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Evaluation of structural lightweight concrete in terms of energy performance: A case study

Taşıyıcı hafif betonun enerji performansı açısından değerlendirilmesi: Bir örnek çalışma

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Abstract

In this study, it is aimed to produce structural lightweight concrete (SLWC) containing pumice aggregate and to evaluate its contribution to energy performance. Fly ash and metakaolin were used as substitutes with cement in the production of lightweight concrete. It was also produced normal weight concrete (NWC) for comparison. The compressive strength, the unit weight and the coefficient of thermal conductivity of the concretes produced were determined in accordance with relevant standards. The unit weights of the lightweight concrete are in the range of 1880-1900 kg/m³, and the compressive strengths are between 20-27 MPa. It was observed that the thermal conductivity coefficients of the SLWCs are ranging from 0.54 to 0.63 W/mK and they decrease as the unit weights decrease. The properties of the SLWCs determined are used in the energy simulation software DesignBuilder to assess the primary energy consumption for a case study. With the use of SLWCs, it can be seen that the annual energy requirement decreases by 15% to 19% compared to NWC. In addition, when monthly heating and cooling loads are analysed, it can be seen that the SLWCs reduces the heating energy requirement significantly. However, the cooling energy needs were not significantly affected due to the type of concrete produced.

Keywords: Structural lightweight concrete, Energy performance, Thermal conductivity, Unit weight.

Öz

Bu çalışmada, pomza agregası içeren taşıyıcı hafif beton üretilmesi ve taşıyıcı hafif betonun enerji performansı açısından değerlendirilmesi amaçlanmıştır. Hafif beton üretimlerinde uçucu kül ve metakaolin çimento ile ikame edilerek kullanılmıştır. Karşılaştırma yapmak amacıyla normal ağırlıklı geleneksel beton üretilmiştir. Üretilen betonların basınç dayanımı, birim hacim ağırlık ve ısı iletkenlik katsayıları ilgili standartlara uygun olarak belirlenmiştir. Üretilen hafif betonların birim hacim ağırlıkları 1880-1900 kg/m³ ve basınç dayanımları 20-27 MPa arasında değişmektedir. Betonların ısı iletkenlik katsayıları birim hacim ağırlıkları azaldıkça azalmış olduğu ve 0.54-1.0 W/mK arasında değerler aldığı görülmektedir. Üretilen betonların belirlenen özellikleri örnek bir vaka için enerji simülasyon yazılımı DesignBuilder programı vasıtasıyla birincil enerji tüketimi ihtiyaçlarını değerlendirmek için kullanılmıştır. Normal ağırlıklı betona kıyasla, taşıyıcı hafif beton kullanımı ile yıllık enerji ihtiyacında %15-%19 oranında bir azalma görülmüştür. Ayrıca, aylık ısıtma ve soğutma yükleri dikkate alındığında, taşıyıcı hafif betonların ısıtma enerjisi ihtiyacını önemli derecede azaltmış olduğu görülmüştür. Soğutma enerji ihtiyacı ise beton tipinden önemli derecede etkilenmemiştir.

Anahtar kelimeler: Taşıyıcı hafif beton, Enerji performansı, Isı iletkenlik, Birim hacim ağırlık.

1 Introduction

Normal weight concrete (NWC) is one of the most widely used structural materials in the construction industry. However, in some cases, it is preferred to use structural lightweight (SLWC) concretes due to some advantages they provide as opposed to normal weight concretes. The dead load of the structures constructed using SLWC is significantly reduced. This enables production of structural elements with smaller cross sections. In addition, the strength/weight ratio fairly increases in structures made of SLWC. It is also important for the energy performance of the structure that constructed with SLWC since it has low thermal conductivity compared to NWC [1]-[5].

Lightweight aggregates have superior properties compared to normal weight aggregates regarding lightness, insulation properties and freeze-thaw resistance. Different artificial and natural lightweight aggregates have been used in lightweight concrete production. Perlite, expanded clay, shale, sintered pulverized fuel ash are typical examples for artificial aggregates and pumice, diatomite, volcanic tuff and volcanic slag are natural lightweight aggregates [6]. The unique property of the lightweight aggregates used in SLWC is its high resistance to crushing [7].

Different classifications may be found for SLWC in different standards. According to the relevant standards, lightweight concretes with a unit weight of 1400 kg/m³ to 2000 kg/m³ and a 28-day compressive strength greater than 17 MPa are defined as SLWC [8]-[9]. In ACI 213R-87 report, SLWC is defined as concretes with a dry air unit weight ranging from 1440 to 1850 kg/m³ and a 28-day compressive strength greater than 17.2 MPa [10].

Different mineral additives at various substitution ratios have been used in the production of SLWC. Mineral additives improve the mechanical and durability properties of concrete due to their pozzolanic properties and filler effect [1]. By replacing these mineral additives with cement, on the one hand, while the consumption of cement decreases, on the other hand, ecological benefit is provided. At the same time, lightweight concrete with lower unit weight can be produced by using

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mineral additives. With a decreased unit weight, the insulation properties of concrete improve and it is possible to construct structures with higher energy performance [1],[11].

In a study on the mechanical properties of SLWC produced with pumice aggregate, SLWCs were produced containing silica fume and fly ash as mineral additives. In the study, it is stated that SLWCs with a unit weight ranging from 1440 to 1850 kg/m^3 and concrete classes LC20/22 and LC25/28 were produced [2]. In another study on the mechanical properties of lightweight concrete, it is stated that SLWC concrete of LC25/28 class can be produced using pumice aggregate from Elazig region [12]. In addition, in a study dealing with the characteristics of SLWCs containing mineral additives, concretes with compressive strengths varying from 22.5 to 43 MPa and with air dry unit weights ranging from 1935 to 1995 kg/m^3 were produced. Compared to NWC, SLWC containing 15% silica fume has a 57% increase in compressive strength, while 14% increase in elasticity modulus. Compared to lightweight concretes without fly ash, lightweight concrete containing 10% fly ash has yielded 18% decrease in compressive strength, while no change in elasticity module is observed [13]. In a study dealing with the compressive strength and thermal conductivity of concretes containing silica fume and fly ash expanded perlite aggregate, it has been stated that with the use of silica fume and fly ash a discernible decrease in the unit weight and the thermal conductivity coefficients were measured. It is stated that there is a 4% and 7% decrease in the thermal conductivity coefficients of concretes containing 10% fly ash and silica fume. With the use of silica fume, a 13% increase in the compressive strength of concrete has been achieved at the end of 28 days. It was also stated that a 27% decrease in the compressive strength of concrete compared to reference concrete was obtained when fly ash was used [14].

One of the most important advantages of lightweight concrete compared to normal weight concrete is the low thermal conductivity coefficient it has. It is stated that this may be attributed to the void structure in lightweight concrete. The use of materials with low thermal conductivity is important in terms of energy consumption and energy saving. [15]. Energy consumption in buildings can exceed energy consumption in industry and transportation. In the past, energy consumption in buildings was not considered. But today, especially in countries such as Turkey, importing quite much energy, the reduction of energy consumption in buildings is of great importance in terms of both economic and environmental aspects. In the residential buildings in Turkey, the heat losses are over 25% from the roofs, 25% from the windows and the doors, 20% from the building walls and 15% from the structural system [16]. In this context, energy consumption can be reduced by using concretes having low thermal conductivity in structural systems of buildings. This can be related to the air entrapped in the pores of lightweight aggregates used in the production of lightweight concrete. In a study on the energy performance of SLWC, it is stated that a 15% save in heating energy is possible when SLWC concrete is used in building instead of NWC in European countries. It is also emphasized in the same study that the energy needed for cooling is not significantly affected by the type of concrete [17].

Although there are many studies conducted on the mechanical and durability properties of SLWC in the literature, studies on energy performance and efficiency are quite limited. Accordingly, the aim of this study is to produce SLWC and to evaluate its contribution to building energy performance.

In the experimental study carried out, 8 different SLWCs along with one NWC as reference were produced. Thermal conductivity coefficients, unit weights and compressive strengths of the lightweight concretes and the reference concrete have been determined. Taking into account the thermal conductivity coefficients and the unit weights of the concretes, it is calculated approximately how much the total energy consumption in a flat can change depending on the type of mixtures. To accomplish this, a computer program named "DesignBuilder" is run and the energy performances of the SLWCs as opposed to NWC were analysed. Figure 1 shows the flowchart of the methodology used in this study.

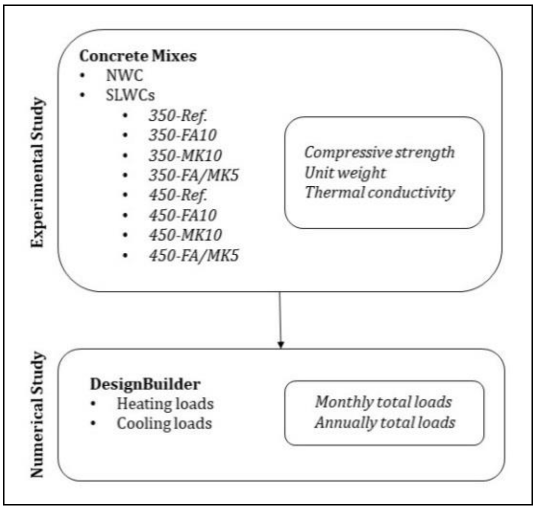

Figure 1. Methodology flowchart.

2 Experimental study

2.1 Materials used

Pumice aggregate, raw perlite aggregate and limestone origin fine aggregate were used in the experimental study. Pumice aggregate was supplied from Van-Erciş region. The water absorption of pumice aggregate was determined as 14% for 30 minutes submersion in water. The dry-loose unit weight of the pumice is 522 kg/m^3. The pumice aggregate satisfies the lightweight aggregate requirement as stated in ASTM C 330. [18]. In the study, perlite aggregate was provided by a private company. Normal weight coarse and fine aggregates were obtained from a quarry located in Maçka region, Trabzon. Chemical analyses of perlite and pumice aggregates were performed in Acme Lab, Bureau Veritas mineral laboratory (Canada). The mixing proportions of pumice, raw perlite and normal fine aggregates were determined as 20%, 30% and 50%, respectively. The granulometry of the mixed aggregate falls within the boundary curves given by TS 802 [19]. The mix proportions for normal weight coarse and fine aggregates were determined as 40% and 60%. The cement used in the study was CEM I 42.5 R type cement with the physical, chemical and mechanical properties are given in Table 1. Fly ash and metakaolin were used as mineral additives. The fly ash used is F type and supplied from Seyitömer thermal power plant. Metakaolin was obtained from a private company. The XRF analyses of metakaolin and fly ash were carried out at the Middle East Technical University Central Laboratory. A polycarboxylic ether based superplasticizer was incorporated in the mixtures to provide equal consistency in all mixes. The chemical compositions of the perlite, pumice, fly ash and metakaolin are given in Table 2.

Table 1. Chemical compositions, along with some physical and mechanical properties of cement.

Chemical Composition		Physical and Mechanical Properties		
Components	(%)	Retained on sieve 45 µm (%)		9.8
SiO_2	19.46	Retained on sieve 90 µm (%)		1.0
Al_2O_3	5.11	Specific surface (Blaine) (m^2/kg)		412.6
Fe_2O_3	3.31	Specific gravity (g/cm^3)		3.12
CaO	60.23	Setting times (Vicat) (min)	Initial	140
MgO	2.08		Final	200
SO_3	3.05	Water demand (%)		29.2
Na_2O	0.27	Soundness (mm)		1.0
K_2O	0.69	Compressive strength (MPa)	2-day	28.0
Cl^-	0.02		7-day	40.4
Loss on Ignition (LOI)	3.00		28-day	51.5

Table 2. Chemical composition of the materials used.

Chemical composition (%)	Perlite	Pumice	Fly ash	Metakaolin
SiO_2	72.05	71.21	49.4	51.4
Al_2O_3	13.09	12.37	19.9	45.2
Fe_2O_3	1.53	1.44	11.3	0.702
MgO	0.39	0.11	-	-
CaO	1.34	0.77	4.35	0.301
Na_2O	3.91	3.62	-	-
K_2O	4.18	4.86	2.50	0.122
Ba	0.02	0.01	-	-
Cr_2O_3	0.01	0.01	-	-
MnO	0.07	0.07	-	-
SO_3	0.015	0.067	1.75	-
P_2O_5	0.01	<0.01	0.120	0.0824
Sr	0.003	<0.002	-	-
TiO_2	0.05	0.09	0.811	1.88
LOI	3.0	4.4	-	-

2.2 Mix proportions and testing

In the experimental study, SLWCs containing different types of mineral additives with different proportions were produced. For comparison, normal weight concrete as reference was also produced. The mixing proportions for the concrete mixtures are given in Table 3. The water to cement ratio was kept constant at 0.40 for all SLWCs. To prevent water absorption from mixing water, the pumice aggregate was soaked before mixing. The water to cement ratio was determined as 0.6 for NWC so as to have close strength level with those of SLWCs. Absolute volume method is considered in designing concrete mixtures. The amount of superplasticizer used was determined in a way to ensure approximately the same consistency (with a slump of approximately 10 cm) in all mixtures.

The compressive strength tests were carried out according to EN 12390-3 standard using 15 cm cubes. The specimens produced were kept in the molds for 24 hours in the laboratory environment and covered with wet sacks, and then cured in standard curing condition until the testing age of 28 days.

To determine the thermal conductivity coefficient, 30x30x5cm sized specimens were produced. Both surfaces of the specimens were smoothened before testing since the surface condition is considered an important factor in determining the thermal conductivity coefficient. Before conducting the test, the specimens were kept at 100-105 °C in an oven until they reached a constant weight. Thermal conductivity test was carried out according to ASTM C 518 (heat flow meter principle) [20]. The device used has two plates, hot and cold plates, with thermal pairs and heat flow meter sensors. Other parts of the device are insulated so that the heat flow can be carried out over the plates. As soon as the heat flow meter reaches the heat equilibrium, the thermal conductivity coefficient has then been obtained on the screen of the computer hooked-up the device. Hot and cold plates can be adjusted at desired temperatures. In the experimentation, the hot plate was adjusted to 30 °C and the cold plate to 10 °C. The thermal conductivity measuring device used in the study and the concrete specimens are shown in Figure 2.

2.3 Compressive strength, unit weight and thermal conductivity measurements

The 28-day compressive strengths of the concrete are given in Figure 3. As can be seen from the figure, a SLWC concrete class of LC20/22 was produced using a cement content of 350 kg/m^3 only. The lightweight concrete containing 10% fly ash with a total binder of 350 kg/m^3 has yielded a compressive strength 7% less compared to that produced without fly ash. In the contrary, concretes containing 10% metakaolin with the same amount of binder has yielded a compressive strength 19% higher compared to the concrete without mineral additive.

Table 3. Mixes proportions (kg/m^3).

Mix ID	Cement	Water	FA	MK	Pumice (8-16 mm)	Perlite (0-4 mm)	Coarse/Fine aggregate	Admx.
350-Ref.	350	140	-	-	280	420	-/700	4.66
350-FA10	315	140	35	-	279	418	-/698	4.93
350-MK10	315	140	-	35	280	420	-/701	5.43
350-FA/MK5	315	140	17.5	17.5	279	419	-/699	5.07
450-Ref.	450	180	-	-	251	378	-/631	3.67
450-FA10	415	180	45	-	239	374	-/624	3.43
450-MK10	415	180	-	45	241	376	-/628	3.83
450-FA/MK5	415	180	22.5	22.5	240	376	-/627	3.76
NWC	350	210	-	-	-	-	1030/689	4.90

Admx. stands for chemical admixture.

Figure 2. Thermal conductivity coefficient measuring equipment and concrete specimens.

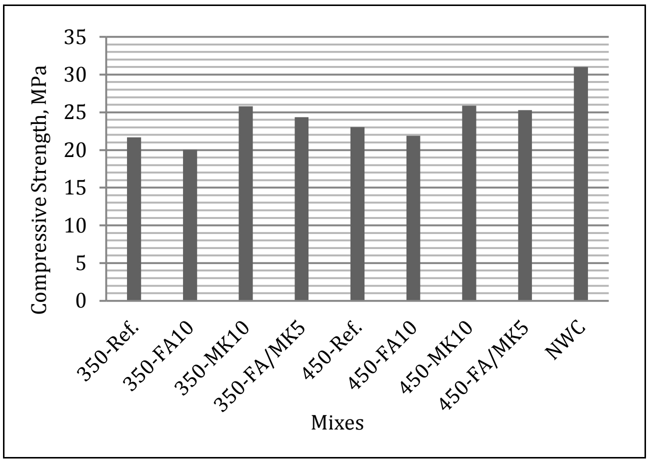

Figure 3. 28-day compressive strengths for concrete mixtures.

In a study on the effect of metakaolin on the strength of SLWC, it is stated that the compressive strength of concretes containing 15% metakaolin is 23% greater than the strength obtained from the concrete without mineral additive [21]. Briefly, it can be said that lightweight concretes containing 10% fly ash are LC16/18 class, concretes containing 10% metakaolin, and 5% fly ash and 5% metakaolin are LC20/22 class based on the classification given by TS EN 206. In a study carried out on lightweight concretes containing mineral additives, it is stated that lightweight concretes containing 10% and 20% fly ash have 28-day compressive strengths lesser than that of the concrete without fly ash [13]. In another study regarding the mechanical properties of SLWC with pumice and mineral additives, it is stated that fly ash causes reduction in the 28-day compressive strength compared to concrete without mineral additive [22].

The concretes produced with a cement content of 450 kg/m^3 are LC20/22 class as indicated in TS EN 206. Concrete containing 10% fly ash with a binder content of 450 kg/m^3 has given a compressive strength 5% lesser than that of the concrete without fly ash. Concretes containing 10% metakaolin with the same binder content has higher compressive strength of 13% compared to concrete without metakaolin. An evaluation indicated that concretes containing 10% metakaolin and 5% fly ash and 5% metakaolin with a binder content of 450 kg/m^3 have yielded SLWCs of LC20/22 class in accordance with TS EN 206.

As can be seen the lightweight concretes produced are all structural lightweight concrete in accordance with TS 2511 and ACI 213 standards. Normal weight concrete is C25/30 class concrete.

The thermal conductivity coefficients and unit weights of the concretes produced are given in Table 4. The thermal conductivity coefficients of the lightweight concretes are in the range of 0.548-0.63 W/mK, while it is approximately 1 W/mK for the normal concrete. As the unit weights of the lightweight concretes decrease, the thermal conductivity coefficients also decrease. The thermal conductivity coefficient of lightweight concrete without mineral additives with a total binder content of 350 kg/m^3 is 0.63 W/mK. However, the thermal conductivity coefficients of lightweight concretes containing 10% fly ash and 10% metakaolin with a binder content of 350 kg/m^3 are 0.57 and 0.615. The reduction in the thermal conductivity coefficient can be attributed to the lower unit weight of concretes produced with fly ash and metakaolin substitution since fly ash and metakaolin have lower specific gravity compared to cement. In a study on compressive strength and thermal conductivity of expanded perlite aggregate containing mineral additives, it is stated that the coefficient of thermal conductivity is reduced with the use of fly ash and silica fume [23]. In another study, it is stated that there is a decrease in unit weight and thermal conductivity coefficients of concrete with the use of mineral additives [24].

Table 4. Thermal conductivity coefficient and unit weights of concretes.

Mixes	Thermal conductivity coefficient (W/mK)	Unit weight (kg/m^3)
350-Ref.	0.63	1893
350-FA10	0.57	1885
350-MK10	0.615	1891
350-FA/MK5	0.59	1888
450-Ref.	0.588	1890
450-FA10	0.548	1880
450-MK10	0.573	1886
450-FA/MK5	0.55	1884
NWC	1.00	2250

Thermal conductivity coefficients of lightweight concrete containing 5% fly ash and 5% metakaolin with two different binder contents (350 and 450 kg/m^3) are determined as 0.59 and 0.55 W/mK. The lowest coefficient of thermal conductivity among all mixtures produced was obtained for concrete containing 10% fly ash with a binder content of 450 kg/m^3 is 0.548 W/mK.

It is emphasized that there is a significant relationship between the thermal conductivity coefficient and the unit weight of concretes [25]-[26]. The relationship between the thermal conductivity coefficient and the unit weight of SLWCs in this study is given in Figure 4. As can be seen from Figure 4, a strong relationship with a high correlation coefficient between the thermal conductivity coefficient and the unit weight of concrete is obtained as $\lambda = 0.0065\Delta - 11.688$ ($R^2 = 0.8964$). Here, λ stands for the thermal conductivity coefficient and Δ for the unit weight of concrete. Considering the concretes produced, it is clearly seen that SLWCs yield higher insulation compared to NWC due to their low thermal conductivity coefficients.

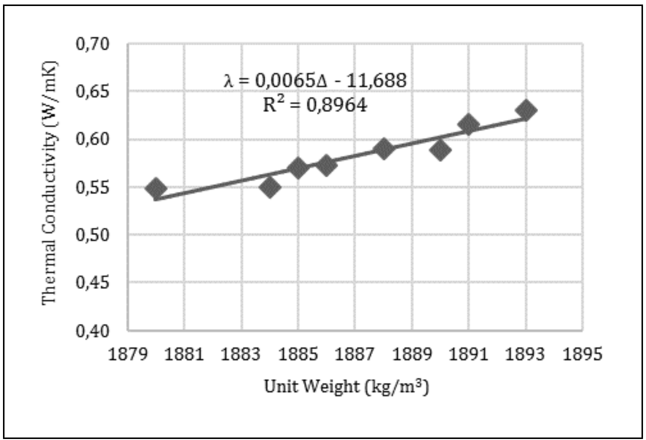

Figure 4. Relationship between unit weight and thermal conductivity.

3 Numerical study

3.1 Description of the case study

The effects of structural lightweight concrete with different mix proportions on the energy performance of buildings were investigated in numerically. In this regard, a flat of which all parameters, except the unit weight and thermal conductivity of concrete were kept constant, were used for the energy performance analysis. The SLWCs with different unit weights and thermal conductivities are compared with NWC. The heating and cooling loads for the concrete types produced were calculated monthly and annually by using the DesignBuilder. Finally, the energy efficiency of the concrete types was investigated.

For the numerical study, a flat with different concrete unit weight and thermal conductivity, with an approximate total useful area of 21.16 m^2 was chosen (Figure 5). The height of the flat is 3 m. The flat is located in Ankara, in Climate Region III, which is accepted a cold climate of Turkey [27].

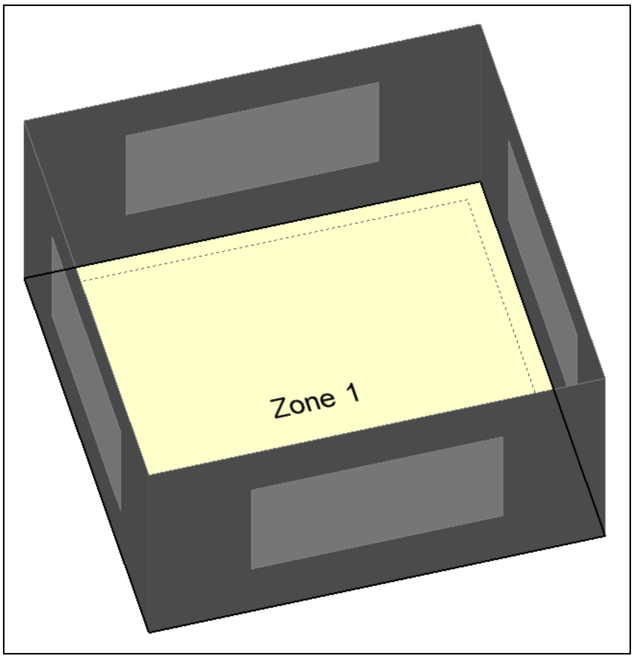

Figure 5. View of the flat model.

The investigated flat has only exterior walls. The thickness of the walls is 200 mm thick concrete produced from each concrete mix. The floors and the roof constructed with the same materials as used for exterior walls. The roof of the flat is not a pitched roof since the flat studied is an intermediate floor. The heat transmittance coefficients (U-value) of the exterior walls, floors and roofs are given in Table 5. A low U value corresponds to high heat protection performance.

Table 5. The U values (W/m^{2}K) exterior walls, floors and roofs made from different concrete mixes.

Mixes	Exterior walls	Floors	Roofs
350-Ref.	2.051	1.896	2.186
350-FA10	1.920	1.783	2.037
350-MK10	2.019	1.868	2.150
350-FA/MK5	1.965	1.822	2.088
450-Ref.	1.960	1.818	2.083
450-FA10	1.869	1.739	1.980
450-MK10	1.927	1.789	2.045
450-FA/MK5	1.851	1.723	1.959
NWC	2.703	2.439	2.941

The window types and the window/wall ratios are all the same for each type of flat made from different concrete mixtures. The windows (3 + 13 + 3 mm) are the same on all facades and the window/wall ratio is 30% on all exterior walls.

3.2 Meteorological data

The flat is located in Ankara (40.12°N, 33.00°E, altitude 949 m), in Climate Region III, representing the cold climate of Turkey. The meteorological data for Ankara provided are given in Table 6 [27].

3.3 DesignBuilder energy simulation software

DesignBuilder v.6.1.3, dynamic building energy simulation software, is used for calculating the monthly and yearly heating and cooling loads in the flats. This software uses the EnergyPlus, which is open-source dynamic building energy simulation software broadly accepted within in the literature, for calculating the thermal performance with multiple zones, different climates and occupancy schedules. With this software, users decide on parameters such as occupancy schedules, operation periods of heating and cooling, air conditioning system and lighting that affect the thermal performance of the building [28].

3.4 Energy performance

The heating and cooling load is caused by heat transitions from the walls, roofs, floors, ceilings and windows forming the building envelope [29]. In order to analyse the effect of concrete types on the total energy consumption of buildings, monthly and annually heating and cooling loads of buildings for each concrete type were calculated using DesignBuilder. The primary energy consumption of the building was found by summing the obtained heating and cooling loads. The primary energy consumption (total loads) for all concrete types is given as annually in Figure 6.

When compared with the NWC, the SLWCs studied have lower total loads ranging from 15% to 19%, on average. In particular, 450-FA10 and 450-FA/MK5 concretes provide more energy saving compared to other types of concretes. This means that the primary energy consumption is also lower in the flats produced with SLWCs compared to NWC.

Table 6. Meteorological date for Ankara [27].

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Outside temperature (°C)	-1.1	0.9	5.8	10.5	15.5	19.9	23.6	23.6	18.0	12.5	5.8	0.8
Dewpoint temperature (°C)	-4.4	-3.9	-1.3	2.2	5.7	8.6	9.0	9.0	6.7	4.1	1.0	-2.4
Wind speed (m^2/s)	1.9	2.3	2.7	2.6	2.4	2.8	3.1	3.0	2.3	2.1	1.7	1.8
Atmospheric pressure (hPa)	909	909	911	913	914	916	917	917	915	913	911	909
Relative humidity (%)	78	70	60	56	52	48	39	39	48	56	71	79
Global radiation horizontal (W/m^2)	69	98	131	194	220	267	271	237	176	120	91	74
Direct radiation horizontal (W/m^2)	32	47	50	105	105	156	162	145	90	55	48	43
Diffuse radiation horizontal (W/m^2)	38	51	81	89	115	111	108	92	86	64	43	31

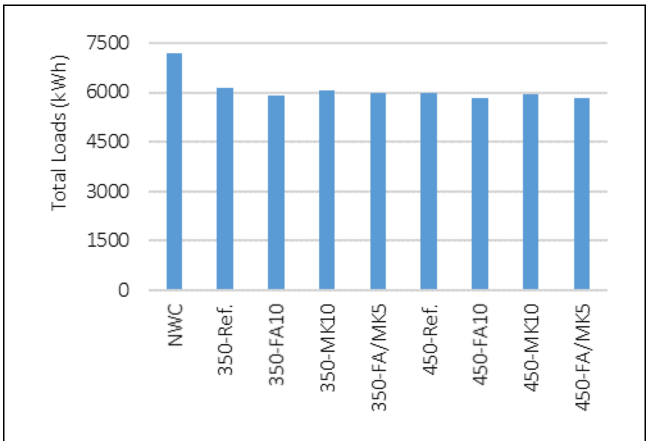

Figure 6. Annually primary energy consumption.

Figure 7 shows the monthly primary energy consumption for the concrete types. The effect of the SLWCs in the heating period (from the beginning of October to the end of March) is more effective than the effect of the SLWCs in the cooling period (from the beginning of April to the end of September). Hence, it can be seen that the lower thermal conductivity of the SLWCs compared to NWC ensures that the total loads in the heating period are low. Although NWC performed better than structural lightweight concretes in some months during the cooling period, cooling energy needs were not significantly affected by concrete types according to heating energy needs.

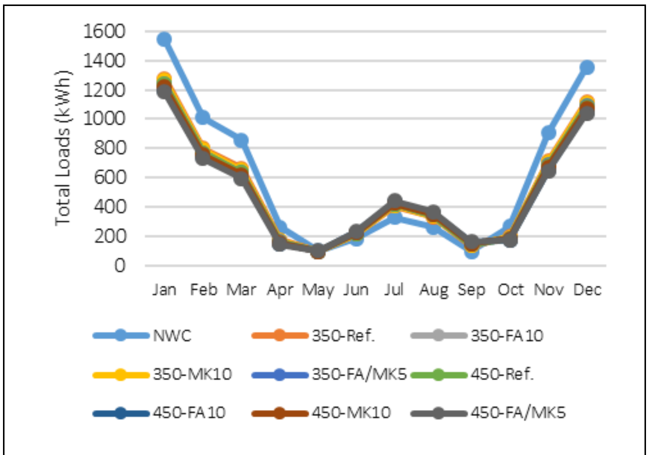

Figure 7. Monthly primary energy consumption.

4 Conclusions

In this study, mechanical and thermal properties of SLWCs produced using pumice aggregates were investigated and compared with NWC regarding energy performance. In this experimental study, SLWCs containing different type of mineral additives with different proportions were produced and for comparison NWC is produced as well. The unit weights of lightweight concretes are ranging from 1880 to 1900 kg/m³ and their compressive strengths are between 20-27 MPa. All the lightweight concretes that are produced have met the criteria for SLWC according to TS2511 and ACI213 standards. The thermal conductivity coefficients of SLWCs produced are ranged between 0.54-0.63 W/mK and it is observed that a strong correlation between the thermal conductivity coefficients and the unit weights of SLWC is existed. The thermal conductivity coefficient of SLWCs decreased in the range from 37% to 41% compared to NWC. Considering this, it can be said that SLWCs can provide higher insulation with respect to NWC.

The energy performance of SLWCs and NWC were investigated numerically using the DesignBuilder v.6.1.3 program. A flat in the cold climate zone was studied. Based on the results obtained numerically, the annual energy required for SLWCs decreased by 15% to 19% compared to NWC. Considering the monthly heating and cooling loads, the SLWCs significantly reduce the heating energy requirement but they did not affect the cooling energy requirement significantly. Overall, the SLWCs reduce the energy required for the buildings and greatly reduce the cost.

5 Author contribution statements

In the scope of this study, the Safa NAYIR and Ümit BAHADIR in the formation of the idea, the design, the literature review, in the assessment of obtained results and supplying the materials used; the Şakir ERDOĞDU and Vedat TOĞAN examining the results, the spelling and checking the article in terms of content were contributed.

6 Ethics committee approval and conflict of interest statement

There is no need to obtain permission from the ethics committee for the article prepared. There is no conflict of interest with any person/institution in the article prepared.

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