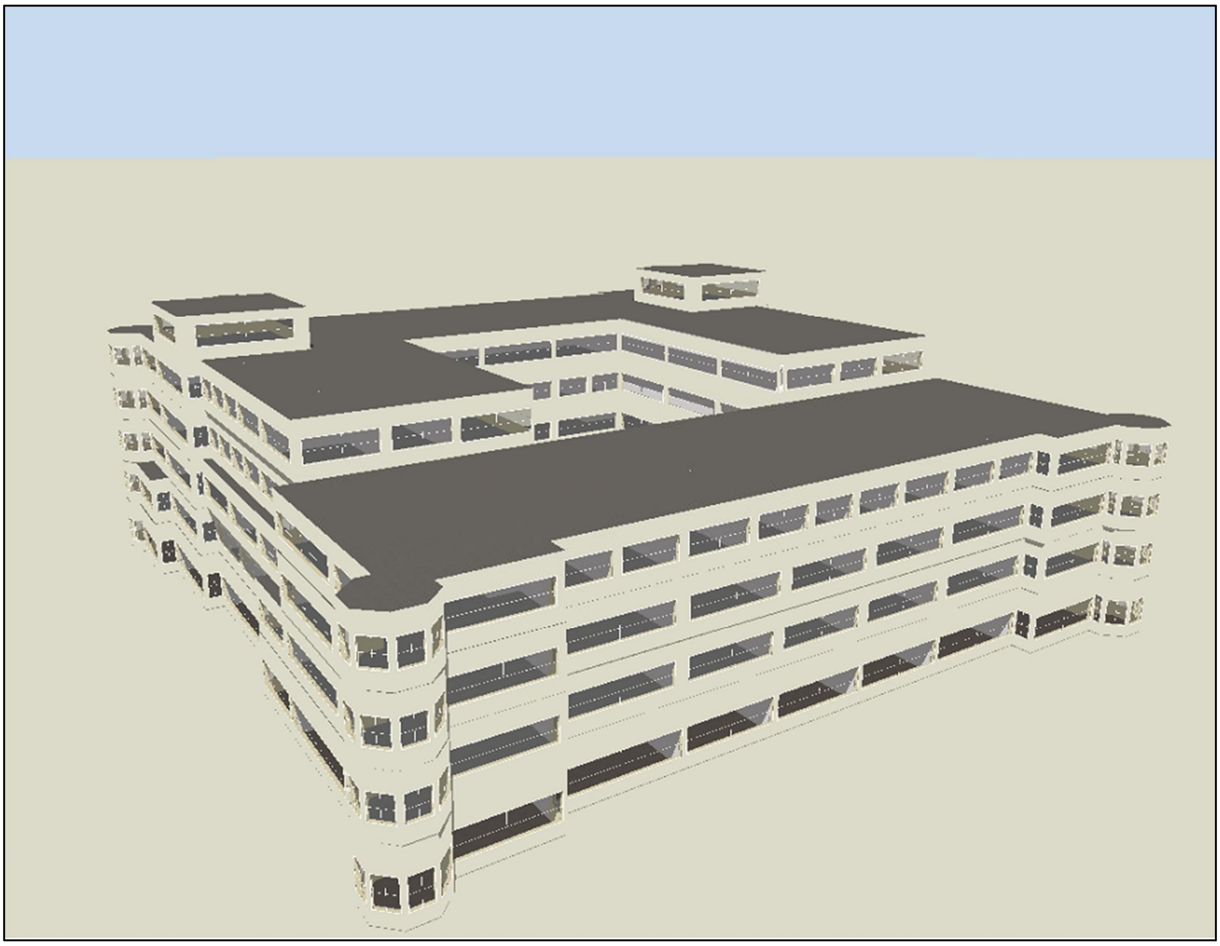

Figure 3 – Faculty of Engineering Three-Dimensional Model Image

Construction Affairs were used to model the faculty building. The plan files of all the floors were transferred to the program and three-dimensional block models were drawn (Figure 2). Then, the floor blocks were combined to get a general three-dimensional model of the building (Figure 3). The wall thickness and material information of the building can be inputted into the program, and the total heat transfer coefficient (U-value) of the walls can be calculated based on the obtained model. However, since information for the external wall material could not be obtained, the U-value of the wall was directly entered as a separate data, and the simulation calculations were conducted accordingly.

In building modeling, data such as the location of the building, activity information, and seasonal periods were also input. The coordinates, altitude and time zone of Yalova have been input for location definition. The building activities were selected as the study offices template and the university building. Metabolic activities were defined as the light office work, standing and walking activities. In addition, internal heat gains from air conditioning systems, office equipment and computers were selected as program defaults. Since the cooling load affect is considered in this paper, only the details of the cooling system of the air conditioning system are processed. The coefficient of performance (COP) of the cooling system was inputs as 2.5. Using grid electricity and operating conditions of the cooling system were entered specific to the university building.

2.2.2.Cooling Load Modeling of the Structure

Cooling load report was obtained from Design-Builder program. All the information such as reinforcement, location, climate, facades of the building are provided; the program calculates heat gains and cooling load. The cooling simulation covers the summer months that are between July and September.

According to the simulation results, the current cooling load of the building is 405.6 kW, and the seasonal electricity consumption due to cooling is obtained as 217 MWh.

2.2.3.Calculation of the Cooling Load of the Structure

The cooling load of the building is also calculated analytically by using the method given in the publication of Chamber of Mechanical Engineers Book of Air Conditioning Installations [27]. The heat gain from roofs, glass surfaces and external walls, as well as solar radiation from glass surfaces were calculated, and the total cooling load was obtained by including the internal heat gains in these calculations.

Equation 1 was used for calculating the heat gains from exterior walls, windows, and roof.

$$\dot{Q} = U\,A\,(CLTD) \quad (1)$$

In this equation, "$\dot{Q}$" is cooling load (W) and "U" is total heat transfer coefficient (W/m^2. K), "A" represents the surface area (m^2), and "CLTD" represents the cooling load temperature difference (K).

Equation 1 was used for calculating heat gain by conduction from external walls. Here; the total wall area is taken from the architectural drawings of the structure, the U value for the walls is taken from the structural works and technical department of the university and from the academic studies previously done for the faculty building [25] [28].

The basic material code of the wall is designated as C9. Secondary wall material is rough or thin plaster, wall R value is determined between 1.59 – 1.89. Since the equivalent of C9 wall type could not be found in these values, C8 wall type with close values was accepted and it was reached that the wall number was 11. In line with these results, the CLTD of wall 11 for the North, South, East and West facades was read for 13:00.

The calculated parameters and the heat gains of the structure from the external walls are given in Table 1. The heat gains were calculated from the walls in the middle opening and outer side of the building and found to be about 21.67 kW.

Table 1 - Heat Gains by Exterior Wall Conduction

Exterior Walls				
Direction	North	South	West	East
Total Wall Area (m^2)	509.1	686.9	870.8	790.8
CLDT value (K)	6.0	7.0	7.0	16.0
U value for walls			0.617	
Q heat gain (W)	1884.6	2966.6	3761.0	7806.8
			Total Heat Gain (kW)	**16.42**
Middle Opening Walls				
Direction	South	North	East	West
Total Wall Area (m^2)	315.6	138.6	238.1	238.1
CLDT value (K)	7.0	6.0	16.0	7.0
Q heat gain (W)	1363.1	513.1	2350.5	1028.4
			Total Heat Gain (kW)	**5.26**
			TOTAL (kW)	**21.67**

Table 2 – Heat Gains from Glass Surfaces by Conduction

Exterior Glass Surfaces				
Direction	North	South	West	East
Total Glass Area (m^2)	380.5	490.4	254.2	254.2
CLDT value (K)			7.0	
U value for glass			2.78	
Q heat gain (W)	7404.5	9543.6	4946.7	4946.7
			Total Heat Gain (kW)	**26.84**
Middle Opening Glass Surfaces				
Direction	South	North	East	West
Total Glass Area (m^2)	219.4	122.0	235.8	235.8
Q heat gain (W)	4269.5	2374.1	4588.7	4588.7
			Total Heat Gain (kW)	**15.82**
			TOTAL (kW)	**42.66**

Table 3 - Heat Gain from the Roof by Conduction

Roof	
Total Roof Area (m^2)	2100.0
CLDT value (K)	23.0
U value for the roof	1.894
Q Total heat gain (kW)	91.48

The total glass area is taken from the architectural drawings of the building, the U for the glass surfaces is taken from the previous studies for the same faculty building [25] [28]. The CLTD corresponding to the time of 13:00 was read from the relevant table.

The heat gains of the building by conduction from glass surfaces are shown in Table 2. The heat gains from the windows by conduction in the middle opening and outer side of the building were calculated to be approximately 42.66 kW.

The U for the roof is taken from academic studies previously conducted for the faculty building [28]. The CLTD was determined according to the insulation was in the outer shell of the building, the suspended ceiling existed, the R was between 0 and 0.9. The main building material was reinforced concrete and the corresponding roof number was obtained as 5 in the tables. This roof number and the CLTD corresponding to 13:00 hours were read.

The determined parameters and the heat gain from the roof are shown in Table 3. The heat gains of the building by conduction from the roof were calculated and found to be 91.48 kW.

It is necessary to determine the choice of the time, the facade of the wall for which the calculation is made and the wall number, when calculating the heat gains generated by the conduction from the walls. Here, in order to determine the wall number, it is necessary to know the material of the wall, the thermal resistance (R).

In order to determine the CLTD for the heat gain from glass surfaces, it is necessary to determine the time the surface is exposed to the sun. In order to determine the CLTD for the heat gain calculations from flat roof surfaces, the time and roof type must be determined. In order to determine the roof type, it is necessary to know the layout of the ceiling, the existence of a suspended ceiling, the thermal resistance (R-value) of the surface and the type of building material.

Equation 2 is used to calculate the heat gained by radiation from the window and glass surfaces.

$$\dot{Q} = A\ (SC)\ (SCL) \qquad (2)$$

In this equation, "A" is surface area (m^2), "SC" is the dimensionless shading coefficient, and "SCL" is the solar cooling load (W/m^2).

In order to obtain the SC to be used when calculating the radiation heat gain from windows, the single or double glazing status, thickness and permeability of the glass must be known. In order to obtain the SCL, the direction of the window, the solar time and the region type must be known. The window zone type is determined by the window/wall ratio, the floor covering, the separator wall type, and the interior shading condition.

The glass type was chosen as the outer heat sink and the inner transparent since the green-colored glasses are used in buildings and the classification of these colored glasses is in the heat sink category [27]. The thickness of each of the double glasses was accepted as 6 mm and the corresponding SC was 0.565. Since the windows in the middle opening of the building (Figure 1) are excessively shaded, a value of 0.36 was used.

Table 4 – Glass Surface Radiation Heat Gains

Exterior Glass Surfaces				
Direction	North	South	West	East
Total Glass Area (m^2)	380.5	490.4	254.2	254.2
SCL value (W/m^2)	101.0	217.0	167.0	189.0
SC value	0.565			
Q heat gain (W)	21713.2	60127.9	23985.0	27144.7
			Total Heat Gain (kW)	**132.97**
Middle Opening Glass Surfaces				
Direction	South	North	East	West
Total Glass Area (m^2)	219.4	122.0	235.8	235.8
SCL value (W/m^2)	217.0	101.0	189.0	167.0
SC value	0.36			
Q heat gain (W)	17139.5	4435.9	16043.8	14176.3
			Total Heat Gain (kW)	**51.80**
			TOTAL (kW)	**184.77**

In the spaces, the number of glass-fronted walls is 1-2, the floor covering is vinyl, the separator type concrete block and the interior shading is half or none. The zone type corresponding to these values was determined as D and different SCL values were read for the North, South, East and West facades of the windows at 13:00 in the D zone. The determined parameters and the radiation heat gains of the building from the glass surfaces are given in Table 4. The heat gains by radiation from the windows in the middle opening and exterior of the building, and the total were calculated to be 184.77 kW.

In the indoor heat gain calculations, the indoor heat gains were evaluated under five categories: human metabolism, lighting, computers, electrical appliances and heat input from hot masses.

The following parameters were considered in the internal heat gain calculations. Since the canteen and cafeteria in the building did not serve, it was accepted that there was no hot food and hot mass entrance. Heat gain by metabolic activities was chosen according to the literatures [24] [29]. There are 905 people in the faculty building, including 116 academic staff, 769 students and approximately 20 administrative staff. The heat dissipation capacity of a person is accepted as 70 W for school [30]. There are 4 different fluorescent lighting in the building: (18W×4), (36W×2), (20W×2) and (40W). The heat dissipation factor of the lighting type was accepted as 0.42 [31]. There are approximately 120 rooms in the building. It is used for different purposes, such as offices, classrooms, laboratories, warehouses, archives. It is assumed that there is at least 1 computer in each room, with 120 desktop computers. The average heat dissipation capacity per computer is considered being 116 W. [30]. It is assumed that there is approximately 1 electrical appliance in active use in each of the 120 rooms. These electrical appliances can be of different types, such as projectors in classrooms and printers in administration. The power consumption of these electrical devices is about 200 W and the heat dissipation factor is accepted as

0.4 [32]. The results of all heat gain calculations are given in Table 5. The internal heat gains of the building were calculated and found to be about 120 kW.

As a result, the total heat gains and cooling load of the structure are given in Table 6. The total of all heat gains of the building were calculated to be 461 kW.

2.3.The Green Shield

The green shield ecologically enriches the environment where the building is located. For this, the environment is afforested or various green plants are used. Thanks to shading, coolness, sound insulation, air pollution, filtration and a natural design are provided. In addition, an increase in oxygen concentration is expected [33]. In

Table 5 – Internal Heat Gains

Heat Source	Power (W)	Heat Dissipation Factor	Piece	Total (W)
Human Metabolism	70	1.0	*116 academic personnel + 769 student + 20 administrative staff = 905*	63350.0
Lighting	72 72 40 40	0.42	651 71 230 468	33559.7
Computer	116		120	13920.0
Electrical Appliances (Office equipment, water heaters, etc.)	200	0.4	120	9600.0
Hot Mass	0	-	0	0
			Total Internal Heat Gain (kW)	**120.43**

Table 6 – Total Heat Gain and Cooling Load (kW)

Heat Gains by Conduction Through Walls	21.7
Heat Gain by Conduction from Windows and Glass	42.7
Heat Gain from the Roof by Conduction	91.5
Heat Gain by Radiation from Windows and Glasses	184.8
Internal Heat Gains	120.4
Total Heat Gain (kW)	**461.0**

Figure 4 – The Green Shield Modeling

the Design-builder program, the south and east facades of the building were modeled as covered with ivy vegetation and shaded, and a green roof applied to the model.

Figure 4 illustrates the green shield modeled besides the building. As seen in the figure, the east and south facades of the building are shaded by planting. In the northern hemisphere, buildings are mainly exposed to the sun's rays from the south during the day, because of this; the green-shield design applies to the east and south facades [34]. Besides this, shading is provided to the eastern facade during the morning hours. The application is not preferred on the Western facade. Because the structure is a school building and was accepted as not using air conditioning intensively during evening sunset hours.

The structure of the block type of the green shield was defined as adiabatic in Design-builder. This block type is selected since it includes all shading effects in the calculations of reflection effects [35].

The permeability calendar was defined as the model that will show active features on summer days in the Northern Hemisphere. The reason for this choice is the applied green ivy provides shading with its leaves in the summer, while it does not cause any effect by shedding leaves in winter. The value of block material is specifically defined for this simulation.

The thermal-solar absorption coefficient and a visible absorption coefficient of the surfaces were selected as 0.7 and 0.2 respectively.

While determining these values, we aimed for the green shield to meet the following conditions;

i. The solar radiation gains of the building should be prevented by at least 70%,

ii. Block the light by no more than 20%

iii. Get maximum benefit from sunlight.

In addition, the rough and green surface details were input, the remaining data were accepted as program defaults, and were selected to be active only on summer days in the Northern Hemisphere. The reason for this preference is that, while the green ivy applied provides shading with its leaves in summer, and it does not create any shading effect by defoliation in the fall and winter season.

In addition, Green Roof tab is activated, and the simple calculation method was selected, 10 cm plant length and 3.5 leaf area index values were entered, all remaining values were left as the program defaults. At this stage, it was assumed that the plants would be kept at a length of 10 cm. The leaf area index of 3.5 was used because it was the leaf area index of the plant known as “American Ivy” and called “Boston Ivy” in the literature [36]. This value is a dimensionless indicator that represents the ratio of the leaf area to the ground surface [37]. This plant can also be used in green shield facade application.

In order to measure the effect of the added green shield and green roof models, the simulation performed in the section “2.2.2.Cooling Load Modeling of the Structure” was repeated. According to the simulation results, with the implementation of the green shield, the cooling load of the building is obtained as 247.16 kW, and the seasonal electricity consumption due to cooling is 169 MWh.

3. RESULTS and DISCUSSION

The current cooling load of the building in Design Builder is 406.6 kW, while the cooling load obtained in the green shield simulation is 247.16 kW. The difference of 158.4 kW indicates a prevention of 39% heat gain. According to the Design-Builder simulation result report, the annual cooling energy consumption of the building is 542 514.6 kWh. Since the seasonal COP of the air conditioning system is accepted as 2.5, electricity consumption is calculated as 217 MWh. In the Design-builder simulation, which includes the green shield application, the annual cooling energy consumption of the building is calculated as 422742.5 kWh. For the case where the seasonal COP of the air conditioning system is 2.5, electricity consumption is calculated as 169 MWh.

An electric energy consumption difference of 48 MWh is observed between the two scenarios that correspond to an annual cooling electricity savings of 22%.

The CO2e emission reduction achieved through the savings obtained from green shield modeling is calculated using Equation 3.

$$\text{tonCO2e} = \frac{\text{kWh Electric Savings} \times (0.555)}{1000} \quad (3)$$

In this equation, “tonsCO_2e” the amount of CO_2e emissions prevented (ton), “0.555” is electricity emission factor (kgCO_2e / kWh) [38].

This electrical savings will indirectly prevent 26.6 tons of CO2e emissions.

As seen in the results, the heat gain from the south direction is higher compared to other directions. This indicates that the correct direction choice was made for the green shield application considered for the south facade.

Also a Design-builder simulation was created for the current cooling load of the faculty building. There is a difference of approximately 55.4 kW between the Design-Builder simulation result and the analytical calculation result presented in Table 6. The difference between the two results obtained is approximately 12%. There is not a perfect agreement between the results, but the calculation results are similar to the Design-Builder simulation results, and the comparison was made using the Design Builder simulation results as the reference. According to the Design-builder simulation, it has been determined that about 48 MWh of energy can be saved and 26.6 tons of CO_2e can be prevented annually during the cooling season.

The application is expected to save energy and have social impacts, besides its technical benefits. Green facades covered with plants provide comforting, promising and satisfying effects to users [39]. Photosynthetic green plants increase the amount of oxygen in the environment and reduce the carbon dioxide. Increased oxygen concentration provides an open mind for building users and students. This ecological structure fills the vegetation gap on campus and throughout the building and provides a pleasant visualization to the occupants. Air cleanliness and quality are very important in industrial cities and metropolises. Green shield acts as a filter, reduces air pollution and particulate concentration in and around the building [40]. Increasing air quality is also a precaution for Sick Building Syndrome [41], one of the global health problems. The vegetation also prevents the noise in the environment, prevents the sound pollution in the building and prevents distraction in the lessons [40].

4. CONCLUSION

In this paper, energy saving opportunity was investigated by reducing the cooling load of the building with the green shield and green roof models. 48 MWh energy savings and the associated emission reduction have been observed. However, the amount of energy consumed for cooling, meter information and invoice price could not be confirmed. That means this study should be confirmed with field or experimental studies. The analysis in this paper reflects the results of a simulation and requires validation with experimental data. Various assumptions made can cause deviation in the application. The error margins of the simulation methods can also cause deviations in the results. However, this study aims to provide a preliminary idea and guidance for practical applications.

Achieving 22% electricity savings due to cooling is a very important benefit in terms of both economy and environmental awareness. It is preferred that such investments are made by a non-profit public institution as exemplary applications. Within this study, an innovative application that will guide other institutions was proposed by Yalova University.

In order to build sustainable built environments and cities, it is necessary to implement various designs, including passive building approaches that yield effective ecological, economic, and socio-cultural outputs. It is important that these designs, which aim to create healthy and sustainable environments, apply to all buildings.

5.ACKNOWLEDGEMENT

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Türkiye'nin Sıfır Enerjili Bina Tarihine Dünya Bağlamında Genel Bir Bakış

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Özet

Küresel topluluk, enerji verimliliğinin önemini giderek daha fazla kabul etmekte ve Türkiye bu eğilime ayak uydurarak sürdürülebilir enerji uygulamaları alanında takdire değer adımlar atmaktadır. Ülke, yenilenebilir enerji kaynaklarını kullanmak ve yaymak için bir yolculuğa çıkarken, aynı zamanda binalarda enerji kullanımını optimize etmeyi hedefleyen iddialı enerji verimliliği girişimlerini de başlatmıştır.
Sürekli değişen bu manzarada, sürdürülebilir enerji tüketimi taahhüdü katlanarak artmıştır. Türkiye'de ve dünya çapındaki araştırmacılar ve politikacılar, enerji tüketim modellerini ve değerli enerji kaynaklarını koruma yöntemlerini araştıran çalışmaları özveriyle araştırmaktadırlar. Bu çabanın önemi, çevreyi korumak ve ekolojik dengeyi desteklemek için güçlü bir araç sunduğundan, ekonomi alanlarının çok ötesine uzanmaktadır. Dünya, enerjinin ortaya çıkardığı çok yönlü zorluklarla boğuşurken, verimli enerji kullanımı arayışı, gelişen ve sürdürülebilir bir geleceğin ayrılmaz bir parçası olarak ortaya çıkmaktadır. Küresel topluluk, en son araştırmaları, yenilikçi teknolojileri ve ilerici politikaları birleştirerek, gezegenin doğal kaynaklarını gelecek nesiller için korurken ekonomik büyümeyi desteklemek için enerji tasarrufu potansiyelinden yararlanabilir.

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A General Overview of Turkey's Zero-Energy Building History in the World Context

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Abstract

Throughout history, the significance of energy has remained unwavering, holding its position as one of the most critical global issues. While in the past, discussions on energy conservation primarily centered around large-scale industrial settings, today's discourse has shifted towards individual energy expenditures, particularly in residential contexts. The evolution of this subject is evident in the transformation of keywords employed in research, progressing from "energy consumption" and "energy saving" to more specialized terms such as "low energy building," "almost zero energy building," and "net-zero energy building."
Globally, there has been a notable emphasis on energy efficiency, and Turkey has followed suit, making remarkable strides in this domain. The country has not only embraced the utilization and dissemination of renewable energy sources but has also initiated various energy efficiency projects focused on optimizing energy consumption in buildings.
The ongoing research and implementation of sustainable energy practices, both on a global scale and within Turkey, hold the promise of not only bolstering economic growth but also ensuring environmental sustainability. As the world continues to grapple with energy challenges, the pursuit of efficient energy use stands as a driving force in securing a prosperous and ecologically balanced future.

Keywords: Energy crisis, energy consumption, zero energy building, zero build.

1.Introduction

The energy crisis refers to a period when the world faced a shortage of energy resources, particularly oil, and experienced significant price increases and economic challenges. The energy crisis began in the early 1970s and continued through the 1980s [1]. The crisis was triggered by a combination of factors, including political instability in oil-producing countries, the increased demand for oil in developed nations, and the decision by the Organization of the Petroleum Exporting Countries (OPEC) to limit oil production and raise prices [2]. In 1973, OPEC declared an oil embargo on countries that supported Israel in the Yom Kippur

War, leading to a significant increase in oil prices and shortages in many countries. This event, coupled with continued political instability in the Middle East and the growing demand for oil in developing nations, contributed to the energy crisis [2, 3]. Governments and industry responded to the crisis by promoting energy conservation, exploring alternative energy sources such as nuclear and renewable energy, and increasing domestic oil production. While the crisis subsided in the 1980s, its effects were felt for years to come, and it remains an important moment in the history of energy policy and global economics [1, 4-6].

Global energy conservation efforts began in the 1970s in response to the energy crisis, which included political instability in oil-producing countries and an increase in oil demand in countries that have developed the one of the earliest and most visible efforts to promote energy conservation was the "Energy Crisis" campaign launched in the US in 1973. It included measures such as reducing speed limits on highways, encouraging carpooling, and encouraging people to save energy at home by reducing thermostats and the use of energy efficient devices [7, 8]. Other countries have launched similar campaigns to promote energy conservation, including Japan, Germany, France, and other European countries. Governments have begun offering tax incentives and subsidies to businesses and individuals who have invested in energy-efficient technologies, such as insulation, efficient lighting, and solar panels. Over time, the focus on energy conservation has expanded to include building codes and standards that require new buildings to be energy efficient, energy efficient appliances and vehicles, and energy renewables such as wind and solar. These efforts aim to promote economic growth and energy security by reducing energy consumption and greenhouse gas emissions [9, 10].

It is known that most of the total energy in the world is consumed in industry, construction, and transportation sectors [11]. Heating, cooling, and lighting used in buildings constitute a large part of the energy consumed. Electricity is mostly used for lighting and cooling, and both fossil fuels and electrical energy are used together for heating [12, 13]. Since more than 30% of the total energy consumed is used in buildings, zero construction can provide great support for increasing energy efficiency, minimizing the use of fossil fuels and using more efficient and clean energy, as it also focuses on renewable energy sources [14].

In all this summarized historical process, energy maintains its currency as one of the most important issues of today as it was in the past. In the past, saving measures were discussed on the consumption of energy in large business areas, but today individual consumption in residences is discussed. While in the past there were studies within the framework of keywords such as "energy consumption, energy saving", this subject has evolved into keywords such as "low energy building, almost zero energy building, net zero energy building" in its historical course. For this reason, the general purpose of this article is to shed light on the current situation in the world today, and to briefly discuss the level of Turkey within the framework of these developments in the world.

2. Consumption Rates of Energy Types in the World

The proportional data of energy consumption varies by country and region. Consumption rates of energy types based on countries around the world may differ due to geographical locations of countries, local resources they have, economic power and many other reasons. However, according to the current 2020 data of the International Energy Agency, an average global distribution is as follows [15]:

- Oil: 33.2%
- Coal: 26.6%
- Natural gas: 22.8%
- Renewables (including hydropower): 11.7%
- Nuclear: 4.4%
- Other (including biofuels and waste): 1.3%

These figures represent the shares of global primary energy consumption by fuel type. It's worth noting that the mix of energy sources used to generate electricity may differ from the mix of primary energy sources due to differences in the efficiency of energy conversion and the availability of different fuels in different regions. The use of renewable energy sources has been growing in recent years, and their share of global primary energy consumption is expected to continue to increase in the coming decades as the world transitions to a lower-carbon energy system [16].

In addition to these consumption rates based on countries in the world, it would be useful to specify the sectoral distribution rates of energy in countries in general. The current data presented by the International Energy Agency in 2019 on this subject can be listed as follows [17]:

- Industry: 37%
- Transportation: 32%
- Buildings: 17%
- Electricity and heat production: 10%
- Other (including agriculture, fishing, and non-specified): 4%

Manufacturing is the most energy-intensive sector, including energy-intensive manufacturing processes such as metal fabrication and chemical manufacturing. Transportation is the second largest sector, which includes fuel consumption in all types of vehicles from cars, trucks, trains, airplanes, and ships. Construction represents the third largest sector, that includes the energy consumption of heating, cooling, and lighting equipment in residential, commercial, and institutional buildings. Electric heat production refers to the energy consumption of electricity and district heating, which is a method of distributing heat from a central location to multiple rooms the "other" section includes the energy consumption of non-industrial activities such as farming, fishing, and unspecified areas. It should be noted that the areas of energy efficiency can vary greatly among countries and regions depending on factors such as budget, climate, and demographics.

In today's scientific world, studies are carried out on energy consumption in buildings, which take priority in energy consumption by leveling up. In this context, when the distribution of energy expenditures in buildings is evaluated according to the data of the International Energy Agency, the following results are obtained [15]:

- Space heating: 49%
- Electricity for appliances and lighting: 27%
- Water heating: 9%
- Cooling: 8%
- Cooking: 4%
- Other (including ventilation and refrigeration): 3%

In dwellings located in cold climates, space heating typically consumes the most energy. The second-largest energy-consuming category is heating water for domestic use. Cooking represents a small section, and the usage of electricity to operate the products which include air conditioners, pumps, and different utilities. It must be noted that energy consumption in buildings can range significantly between typology and locations, relying on factors along with building age, insulation stage, HVAC (heating, ventilation, and air conditioning) performance, occupancy, and local climate. Improving energy efficiency in buildings may be achieved with proper insulation, an efficient HVAC, and appliances [18].

3. Steps Taken within the Framework of Today's Goals and Emerging New Definitions

There are many things that individuals, organizations, and governments are doing to prevent energy consumption and promote energy conservation. Within the framework of the important sources examined, the prominent ones can be listed as follows [19]:

1. Improving energy efficiency: Energy efficiency improvements can be made in homes, buildings, and industrial processes by using energy-efficient technologies, such as LED lighting, energy-efficient appliances, and insulation. Improving the energy efficiency of buildings can be particularly effective, as buildings account for a significant portion of global energy consumption.
2. Promoting renewable energy: Renewable energy sources, such as wind, solar, and hydropower, are becoming increasingly competitive with fossil fuels in terms of cost and performance. Governments and private organizations are promoting the adoption of renewable energy through policies, such as feed-in tariffs, tax incentives, and renewable energy mandates.
3. Encouraging behavior change: Changing individual behavior can also help to reduce energy consumption. This can include simple actions such as turning off lights and unplugging electronics when not in use, as well as more significant changes such as reducing car usage and shifting to public transportation or electric vehicles.
4. Developing new technologies: Research and development efforts are focused on developing new, more efficient technologies for energy generation, storage, and distribution, such as advanced batteries and smart grids.
5. Implementing policy measures: Governments can implement policy measures to encourage energy conservation and promote the adoption of renewable energy sources, such as carbon pricing, emissions regulations, and energy efficiency standards for buildings and appliances.

Overall, there is a wide range of activities underway to reduce energy consumption and promote a shift to cleaner, more sustainable energy sources [20,21]. These efforts will be critical in reducing greenhouse gas emissions and addressing the global climate crisis [22, 23].

Below are definitions of new concepts being discussed today in the context of low energy, passive power generation and energy efficiency around the world.

1. Energy Efficient Building: An energy efficient building is a building designed to use less energy than a conventional building while providing greater comfort to its occupants. Low-energy buildings often achieve energy savings through a combination of energy efficient buildings, high-efficiency HVAC systems and the use of renewable energy sources [18].
2. Nearly/Almost-Zero Energy Building (N/A-ZEB): a zero-energy building is a building with very high energy performance and uses a very small amount of energy from external sources. The energy consumption should be close to zero or minimum and energy requirement should be covered by renewable energy produced in or near the site [24].
3. Net Zero Energy Building (NZEB): A net zero energy building is a building that produces the energy it uses in a year.

Energy-efficient buildings typically achieve this through a combination of energy-efficient building designs, efficient HVAC systems and on-site renewable energy sources such as solar or wind power [24].
It should be noted that definitions of these concepts may vary depending on the country or region. [1, 25].

4. The Latest Status of Zero Energy Building Studies in the World and in Turkey

Energy-efficient construction is becoming more widespread globally. Building codes and standards are being updated to encourage energy efficiency and the use of renewable energy sources. However, the acceptance of these practices varies by region. In 2010, low-energy housing was still a small portion of the total housing available. Energy efficient construction is gaining momentum and becoming more common, especially in some European countries. Today in Europe, more than 2,000 buildings certified zero-energy by 2019. The number of low-energy and zero-energy buildings in the United States is also increasing, but only in percentage terms a few percent are still new buildings. Globally, the energy-efficient construction market is expected to grow exponentially in the coming years, driven by factors such as rising energy costs, growing concerns about climate change, and building codes and standards adoption of more severe forms results [25, 26]. It should be noted that achieving an uncertain energy state can be difficult and may require a significant upfront investment. However, longer-term benefits could include lower energy costs, improved resident comfort and reduced greenhouse gas emissions [27, 28].

There are many laws, regulations, directives, and standards that have been put in place to support the goals of reducing energy consumption and promoting zero energy buildings. Here are some examples of these measures:

1. Building codes: Many countries have building codes that require minimum energy efficiency standards for new construction and major renovations. For example, the International Energy Conservation Code (IECC) in the United States sets minimum standards for energy efficiency in buildings.
2. Energy performance standards: Some countries have energy performance standards that require buildings to meet specific energy consumption targets. For example, in the European Union, nearly zero energy building (nZEB) standards have been introduced for new construction and major renovations.
3. Renewable energy incentives: Governments around the world offer incentives, such as tax credits or subsidies, to encourage the adoption of renewable energy technologies, such as solar panels or wind turbines.
4. Energy labeling schemes: Energy labeling schemes provide information to consumers about the energy efficiency of products, such as appliances or HVAC systems. Labels, such as the Energy Star label in the United States or the EU energy label, provide information about the energy consumption and efficiency of products.
5. Green building certifications: Green building certifications, such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method), provide a framework for evaluating the sustainability and energy efficiency of buildings [29].
6. Emissions regulations: Some countries have emissions regulations that limit the amount of greenhouse gases that can be emitted from buildings. For example, in California, the Title 24 Energy Efficiency

Standards require buildings to meet specific energy efficiency and emissions standards.

The aim of these measures is generally to promote energy efficiency and the adoption of renewable energy sources and support the transition to a low-carbon economy [30,31]. Turkey has set ambitious goals for reducing energy consumption and promoting zero energy buildings. In 2017, Turkey launched the "Energy Efficiency in Buildings" project, which aims to improve energy efficiency in buildings and reduce greenhouse gas emissions. The project focuses on a range of measures, including energy audits, retrofits, and the use of renewable energy sources. The Turkish government has also introduced building codes and regulations aimed at promoting energy efficiency, including requirements for thermal insulation and efficient lighting systems. In addition, Turkey has implemented an Energy Performance Certificate (EPC) system, which provides information to consumers about the energy efficiency of buildings. Despite these efforts, progress towards zero energy building targets has been slow. According to a 2019 report by the International Energy Agency (IEA), Turkey has a small number of nearly zero energy buildings, and the adoption of energy-efficient building practices remained low. One challenge is that the upfront costs of energy-efficient building design and renewable energy technologies can be high, which can make them less accessible to developers and building owners. In addition, there is still a lack of awareness and understanding of the benefits of energy-efficient buildings among the public. However, Turkey has set a goal of reducing its energy consumption by 14% by 2023, and energy efficiency has identified as a key area for achieving this goal. With continued government support and public awareness efforts, it is possible that Turkey can make progress towards its energy efficiency and zero energy building targets in the coming years [32,33].

5. "ZeroBuild" as One of the Most Important Awareness Studies in Turkey

The ZeroBuild Summit is an annual event that has been held in Turkey for the past four years. The summit is focused on promoting sustainable and energy-efficient building practices, with a particular emphasis on zero energy buildings. The event brings together a wide range of stakeholders, including architects, engineers, policymakers, and building owners, to share knowledge and best practices for designing, constructing, and operating energy-efficient buildings. The summit features keynote speeches, panel discussions, and workshops on topics such as building materials, energy-efficient design, renewable energy systems, and financing for energy-efficient buildings. The ZeroBuild Summit is organized by the Sustainable Production and Consumption Association (SPCA), a non-governmental organization that aims to promote sustainable development and resource efficiency in Turkey. The event is also supported by several government agencies, academic institutions, and private sector organizations. The summit has grown in popularity over the past few years, reflecting a growing interest in energy-efficient building practices in Turkey. By bringing together experts and stakeholders from different sectors, the summit helps to facilitate knowledge-sharing and collaboration, and it serves as a platform for promoting sustainable building practices in Turkey and beyond [34].

6. Conclusion

The energy crisis that started in the 1970s has been an important issue worldwide from past to present. This crisis has triggered attention and savings in energy consumption, as well as efforts towards alternative energy sources. Industry, transportation, and buildings are accepted as three sectors of energy consumption in the world. The measures taken on energy consumption from the past to the present, together with the incentives of the governments and technological developments, have increased the use of energy efficiency and renewable energy in these sectors. While in the past general terms such as "energy consumption, energy saving and renewable energy" were emphasized to draw attention to the energy issue, today the importance of individual energy expenditures in residences is emphasized and concepts such as low-energy buildings and zero-energy buildings became popular. Parallel to these improvements in the world, it is seen that Turkey has also made progress in regard of energy efficiency. In addition to the use and dissemination of renewable energy sources, also initiated energy efficiency projects in buildings. The continuation of studies on energy consumption and sustainable use of energy resources throughout the world and of course in Turkey will both support economic growth and ensure environmental sustainability.

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Araştırma Makalesi

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Sıfır Enerji Bina Hedefleri Doğrultusunda Pomza ve Perlit Bileşenleriyle Şap Tasarımı

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Anahtar Kelimeler:
Pomza, genleştirilmiş perlit, şap, ısı transferi, döşeme, sıfır enerji.

Öne Çıkanlar:

- İnşaat malzemesi olarak pomza ve perlitin tanıtılması
- Pomza ve perlit malzemesinin şapının mühendislik özellikleri üzerine etkileri
- Geleneksel şap üretimi yerine üretiminde pomza ve perlit kullanımıyla daha üstün mühendislik ve yalıtım özelliklerine sahip, enerji tasarrufuna katkıda bulunan şap üretilebilir.

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Amaç

Bu çalışmada, sıfır enerjili bina hedeflerine yönelik olarak pomza taşı ve genleştirilmiş perlit malzemeleri kullanılarak şap tipinin tasarlanması amaçlanmaktadır. Bu amaçla günümüzde kullanılan geleneksel şap çeşidini temsil edecek ve çalışmada kontrol örneğini temsil edecek şap için dere kumu ile üretilmiş şap çeşidi üretilmiştir.

Metot

Pomza taşı ve genleştirilmiş perlit malzemeleri içeren 8 farklı karışım üretilmiştir. 28 günlük kürleme sürecinden sonra bu 9 farklı şap örneğine ultrasonik ses hızı (USH), basınç dayanımı ve ısıl iletkenlik testleri uygulanarak mühendislik özellikleri belirlenmiştir.

Sonuçlar

Ultrasonik ses hızı (USH) sonuçları incelendiğinde en yüksek değer (3797,2 m/s) kontrol serisinde elde edilmiştir. Buna en yakın değer BR-3 (3713,1 m/s) pomza serisinden elde edilmiştir. Basınç dayanımı sonuçlarına bakıldığında BR-3 (12,76 N/mm^2) serisinin kontrol serisine göre daha iyi sonuç verdiği görülmüştür. En düşük veriler ise BR-7 (1,68 N/mm^2) ve BR-8 (0,96 N/mm^2) perlit serisinde gözlenmiştir. Isıl iletkenlik test sonucu incelendiğinde en yüksek değer kontrol örneğinde (0,441 W/m.K) bulunmuş, buna en yakın değerler BR-4 (0,436 W/m.K) ve BR-2'de (0,304 W/m.K) pomza serisinde elde edilmiştir. En düşük değer ise BR-7 (0,191 W/m.K) ve BR-8 (0,105 W/m.K) perlit serisinde elde edilmiştir. Yapılan test sonuçları sektörde kullanılan şaplara göre pomza ve genleştirilmiş perlitli şap üretiminin mümkün olduğunu göstermiştir. Ancak genleştirilmiş perlit kullanımı ile basınç dayanımı önemli ölçüde azalırken, ses ve ısıl iletkenlik katsayıları çok daha iyi sonuçlar elde edilmiştir. Pomza taşının farklı ebatlarda kullanılması ise ses ve ısıl iletkenlik sonuçlarında iyileşmeler gösterirken, basınç dayanımı özelliklerini de değiştirmektedir.

Research Article

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The Screed Design with Pumice and Perlite Components in Zero Energy Building Targets

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Highlights:

- Engineering properties of conventional screed
- Introducing pumice and perlite as construction materials
- Effects of pumice and perlite materials on the engineering properties of screed

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Abstract

In this study, it is aimed to design a screed type using pumice-stone and expanded-perlite materials towards zero energy building goals. For this purpose, a screed type produced with river sand was produced for screed, which will represent the traditional screed type used today and will represent your control sample in our study. Then, 8 different mixtures containing pumice stone and expanded perlite materials were produced. After a 28-day curing process, nine different screed samples underwent engineering property tests: ultrasonic pulse velocity (UPV), compressive strength, and thermal conductivity. The control series showed the highest UPV value at 3797.2 m/s, followed closely by pumice BR-3 at 3713.1 m/s. BR-3 also outperformed the control series in compressive strength (12.76 N/mm^2), while perlite series BR-7 (1.68 N/mm^2) and BR-8 (0.96 N/mm^2) had the lowest values. In thermal conductivity, the control sample had the highest value (0.441 W/m.K), with pumice BR-4 (0.436 W/m.K) and BR-2 (0.304 W/m.K) close behind, and perlite series BR-7 (0.191 W/m.K) and BR-8 (0.105 W/m.K) having the lowest values. Using pumice and expanded perlite as screed materials offers improved sound and thermal conductivity results compared to traditional screed. However, expanded perlite leads to a significant decrease in compressive strength. Incorporating these alternatives has the potential to reduce building weight and enhance heat and sound insulation properties.

Keywords: Pumice, expanded perlite, screed, heat transfer, flooring, zero energy.

1. Introduction

The issue of energy in the world has not lost its importance since the beginning of the energy crisis, on the contrary, it has come to this day with increasing importance. Developments in energy have evolved from issues such as energy consumption-energy saving-renewable energy to issues such as low energy-nearly zero energy-net zero energy. One of the sectors where energy is consumed the most is building and construction, after industry and transportation. In this respect, zero energy building targets have become one of the most important concept issues today. Although insulation materials come to the fore in this regard, they are not sufficient on their own to achieve this goal. Along with insulation materials, other elements that make up the buildings should be designed in accordance with these objectives and have positive contributions [1,2]. In this context, the subject of this article emphasizes that the screed material used on building floors and back floors can be designed to reduce the dead load of the building and to contribute to sound and heat insulation at the same time. Today, technology is advancing rapidly and brings with it many innovations. One of the sectors where we feel the presence of technology the most is the construction sector [3,4]. Researchers further promote the construction industry by doing research and inventions to improve building materials, meet the needs better, keep up with the speed of technology and complete the deficiencies.

Concrete, which has an extensive and widespread usage area, is one of the first products that come to mind regarding building materials. Concrete and concrete-like materials have many advantages as well as disadvantages [3,4]. Researchers have focused on addressing the drawbacks of concrete, the primary building material. In this context, efforts have been made to enhance the screed material used for floor applications. Screed provides a smooth surface necessary for proper floor coating, offering advantages such as high strength and insulation properties. Its usage aims to provide floor insulation, improve aesthetics, increase resistance to external factors, and extend the lifespan of the concrete subfloor. Screed finds applications in various areas, including parking lots, water-exposed regions, factories, sports and exhibition halls. There are two main types of screed application: poured with cement and ready screed. These advancements contribute significantly to the overall enhancement of building systems [5].

Pumice is a type of natural stone with a spongy structure, which is formed because of volcanic eruptions, with many macro and micro cavities that are independent of each other [6-7]. The maximum particle porosity is 85%, the remaining 15% is solid material [7]. Pumice, which is a volcanic rock, is a natural, low cost and very light material with low permeability, high heat and sound insulation thanks to its independent macro and micro cavities [6,8]. Besides these, pumice has reasonable flexibility and good fire resistance [7]. Pumice has a light or dark color structure and is highly resistant to chemical and physical events. Due to these superior properties, pumice has gained value in the construction sector and has become a frequently preferred building material in advancing and developing technology. The world is very rich in terms of pumice reserves

[9]. Turkey is in one of the most important positions in terms of ownership of pumice deposits [6]. The pumice reserves in the world are approximately 18 billion m^3 and approximately 2.8 billion m^3 of these reserves are in Turkey. Bitlis province is the leading province in terms of pumice reserve due to the geological structure of Bitlis province and being built on a volcanic area, pumice deposits have an important potential. The deposits in question are in Tatvan and Ahlat districts of the province and there are 81,500,000 m^3 of good quality pumice deposits that do not require partial washing [6]. 80% of the pumice produced in Turkey is used as lightweight concrete aggregate in the construction industry [9]. Due to pumice concrete is a very light construction material compared to normal concrete [9]. Pumice is used in many sectors apart from the construction sector. Some of those; textile, agriculture, and chemical sectors. Pumice stone is divided into two as acidic pumice stone and basic pumice stone [4]. In this study, acidic pumice was used as pumice stone and specific weight between 0.69 and 0.95 kg/dm^3 obtained from Bitlis region [10].

Perlite is a pearly, acidic volcanic glass that becomes very light and porous when suddenly heated to a suitable temperature. The word perlite is used for both raw perlite and expanded perlite [11]. When raw perlite is suddenly heated to a temperature between 800 and 1100 °C, the perlite particles expand as the water in it comes out as steam, increasing its volume to about 20 times the original, and as a result, expanded perlite is formed [12]. The color of raw perlite varies from transparent light gray to glossy black, while the color of expanded perlite is white. In terms of its lightness, heat and sound insulation and cheapness, it is the most suitable material known to produce light construction materials [11]. Expanded perlite is a material used worldwide. Due to its low mass density, it is a material used especially in building materials technology, lightweight composites, heat, and sound insulation. Dust formation is the most important factor that complicates the use of expanded perlite due to its extremely low bulk density [13].

In this article, first, the properties of the screed varieties available in the market were investigated. Then, it was aimed to investigate whether it is possible to produce a screed type with better and more advantageous engineering properties by producing the screed application applied in the buildings with acidic pumice stone and expanded perlite. For this purpose, different from the ready-made screeds in the market, mixtures were prepared from acidic pumice stone and expanded perlite materials in different proportions and different particle sizes using chemical additives, and some engineering properties of the produced samples were investigated. In addition, the other aim of this study is to discuss increasing the usage areas of acidic pumice stone, which is a natural material of the Bitlis region, which has a significant proportion of the world's pumice reserves, and expanded perlite, another material with similar properties in the construction sector. Taking advantage of the physical and chemical properties of acidic pumice stone and expanded perlite material, reducing the structural load, which is a very important problem for the construction industry, benefiting from the advantages of sound and heat insulation, which

Table 1. CEM-1 42,5 N Portland cement properties

Analysis results	CEM I 42.5 N	TS EN 197-1 [4]
2 days compressive strength (MPa)	22,4	≥20
7 Days Compressive Strength MPa)	39,4	-
28 Days Compressive Strength (MPa)	51,0	62,5 ≥ x ≥ 42,5
SO_3 (%)	2,6	≤ 3,5
MgO (%)	2,1	≤ 5
CI (%)	0,007	≤ 0,1
LOI (%)	1,7	≤ 5
Insoluble matter (%)	0,3	≤ 5
Specific surface (cm^2/g)	3749	-
Initial setting time (min)	161	≥ 60
Shrinkage (mm)	0,4	≤ 10
Free lime (%)	0,5	-
Water demand (%)	29,6	-

Table 2. Physical properties of acidic pumice aggregate

Aggregate Group	0-4 mm	4-8 mm	8-16 mm
Water absorption rate (%)	40,16	38,9	51,8
Loose unit weight (kg/m^3)	450,1	381,7	295,5
Dry specific gravity (kg/m^3)	940	880	690

Table 3. Chemical composition of acidic pumice [6]

Chemical composition (%)	Acidic pumice
SiO_2	70
Al_2O_3	14
Fe_2O_3	2,5
CaO	0,9
MgO	0,6
Na_2O+K_2O	9
LOI	3

Table 4. Chemical composition of expanded perlite [6]

Chemical composition (%)	Expanded perlite
SiO_2	71-75
Al_2O_3	12,5-18
Fe_2O_3	0,3-1,5
CaO	0,3-2
MgO	0,1-0,5
Na_2O	2,7-4
K_2O	3,5-5
LOI	2-5

Table 5. Technical specifications of expanded perlite aggregate [14]

Properties	Expanded perlite aggregate
Color	White
Hardness (Mohs Scale)	5-5,5
pH	6,6-8
Specific mass (g/cm^3)	2.300
Dry Unit Volume Weight (kg/m^3)	40-220
Water absorption (%)	40-60
Solidity ratio (%)	1,80-9,60
Actual porosity (%)	98,2-90,4
Sulfur analysis (%)	0,34
Structural degradation (˚C)	870
Melting point (˚C)	1100
Fire resistance	Fireproof
Fire retardant (hour)	3
Specific heat capacity (kcal/kg℃)	0,200-0,215
Thermal conductivity (W/Mk)	0,040-0,050
Sound Transmission Coefficient	0,25
Sound absorption (dB)	35-40

Table 6. Physical properties of sand

Properties	Sand
Water absorption rate	3.72
Specific weight (kg/m^3)	2.22

are the physical properties of expanded perlite and acidic pumice stone, and resistance to physical and chemical events, and another important factor, it is aimed to gain from the cost, which is one of the problems.

2. Material and Method

In the experimental study, CEM I 42.5 N type Portland cement obtained from Elazığ Cement Factory, water absorption rate of 3.72, creek sand of Bitlis-Ahlat region with a specific weight of 2.22 kg/m^3, acidic pumice stone from Bitlis region, expanded perlite, Plastocrete N (water impermeability additive), Sika Lightcrete I-500 (air entraining additive), Sika Viscocrete Hi-Tech 28 (hyper plasticizer additive) and Bitlis Eren University drinking water was used as mixing water. The properties of the materials used are presented in Table 1 to Table 6. The properties of CEM-1 42,5 N Portland cement in Table 1, the physical properties of acidic pumice aggregate belonging to Bitlis region in Table 2, the chemical composition of acidic pumice belonging to Bitlis region in Table 3, the chemical composition of expanded pearlite in Table 4, the technical properties of expanded pearlite aggregate in Table 5, the physical properties of sand in Table 6 are given. The mixture calculations were made by taking into account the properties of the materials given in the tables.

In the study, mixing ratios were calculated by using 0-4 mm, 4-8 mm, 8-16 mm acidic pumice stones and fine and coarse expanded perlite together with and without 3 different chemical additives. In addition to these, a sand-mixed screed sample, which is mostly used today, was created for comparison. Calculated mixing ratios are given in Table 7. Then, the casting process was started according to the mixing ratios given in the table. All materials were mixed in a 50 dm^3 concrete mixer and placed in sample molds measuring 100x100x100 mm, which were previously cleaned and lubricated. A stand type vibrator was used to place the mixtures in the sample molds without gaps. After the poured samples were kept in the molds for 24 hours, they were removed from the molds and subjected to a 28-day water cure in the curing tank. UPV, compressive strength tests were applied to the samples that completed their curing periods. Each experiment was performed on 3 samples and the average of the obtained results was taken. Then, the thermal conductivity coefficients of the samples that completed the curing age of 28 days were determined. Finally, result graphics were created with the obtained data.

The compressive strength test of concrete is a concrete test applied to cube or cylindrical specimens to determine the compressive strength of hardened concrete at certain curing ages [15]. The compressive strength test was carried out after 28 days of curing, and the results were recorded and converted into tables and graphics. The compressive strength test was applied based on TS EN 1354 and TS EN 12390-4 standards [16,17].

The UPV test is an experiment in which the compressive strength of concrete is measured with a non-destructive method based on the principle that sound does not propagate in a air [18]. The wave velocity is calculated by measuring the time it takes for the ultrasonic pulse waves sent to the sample to reach the other side of the sample. With this wave velocity found, the compressive strength properties of the sample are obtained. This test was applied to specimens those curing period had expired before applying the compressive strength test. However, in this study, it was applied to obtain information about the sound permeability of the samples created beyond the purpose of obtaining information about the compressive strength.

Determining the thermal conductivity of the material is very important for building materials. A thermal conductivity test is performed to determine the heat conduction coefficients of the material. In the thermal conductivity test, the desired temperature difference is created on the two surfaces of the sample, and the heat transmission coefficient of the sample is calculated by controlling and measuring the heat flux passing through the sample. The thermal conductivity coefficient is the amount of thermal energy passing through the perpendicular unit thickness of the unit area per unit mass when the temperature difference between two surfaces is 1 degree. Thermal conductivity (k) and specific heat (Cp) of 10*10*10 cm samples were calculated by hot wire method according to DIN 51046 norm.

Table 7. Mixing ratios (kg)

Type	Water	Cement	Sand	Acidic pumice			Expanded perlite	Chemical Additives (%)
				0-4 mm	4-8 mm	8-16 mm		
Control	60	150	1331	-	-	-	-	-
BR1	60	150	-	619	-	-	-	-
BR2	60	150	-	468,6	105,6	-	-	-
BR3	60	150	-	406,12	84,48	46,2	-	-
BR4	60	150	-	624,8	-	-	-	1.5
BR5	60	150	-	468,6	105,6	-	-	1.5
BR6	60	150	-	406,12	84,48	46,2	-	1.5
BR7	60	150	-	468,6	-	-	52,8 (coarse)	1.5
BR8	60	150	-	-	156,2	-	158,4 (fine)	1.5

* Each different chemical additive, whose names are specified in the materials section, was used at 0.5%.

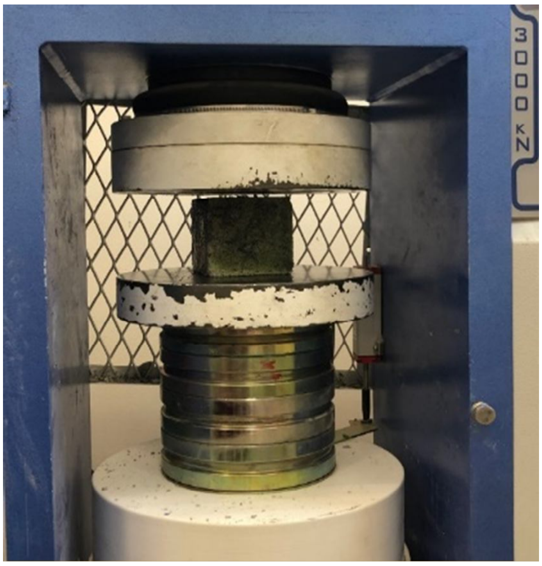

Figure 1. Compressive strength test

Figure 2. UPV test

The thermal conductivity values of the samples were measured using the ISOMET 2104 model heat transfer device. Measurements were taken from different points on each sample at room temperature, the average of these measurements was taken, and the thermal conductivity (k) and specific heat (Cp) values of the samples were calculated. ISOMET 2104 heat transfer device measures the heat transfer coefficients of the samples with 5% precision in the range of 0.04-6 W/mK, and the volumetric specific heat with 5% precision in the range of 4.0*104 – 4.0*106 J/m^3K. Ambient temperature and heat transfer coefficient can be read from the device's screen. The ISOMET 2104 model device has been developed especially to determine the thermal properties of natural stones and building elements. The device has 3 different solid surface probes, these probes are used for different measuring ranges [19].

3. Results and Discussion

3.1 Ultrasonic Pulse Velocity Test Results

Ultrasonic Pulse Velocity (UPV) test is a non-destructive concrete test performed without damaging the concrete to obtain information about the physical properties of building materials, concrete quality, and concrete strength [20,21]. There is a connection between UPV and concrete compressive strength and of course sound isolation. UPV value in concrete varies depending on the number of pores in the structure [22]. When the UPV test results are examined, a general judgment can be made about the concrete compressive strength of all series. There is no direct relationship between the strength of the concrete and the P wave passing through the concrete, but there is a relationship between it and the concrete density. The transition time of P wave velocity from one surface of the concrete to the other surface of the concrete is longer in concretes with low density, that is, with a large concrete void volume. In other words, the P wave velocity is lower in concrete with a higher concrete void ratio and pore amount [23]. When the UPV test results in Fig. 5 are examined, it is seen that the series with the lowest UPV value, that is, the void ratio, is the control sample. It is seen that the BR3 pumice series with different grain sizes and different mixing ratio gives the closest value to these results. The judgment that should be understood from here is that the small diameter pumice stones fill the voids created by the larger diameter pumice stones, causing the concrete void volume to decrease, resulting in a higher UPV value. Unlike BR1, BR2 and BR3 series, BR4, BR5 and BR6 series were created by adding 3 different chemicals into the mixture. When these two groups are compared, there is no big difference between the UPV values, but it is assumed that the reason for the small decreases is the air-entraining additive used in the mixture. The lowest UPV value was obtained from the BR8 series in which perlite, pumice and chemical additives were used. It is understood that the reason for this is the difference in aggregate used in the mixture, the mixing ratios and the large volume of concrete voids depending on these. In general, it is understood that the BR3 sample, which is the closest to the control sample, has the densest structure after the control sample, and the BR8 sample has the lowest density. It was concluded that the reason for the lowest results in the BR8 sample was the air voids created in the concrete

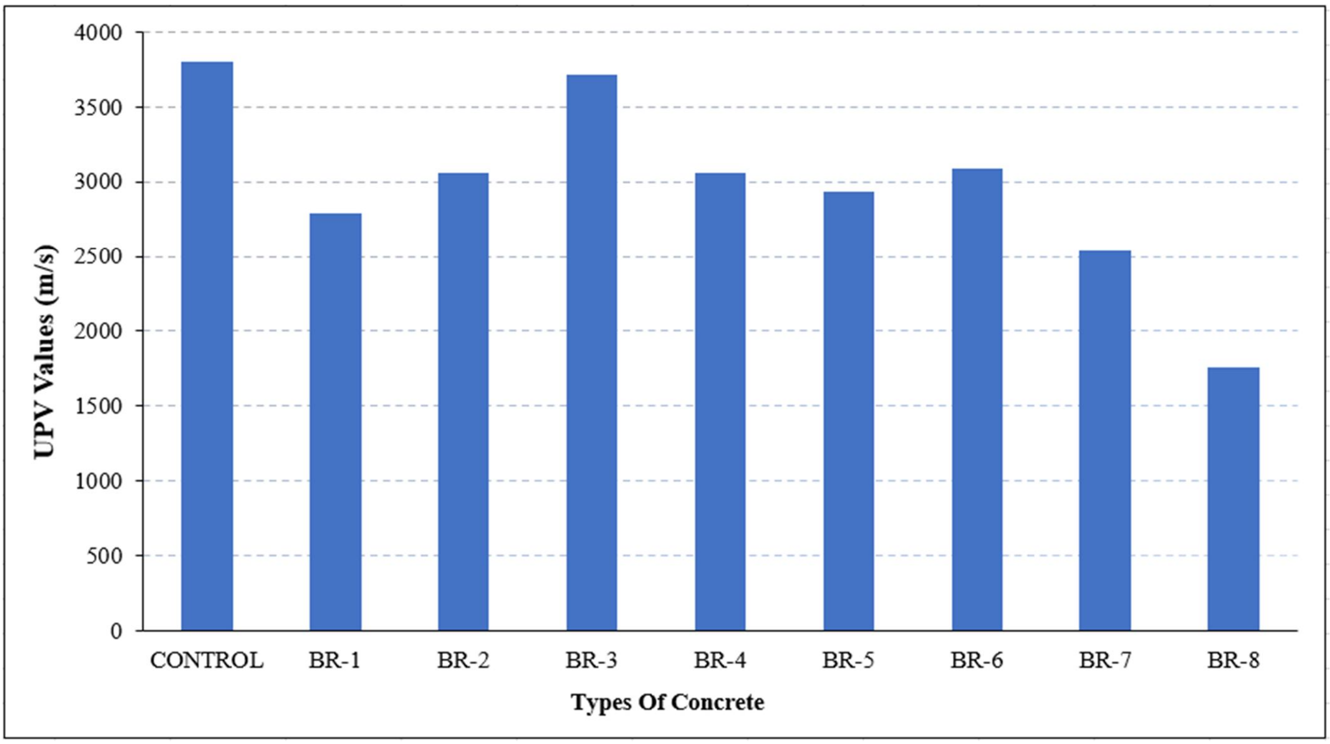

Figure 5. UPV test results

by the air-entraining admixture used in the mixture, in addition to the porous structure of perlite and pumice. When the compressive strength results are examined, the highest-compressive value was obtained from the BR3 series with high density and strong skeleton structure, and the smallest compressive strength value was obtained from the BR8 series with the lowest density and weak skeleton. It is understood from these results that the UPV and compressive strength results support each other. On the other hand, these results emphasized that the use of pumice or perlite in the mixture indicated a decrease in compressive strength as well as an improvement in sound insulation.

3.2 Compressive Strength Test Results

The compressive strength test results are given in Fig. 6. The series presented with the control code from the samples created here represents the incoming screed method produced today. For this reason, each series was compared with the results of this series. When BR1, BR2 and BR3 series are compared with the control series, BR1 and BR2 gave lower compressive strength than the control series, while the BR3 series has higher compressive strength than the control series. In the BR1 series, a content equivalent to the control series was created by using only 0-4 mm fine aggregate, and the compressive strength decreased because the aggregate used in the BR1 series was pumice stone aggregate. These results were obtained because the river sand used in concrete and concrete materials is physically stronger than the porous pumice aggregate. When BR1, BR2 and BR3 are examined among themselves, it is seen that the strength increases in each sample, respectively. The reason for the increase here is that the use of coarse aggregate in the spine structure of the samples was preferred and the maximum aggregate grain diameter was increased in each series, resulting in an increase in strength. With the use of 0-4 mm pumice, 4-8 mm, and 8-16 mm coarse pumice stone aggregate in the BR3 series, the compressive strength values of this series were higher than the compressive strength values of the control series. When the BR1 and BR4 series are evaluated among themselves, 0-4 mm pumice stone was used as an aggregate in the BR4 series, as in BR1, but 3 different chemical additives were used in the mixture in addition. Therefore, a more fluid mixture is obtained. The reason for using hyper-plasticizer from 3 different chemicals is to produce self-leveling screed. However, when the material with such a low specific gravity is liquefied, segregation and vomiting problems arise. These problems were avoided by using an air-entraining additive and a uniform fluid mixture was obtained.

When the UPV result graph was examined, the UPV value of the BR4 sample was higher than the BR1 sample. The reason for this is the water impermeability and air-entraining chemical additives used in the mixture. Considering these results, it is an expected result that the compressive strength value of the BR4 sample is higher than that of the BR1 sample.

When the BR2 and BR5 samples are compared among themselves, the difference between the two mixtures is the use of 3 different chemical additives in the BR5 sample, unlike BR2. When the UPV test results are examined, there is no big difference between the two series. Although the UPV values are close to each other, the compressive strength of the BR5 series was lower than the BR2 series. It has been concluded that the reason for this result is the voids created by the air-entraining admixture in the concrete.

When the BR3 and BR6 samples are compared, the difference between the series is the chemical additives used in the BR6 sample. When the UPV values are examined, there is no big difference between the BR3 and BR6 series. When the compressive strength values are examined, the compressive strength value of the BR3 series is higher than that of the BR6 series. As evaluated in other series, it was concluded that the reason for this in this series was the air voids formed in the concrete due to the air-entraining additive.

The mixture content of the BR7 and BR8 series varies. In addition to pumice stone, perlite material was also used. While 0-4 mm fine pumice stone, coarse perlite and 3 chemicals were used in the BR7 sample, on the contrary, 0-4 mm fine perlite and 4-8 mm coarse pumice were used in the BR8 sample. Since a high percentage of pumice stone and low percentage of perlite were used in BR7 sample, a stronger skeleton structure was formed compared to BR8. Therefore, the BR7 sample gave a higher compressive strength value. These results can also be understood by looking at the UPV results. The high void ratio of the BR8 sample can be explained as the reason for the low-compressive strength value.

The physical, mineralogical, and textural properties of the aggregate, which constitutes 60-80% of the concrete, directly affect the concrete compressive strength [22]. The porosity ratio of the concrete, the void volume, that is, the internal structure affects the compressive strength of the concrete. To obtain information about the void ratio in the concrete, the UPV test is performed and the transition time of the P wave velocity in the concrete is found. Even if the transition time of the P wave velocity does not directly give information about the compressive strength, it allows us to indirectly obtain information about the compressive strength of concrete by enabling us to establish a connection between the concrete density and the concrete compressive strength. Concrete with a large void structure and low P-wave velocity has less density and, accordingly, concrete compressive strength is lower [23]. These results show that, considering the destructive effect of the earthquake and dead load, which is one of the most important problems in buildings, it is possible to design concretes with high strength, economic, load bearing, lightweight, high heat and sound insulation properties due to their independent cavities.

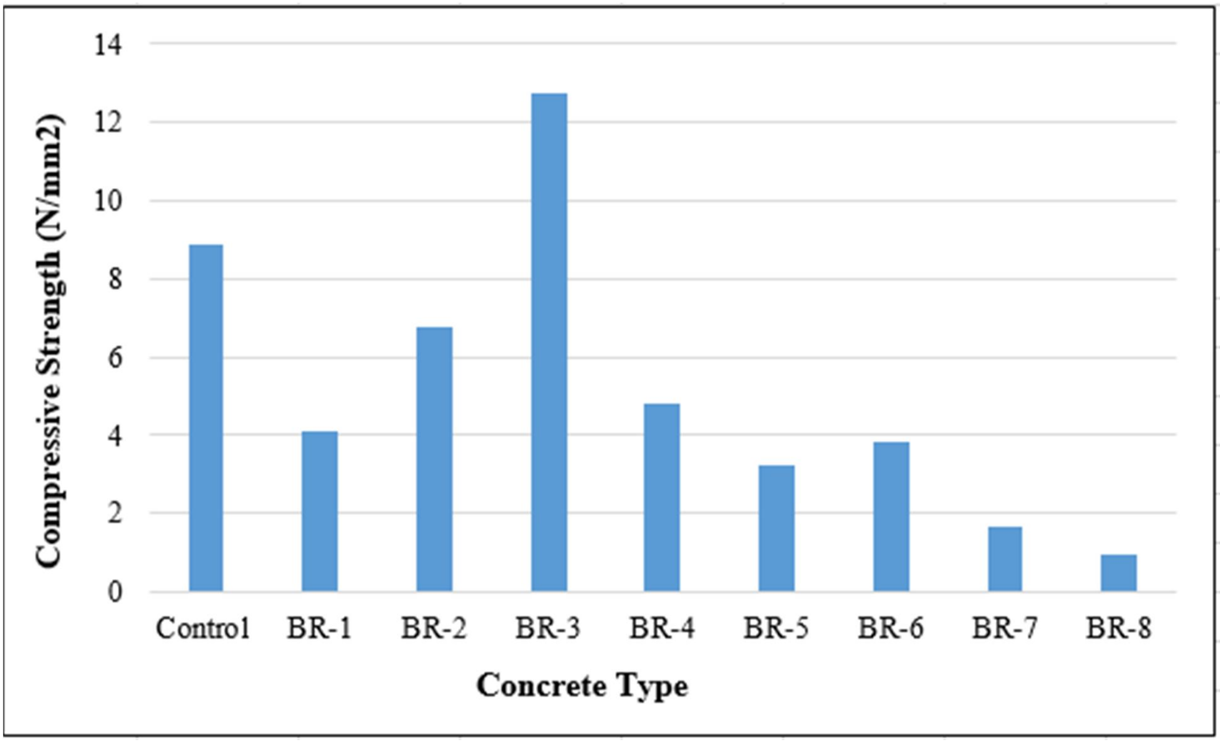

Figure 6. Compressive strength test results

Table 8. Compressive strength classes for screed materials [28]

Class	C5	C7	C12	C16	C20	C25	C30	C35	C40	C50	C60	C70	C80
Compressive strength value (N/mm^2)	5	7	12	16	20	25	30	35	40	50	60	70	80

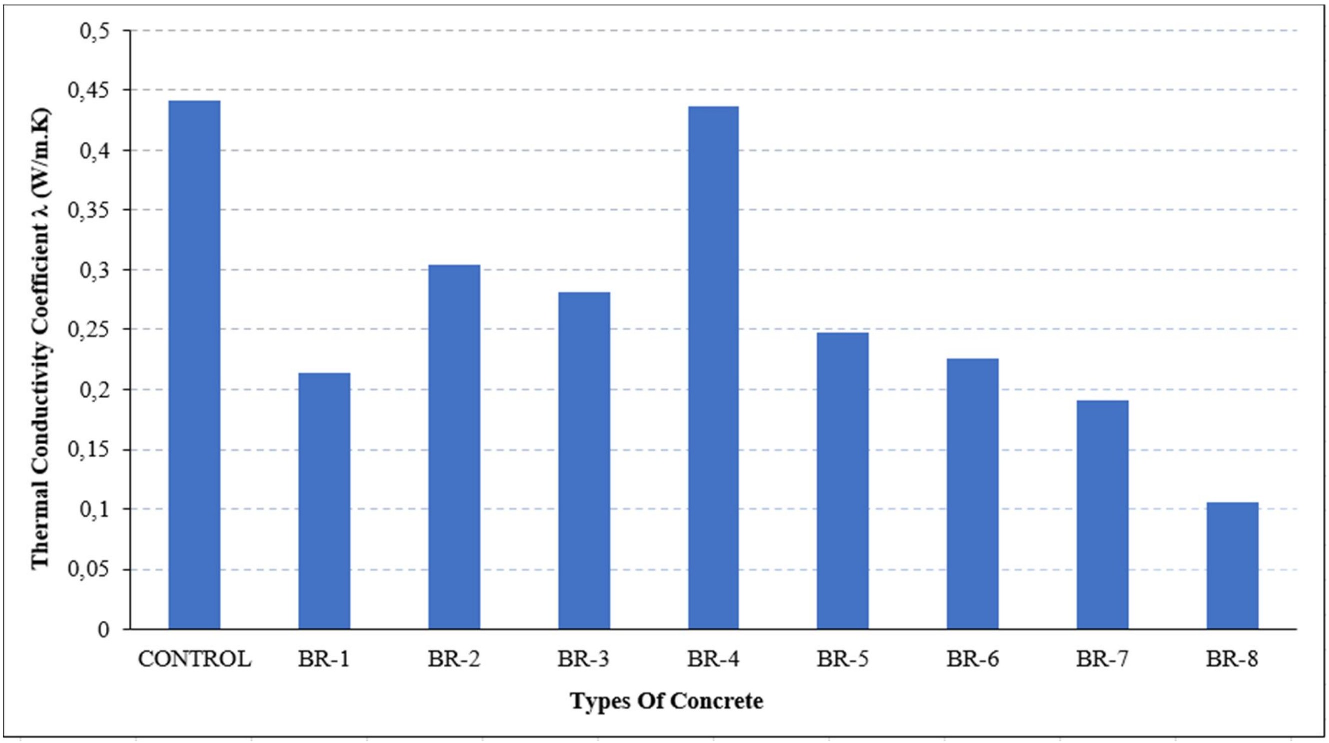

Figure 7. Thermal conductivity test results

Engineering properties of ready-made screed brands such as Ardex, Roxol, Baumit, Bonafix in the market were examined. It is seen that they have different compressive strength due to their properties and different concrete classes. The compressive strength of the screeds belonging to different concrete classes has taken values such as 12, 16, 20, 25, 30, 40 [24-27].

In the TS EN 13813 standard, the concrete compressive strength values of the screeds according to the concrete classes are examined and indicated in Table 8. The desired compressive strength values for the C5, C7 and C12 concrete classes in the TS EN 13813 standard were obtained in the BR2, BR3 and BR4 series. The highest compressive strength value was obtained from the BR3 sample [28].

3.3 Thermal Conductivity Test Results

The lower the thermal conductivity coefficient value, the better the thermal insulation of the material. Figure 7 illustrates the thermal conductivity coefficients. The thermal conductivity coefficient varies with the change of aggregate type used in the production of screed concretes and the change of consistency according to the chemical additives used.

While the highest thermal conductivities (0.441 W/mK) were obtained in the control series, the lowest thermal conductivity was obtained from the BR8 screed concrete series (0.105 W/mK). After the control series, the highest value was obtained from the BR-4 (0.436 W/mK) series. An irregularity was observed between the BR1-BR3 series in terms of thermal conductivity coefficients. The expectation here was actually a decrease in the thermal conductivity coefficient from BR1 to BR3. However, since these series are created without using any chemical additives and are prepared in the consistency of screed used in the field, that is, in a solid consistency, it is assumed that this data irregularity occurs due to the adverse effects of material distribution in the molds or the formation of undesired irregular air spaces. On the other hand, this data formation was observed in the BR4-BR6 series. In these samples, where pumice stone material of different sizes was used together with chemical additives, a decrease was observed in the thermal conductivity coefficient as the size of the pumice stone used increased. However, the use of expanded perlite along with pumice stone in the mixture further reduced the thermal conductivity coefficient and provided better results. When the control series is compared with the BR8, there is an improvement of 76.2% in terms of thermal conductivity coefficient. It is clear that using such materials instead of traditional screed will contribute to sound and heat insulation as well as to lighten the weight of the building. This result reveals that in these days when zero energy buildings are targeted, other elements or materials that make up the building can also help to achieve this goal besides insulation materials.

4. Conclusion and Recommendations

As a result of the laboratory studies, the engineering properties of the screed samples designed with pumice stone from the Bitlis region were determined and it was determined that they could be used in flooring. An improvement in concrete compressive strength was observed by increasing the maximum aggregate particle size of the pumice stone used. An increase of 45% was observed in the compressive strength obtained from the BR-3 sample. The use of perlite material in the mixture affected the concrete compressive strength negatively. Considering compressive strength results, the best result was obtained from the mixture formed with BR-3, and the worst results were obtained from the perlite samples for all experiments. When all these results are taken into consideration and evaluated, it is seen that it is possible to produce screed with pumice material when the data obtained from the calculation of the mixture made according to 150 kg dosage, the characteristics of the screed types used in the market and TS-EN-13813 standards. On the other hand, it has been determined that the use of perlite significantly reduces the compressive strength by approximately 81% (BR-7) and 89% (BR-8) but improves the insulation properties by approximately 57% (BR-7) and 76% (BR-8). In this type of designs, it is recommended to add perlite as an additive instead of using it as an aggregate, thus keeping the aggregate skeleton structure strong in terms of strength. By using pumice and perlite materials, screed types can be produced that will have a low dead load on the building and show similar properties to their counterparts in the market. In addition, with the increase of the energy crisis today, the importance of the energy issue is increasing day by day. Reducing energy consumption to a minimum and ensuring energy savings has made it necessary to turn to the design of low-energy or even zero-energy buildings. the construction sector is a very important sector in terms of energy consumption potential. This makes the work on increasing zero-energy buildings in the construction sector more important. Even though insulation applications provide energy savings, these materials alone are not enough. for this reason, the other elements that make up the buildings should be in accordance with the concept of zero energy. For this reason, the types of screeds to be made with these materials will gain even more importance in these days when individual heating and insulation on the floors come to the fore.

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