Building materials are an essential element in building construction. Improving the properties of building materials is becoming increasingly important. Many different disciplines must be involved in this process to improve building materials. This book, prepared in this context and titled " ACADEMIC STUDIES IN THE FIELD OF BUILDING MATERIALS ", includes different studies and ideas in this field. This book, which is very useful for the scientific world, has emerged as a result of the meticulous preparation of different materials and subjects.

Assoc. Prof. Dr. Arzu ÇAĞLAR was born in Erzincan in 1985. She completed his undergraduate education in 2009 and her master's degree in 2012. She completed his doctoral education in 2018. She currently continues to work at Kırşehir Ahi Evran University, Faculty of Engineering and Architecture. ÇAĞLAR has written many articles and books.

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ACADEMIC STUDIES IN THE FIELD OF BUILDING MATERIALS

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1. Chapter

ACADEMIC STUDIES IN THE FIELD OF BUILDING MATERIALS

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2. Chapter

ANALYSIS OF THE URBAN TRANSFORMATION PROJECT IMPLEMENTED IN KIRŞEHİR/KAMAN WITH GEOGRAPHICAL INFORMATION SYSTEM (GIS)

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3. Chapter

INVESTIGATION OF ENGINEERING PROPERTIES OF PUMICE-BASED RICE HUSK ASH SUBSTITUTED LIGHTWEIGHT CONCRETE

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USE OF NATURAL STONE IN TRADITIONAL HOUSES (KAYSERİ/TALAS/HAN NEIGHBORHOOD EXAMPLES)

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5. Chapter

EFFECT OF RICE HUSK ON SUSTAINABLE BRICK (IN THE CONTEXT OF POROSITY AND HEAT CONDUCTION COEFFICIENT)

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Investigation Of Engineering Properties Of Pumice-Based Rice Husk Ash Substituted Lightweight Concrete

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Abstract

Concrete is an indispensable material in the construction industry. This material has different properties and different names depending on its intended use. One of these is lightweight concrete (LC). In this study, it was aimed to investigate of effects occurring in case of substitution rice husk into pumice-based LC. Rice husk ash (RHA) was used instead of cement in at a rate of 10%, 20% and 30%. LC was produced by using 90% pumice and 10% sand instead of agega. Physical (dry unit volume weight, porosity, compactness, water absorption (by weight), effect of freezing and thawing on compressive strength) and mechanical (compressive strength, splitting tensile strength) tests were applied to the produced LC samples. At the end of the study, a decrease was observed in dry unit weight, porosity, compactness and water absorption values with increasing RHA substitute. In addition, the RHA substitute caused an increase in compressive strength and splitting tensile strength values. It was concluded that RHA substitute can be used in the production of sustainable and environmentally friendly LC.

Keywords: Concrete, lightweight concrete, rice husk ash, pumice

Pomza Tabanlı Pirinç Kabuğu Külü İkameli Hafif Betonun Mühendislik Özelliklerinin İncelenmesi

Özet

İnşaat sektörünün vazgeçilmez malzemesi betondur. Bu malzeme kullanım amacına göre farklı özelliklerde ve farklı isimlerde bulunmaktadır. Bunlardan biri de hafif betondur. Bu çalışmada, pomza tabanlı hafif betona pirinç kabuğu ikamesi durumunda meydana gelen etkiler araştırılması amaçlanmıştır. Pirinç kabuğu hafif betonda çimento yerine %10, %20 ve %30 oranında kullanılmıştır. %90 oranında pomza ve %10 oranında kum agega yerine kullanılarak hafif beton üretilmiştir. Üretilen hafif beton numunelerine fiziksel (kuru birim hacim ağırlık, porozite, kompasite, su emme (ağırlıkça), donma çözülmenin basınç dayanımına etkisi) ve mekanik deneyler (basınç dayanımı, yarmada çekme dayanımı) uygulanmışır. Çalışma sonunda, pirinç kabuğu külü ikamesinin artmasıyla kuru birim hacim ağırlık, porozite, kompasite ve su emme değerlerinde azalma görülmüştür. Buna ek olarak, pirinç kabuğu külü ikamesinin basınç dayanımı ve yarmada çekme dayanım değelerinin artmasına neden olmuşur. Pirinç kabuğu külü ikamesinin sürdürülebilir ve çevre dostu hafif beton üretiminde kullanılabileceği sonucuna varılmıştır.

Anahtar Kelimeler: Beton, hafif beton, pirinç kabuğu külü, pomza

1. Introduction

In the list of the most used building materials in the field of construction, water comes first and concrete comes second. The fact that it is consumed in large amounts, the development of technology and the differentiation of user demands make concrete a constantly developing and changing material. For these reasons, some properties of concretes have been improved and they are called special concretes [57]. Self-compacting concrete, jetcrete, powder concrete, LC are some of them.

LC, one of this concretes, is considered as a resourceful material that has generated great interest and huge industrial demand in a wide variety of construction projects in recent years [1]. LC has become a versatile material for buildings thanks to its technical, economic and environmental advantages. Recently, it has started to be used more in buildings [2].

Different studies are carried out to improve the properties of LC. The first of these works is the substitution of waste material into LC. Due to the increase in population and the development of industry, production of different industrial and agricultural wastes has increased in the last few decades [3]. Some researchers include these wastes in the production of LC. In studies, fly ash [4-7], silica fume [8-10] , blast furnace slag [11-12], RHA [13-15], perlite [16-19], pumice [20-22] and volcanic tuff [23-24] was used.

Anwar et al., (2000) stated that rice husk ash improves different properties of concrete [54]. Adnan et al., (2021) determined that when rice husk ash is used in certain proportions instead of cement, the compressive and flexural strengths are equivalent to normal concrete [55]. Karthika et al., (2018) stated that the density, compressive strength and tensile strength of self-compacting lightweight concrete are improved when 30-40% pumice is used [56]. The LC produced within the extent of the study was produced by substituting pumice and rice husk.

Grain is cultivated in approximately 700 million hectares of the world's existing cultivated areas [25], and 22% of this area consists of rice. In addition, in terms of production shares, rice comes after wheat with a share of 28%. When countries are compared in terms of rice husk production, China ranks first, followed by India, Indonesia and Bangladesh. Türkiye is among the countries with the highest increase in paddy production in the last 10 years. The reasons for this increase are the increase in cultivation areas and the increase in the yield obtained per unit area. The outer hard protective cover of rice grains is called rice husk [26-27]. Rice husk is becoming an important waste problem due to the high production in the world and in Turkey and 22% of the rice produced is husk and the rest is rice and bran. RHA, obtained by burning the husk, is a by-product with extraordinary pozzolanic qualities when ground into powder [28-29].

Many studies have been carried out by scientists on the use of RHA. As a result of these studies, it has been defined that RHA can be used in various fields from construction to solar panel production [30].

In this study, it was puposed to examine of effects occurring in case of substitution rice husk into pumice-based LC. Rice husk was used instead of cement in LC at a rate of 10%, 20% and 30%. LC was produced by using 90% pumice and 10% sand instead of aggregate.

2. Materials and Methods

2.1. Material

2.1.1. Pumice

Pumice (Figure 1), which was determined as the material within the extent of the study, was get from the quarries of Miner Madencilik A.Ş. located in Nevşehir/Çardak region and it was used as aggregate in the production of LC. The physical and chemical properties of the supplied acidic pumice are shown in Table 1.

Figure 1. Acidic pumice from Nevşehir region

Table 1. Physical and mechanical properties of pumice

Physical Property	
Color	Light grey
Crystal Shape	Amorphous
Hardness (Mohs)	5.8
Dry Unit Volume Weight (g/cm^3)	0.47
Porosity (%)	2.38
Warming Temperature (Cal/gr.^{o}C)	0.27
Water Absorption (% by Weight)	37
Chemical Property	
SiO_2	75.35
Al_2O_3	12.43
Fe_2O_3	1.30
CaO	1.15
MgO	0.46
K_2O	3.95
Na_2O	3.72
SO_3	-
Loss of ignition	1.64

2.1.2. Rice Husk Ash

The RHA used in the study was purchased from Silo Gıda San. in Edirne/İpsala. Instead of cement, RHA with a specific surface area of 14750 cm^2 /g was used. Physical and mechanical properties of RHA are shown in Table 2 and the image is given in Figure 2.

Figure 2. Rice husk ash

Table 2. Physical and mechanical properties of RHA

Physical Property	
Specific weight	2.15
Specific Surface (cm^2/g)	14740
Chemical Property	
SiO_2	95.24
Al_2O_3	0.82
Fe_2O_3	0.18
MgO	0.33
SO_3	0.16
Na_2O	0.11
CaO	0.68
K_2O	1.33
Loss of Ignition	1.45

2.1.3. Cement

The cement to be used in the experimental research is CEM I 42.5 N type Portland Cement produced according to TS EN 197-1 [31] standard (Figure 3). Cement was supplied from BAŞTAŞ cement factory operating in Ankara. In order to avoid incorrect test results, the amount of cement to be used in the samples to be produced within the extent of the research was calculated and taken at once. In the study, the water/cement ratio was determined as 0.55. The physical and chemical properties of cement are shown in Table 3.

Figure 3. Cement

Table 3. Physical and mechanical properties of cement

Analysis Results	CEM I 42.5 N
2 Day Compressive Strength (MPa)	22.4
7 Day Compressive Strength (MPa)	39.4
28 Day Compressive Strength (MPa)	51.0
SO_3 (%)	2.6
MgO (%)	2.1
Cl (%)	0.007
Loss of ignition (%)	1.7
Insoluble Residue (%)	0.3
Specific Surface (cm^2/g)	3749
Initial set (minute)	161
Final set (Hour)	4:20
Volume Constancy (mm)	0.4
Free Lime (%)	0.5
Equivalent Alkaline (Na_2O+0,658K_2O) (%)	----
Water Need (Vicat Water) (%)	29.06

2.1.4. Sand

The sand to be used as fine aggregate in the study was taken from Kırşehir provincial borders. The river sand was washed to remove organic and plant residues. The grain diameter of the sand is between 0-4 mm (Figure 4).

Figure 4. Sand

2.1.4. Super Plasticizer

In order to increase the workability of the LC samples produced within extent of the research, super plasticizer was used at the rate of 1% of the cement amount. The properties of the super plasticizer are shown in Table 4.

Table 4. Properties of the super plasticizer

Property	**Value**
Appearance	Dark brown liquid
Structure	Naphthalene Formaldehyde Sulfonate Modification
Consumption amount	Between 0.8-1.5% depending on the amount of cement
Intensity	1.17±0.03 kg/lt
pH	7-9
Chloride	None
Application temperature	+5 ^{o}C to +35 ^{o}C

2.1.5. Mixing water

As mixing water, city tap water from Kırşehir province was used, in accordance with the TS EN 1008 [32] standard.

2.2. Method

2.2.1. Production of pumice and RHA substituted samples

In the study, 4 different series (REF, RLC10, RLC20 and RLC30) LC were produced. REF; reference sample, RLC10; sample with 10% RHA substitution, RLC20; sample with 20% RHA substitution, RLC30; It refers to the sample with 30% RHA substitution.

In all samples, 10% sand and 90% pumice were used as aggregate. RHA was substituted at the rate of 10%, 20% and 30% of the cement amount. Super plasticizer was used at 1% of the cement ratio. The water/cement ratio is fixed at 0.55. The mixing ratios of the produced samples are shown in Table 5.

Table 5. Mixing proportions

Sample Name	Pumice(%)	Sand(%)	Cement (%)	RHA (%)	Super Plasticizer (%)	Water/Cement
REF	100	---	100	----	%1	0.55
RLC10	90	10	90	10	%1	0.55
RLC20	90	10	80	20	%1	0.55
RLC30	90	10	70	30	%1	0.55

LC is produced based on TS 2511 [33] standard. Firstly, pumice, which is a lightweight aggregate, was subjected to pre-treatment. After the procedures were completed, the pumice was taken into the mixing container. The determined amount of water was placed into the pumice aggregate and subjected to pre-saturation. After the process, sand was added and mixed with the help of a mixer. The specified amounts of cement and RHA were added to the aggregate mixture and mixed again. Water and super plasticizer were added to the homogeneous dry mixture, mixed and the LC dough was made ready (Figure 5).

Figure 5. LC paste

The mixture was filled and compressed into cube samples of 15 cm x 15 cm x 15 cm dimensions. The samples were left in the mold for a day to set (Figure 6).

Figure 6. Keeping the samples in the mold

At the end of the day, the samples that were extracted from the molds and put in curing pools at a temperature of ±20 °C for 28 days (Figure 7). At the end of 28 days, the samples were removed from the curing pool and then physical and mechanical tests were applied.

Figure 7. Curing of samples

2.2.2. Physical Experiments Applied To Samples

Dry unit volume weight; TS EN 12390-7 [34] standard was used to determine the dry unit volume weight value of the produced LC samples. The test was occured in three steps. In the first step, the samples were kept in a cap filled with water for 24 hours. In the second step, the samples taken out of the water were dried on the surface with the help of a cloth and left to dry in the oven at ±105 °C for 24 hours. In the third and final step, the samples were weighed on a precision scale. The obtained values were written into the formula below and the dry unit volume weight value was calculated (Equation 1). E; Oven dry weight (kg), V; Volume (m^3)

$$\text{Dry Unit Volume Weight } (kg/cm^3) = E/V \qquad \text{(Equation 1)}$$

Porosity and compactness; TS EN 772-4 (2000) [35] standard was used to find the porosity value, defined as the void ratio of the material. The test was occured in four steps. In the first step, the samples were boiled in a cap filled with water for three hours. In the second step, the samples were taken from boiling water and placed in a cap filled with water and their weight in the water was measured (K3). In the third step, the samples that taken out of the water were left to dry in the oven for 24 hours after the surface was made dry (K2). Then, its dry weight (K1) was measured and written into the formula below (Equation 2, Equation 3).

$$\text{Porosity (\%)} = ((K2-K1) / (K2-K3)) \times 100 \quad \text{(Equation 2)}$$

$$\text{Compactness (\%)} = 100 - \text{Porosity} \quad \text{(Equation 3)}$$

Water absorption (by weight); TS EN 772-4 (2000) [35] standard was used for water absorption test. The experimental study was occured in two steps. In the first step, the samples were left in water for 24 hours and then their weight was measured (S_{sh}). In the second step, sample that was made dry to surface was left to dry in an oven at ±105 ºC for 24 hours. The samples taken from the oven were measured (S_0) and the water absorption value was calculated using the formula below (Equation 4).

$$\text{Water Absorption (By Weight) (\%)} = (S_{sh}-S_0)/S_0 \quad \text{(Equation 4)}$$

The effect of freezing and thawing on compressive strength; TSE CEN/TS 12390-9 (2017) [36] standard was used for the freeze-thaw experiment. The test was occured in three steps. In the first step, the samples were left in a cap filled with water for 60 minutes. In the second step, the samples, whose surface was dried, were subjected to freezing at -20 ºC. In the third step, the samples were taken from the refrigerator and left to thaw at room temperature for 60 minutes. This cycle was repeated 20 times. After the cycle was completed, the samples were subjected to compressive strength testing and the obtained values are given as percentage (%).

2.2.3. Mechanical Tests Applied To Samples

Compressive strength; This experimental study was made according to TS EN 772-1 [37] standard. Firstly, the samples were extracted from the curing pool and the surface was dried with the help of a cloth. After, it was kept in the oven at ±105 ºC until it reached a constant weight. Then, the compressive strength test was carried out in a computer-controlled pressure press. The compressive strength value was calculated by dividing the breaking load by the surface area.

Tensile splitting strength; This experiment applied to the samples was carried out according to TS EN 12390-6 [38] standard. The samples were taken out of the curing pool and the surface was dried with the help of a dry cloth. After, it was kept in the oven at ±105 °C until it reached a constant weight. Care was taken to ensure that the press head and the surface on which the load would act overlapped. Then, the load with a loading rate of 0.05 MPa was transferred to the sample surface. The highest load (Pmax) at the time of breaking on the computer screen was noted [39-40]. A 10x15 cylindrical specimen was used for the splitting tensile strength test. At the end of the experiment, splitting tensile strength was calculated using the formula given below (Equation 5).

$$f_t = (2 \cdot P_{max}) / (\pi \cdot D \cdot L) \qquad \text{(Equation 5)}$$

3. Research Results And Evaluation

3.1. Physical Test Results of LC Samples

3.1.1. Dry Unit Volume Weight

Figure 8 shows the graph created by averaging the dry unit volume weights. According to the graph, the highest value with 993 kg/m^3 was get from the RLC10 sample, while the lowest value with 971 kg/m^3 was get from the RLC30 sample. It was observed that the dry unit volume weight of the RLC10 sample with 10% ash substitution increased slightly with the increase in RHA. It was determined that the dry unit volume weight decreased when 20% and 30% were substituted.

It is thought that the decrease in dry unit volume weight is due to the unit weight of RHA being lower than the unit weight of cement.

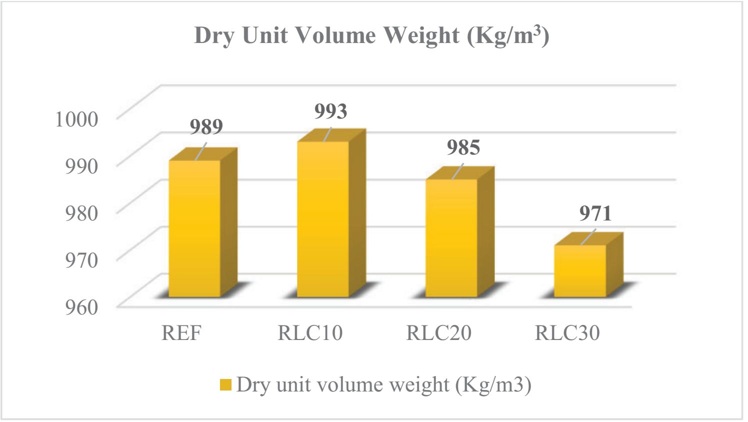

Figure 8. Dry unit volume weight graph

Düzgün (2001) [41] substituted 25%, 50%, 75% and 100% pumice (by volume) for normal aggregate during concrete production. At the end of his study, he observed that the unit weight of the samples decreased by 9-28%. Ceylan (2005) [42] produced LC samples using pumice taken from the Nevşehir region. He stated that dry unit volume weight values vary between 659 and 978 kg/m^3. Kale et al. (2020) [43] produced LC using pumice aggregate. As a result of the study, it was reported that there was a decrease in dry unit volume weight. All these studies in the literature support the study.

3.1.2. Porosity

Figure 9 shows the graph created by averaging the porosity ratios. According to the graph, the highest porosity value with 21.9% was get from the REF sample, while the lowest porosity value with 18.4% was get from the RLC30 sample. In other words, as the amount of RHA increased, the porosity rate decreased. The reason of this decrease is fills the pores of LC samples of RHA, which has a very fine structure.

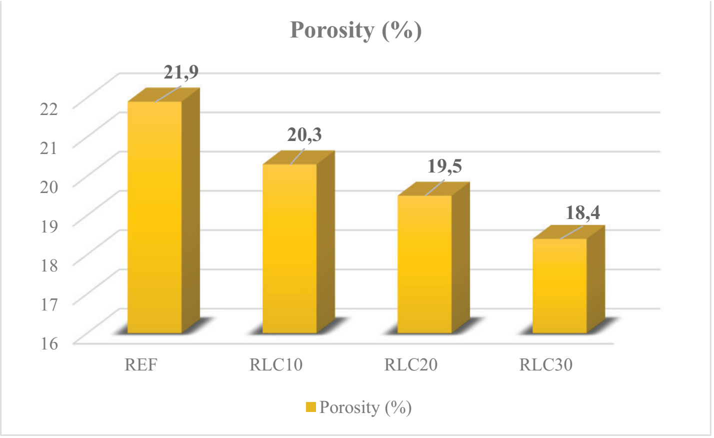

Figure 9. Porosity graph

Kale et al., (2020) [43] and Tezel et al., (2020) [44] reported that there was a decrease in the porosity values of LC samples with pumice aggregate. Chopra (2015) [45], He was stated that substitution of 15% RHA caused the porosity value of LC to decrease.

3.1.3. Compactness

The values of compactness, defined as the ratio of the volume of the filled part of the material to the entire volume [43] are given in Figure 10. According to the graph; While the lowest compactness value was obtained from the REF sample with 78.1%, the highest value was get from the RLC30 sample with 81.6%. In short, it has been observed that the compactness value increases with the increase in the amount of RHA substitution. The reason for this is that RHA fills the gaps in the material and makes it a full material.

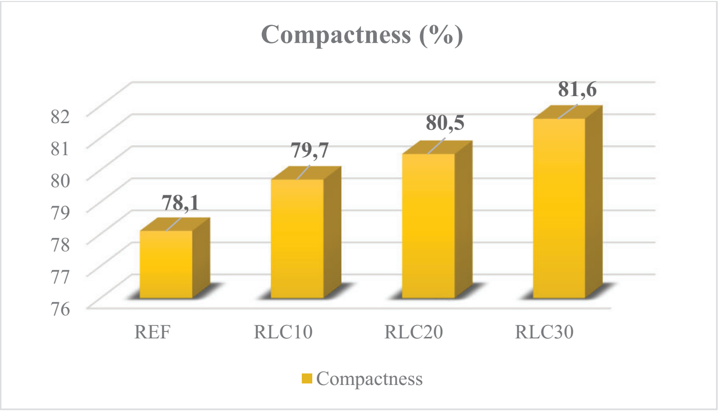

Figure 10. Compactness graph

3.1.4. Water Absorption (By Weight)

The water absorption values of the samples are presented in the graph in Figure 11. According to the graph; While the highest water absorption rate of 8.7% belongs to the REF sample, the lowest water absorption rate belongs to the RLC30 sample with 7.1%. As the amount of RHA increased, the water absorption rate decreased. This decrease is due to the filling of the voids within the sample with RHA.

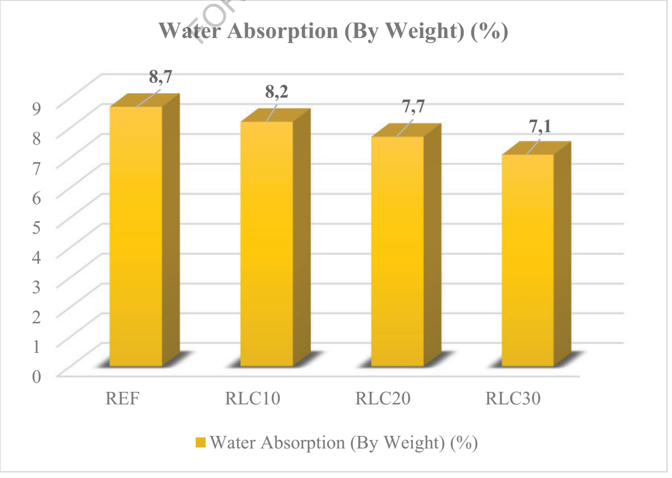

Figure 11. Water absorption (by weight) graph

When the studies in the literature are examined; Öztürk (2012) [46] and Tezel vd., (2020) [44] reported that there was a decrease in the water absorption rate of LC samples produced with pumice in the Nevşehir region. Rahman et al., (2018) [47] reported in their study that substituting RHA in LC reduced the water absorption rate. Coutinho stated that adding RHA to concrete samples reduced water absorption.

3.1.5. Effect of freezing and thawing on compressive strength

Compressive strength values of RHA substituted LC samples after freezing and thawing are presented in Figure 12. According to the graph, the lowest compressive strength after freeze-thaw was get from the REF sample with 16.3 MPa, while the highest compressive strength after freeze-thaw was get from the RLC30 sample with 22.6 MPa.

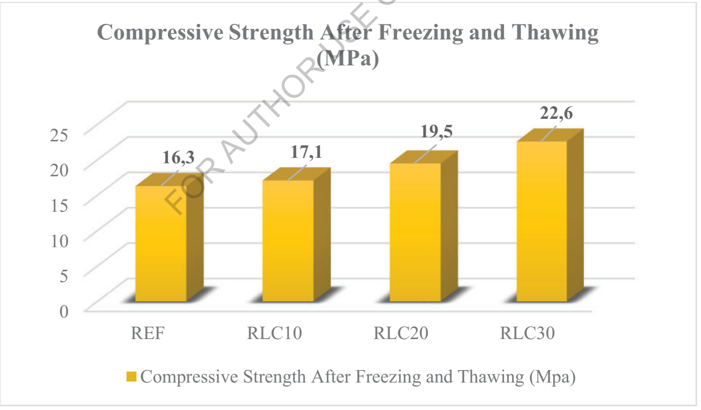

Figure 12. Compressive strength graph after freezing and thawing

The effect of freezing and thawing on compressive strength is given in % in Figure 13. According to the graph, the effect of freezing and thawing on pressure was observed to vary between 2.4% and 9.3%. The highest compressive strength loss was get from the RLC30 sample with 30% rice husk substitution. As the amount of rice husk increased, the effect of freezing and thawing on pressure increased and it was observed that there was a decrease in compressive strength.

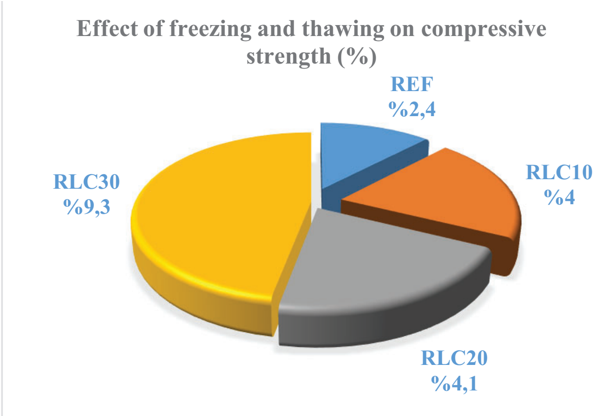

Figure 13. Graph of the effect of freezing and thawing on compressive strength

Kale et al., (2020) [43] was reported in their study that pumice aggregate LC samples reduced the effect of freezing and thawing on compressive strength.

3.2. Mechanical Test Results of LC Samples

3.2.1. Compressive strength

Figure 14 shows the compressive strength graph of the samples. Based on the graph; It was observed that the compressive strength values varied between 16.7 MPa and 24.7 MPa. The highest compressive strength value was get from the RLC30 sample, and the lowest compressive strength was get from the REF sample. In addition, increasing RHA substitution had a positive effect on compressive strength. RHA's high silicon content and pozzolanic properties cause its compressive strength to increase.

According to the compressive strength results, it was observed that LC's manufactured with pumice aggregate and RHA substitution (including all proportions) had a value above the value reported for LC strength in the ACI 213R-87 [48] standard (17.2 MPa). All LC samples produced within the extent of the study are in the carrier LC class. It has been observed that the rates determined in the study and the substitution of RHA will not cause any harm in the production of LC.

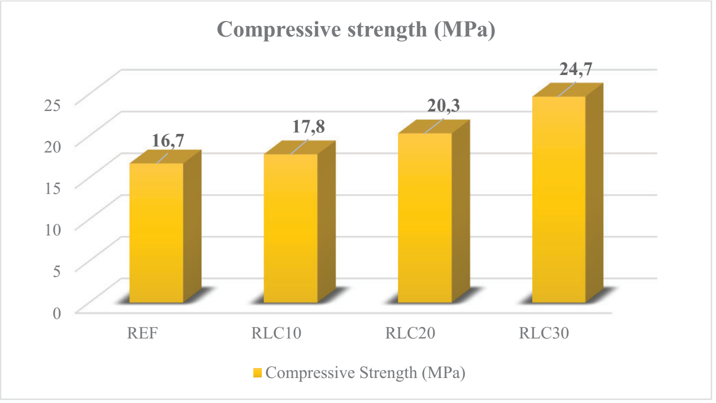

Figure 14. Compressive strength graph

When the studies in the literature are examined; Akçakale (2010) [49] produced concrete using pumice material found in Osmaniye and Nevşehir regions. When he looked at the 7-day compressive strength, he reported that the value varied between 4.9-16.3 MPa. In their study, Kabay and Aköz (2012) [50] used pumice as coarse aggregate and crushed sand as fine aggregate and found that there was an increase in compressive strength. Hossain et al. (2011) [51] stated that the strengths of the LC's they produced using coarse and fine pumice and 10% sand were 10-12-15-16-19-21 MPa higher. Ahsan et al., (2017) [52] reported that the maximum compressive strength get from 10% RHA substituted concrete was 56% of the control sample. Rahman et al., (2018) [47] and Kartini (2011) [53] reported in their studies that substitution of RHA in LC increased the compressive strength.

3.2.2. Splitting Tensile Strength

Figure 15 shows the splitting tensile strength graph of RHA substituted LC samples. According to the graph, it can be seen that the splitting tensile strength values in vary between 1.09 MPa and 1.58 MPa. While the lowest splitting tensile strength was get from the REF sample, the highest value was get from the RLC30 sample. In shortly, it has been observed that as the RHA substitution increases, the splitting tensile strength value decreases.

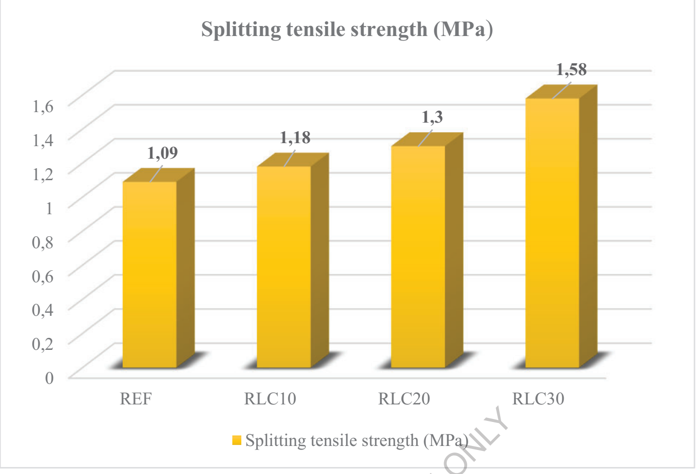

Figure 15. Splitting tensile strength graph

Ahsan et al., (2017) [52] reported that there was an increase in splitting tensile strength by substituting 10% RHA.

4. Conclusion and Recommendations

In the study, LC was produced by using acidic pumice from Nevşehir region and RHA in different amounts (10%, 20% and 30%) as cement substitution material. Physical and mechanical tests were applied to the samples. The results obtained from the experimental data are given in the Table 6.

Table 6. Comparison of the obtained data

Experiments	Samples		
	RLC10	RLC20	RLC30
Dry Unit Volume Weight	+	-	-
Porosity	-	-	-
Compactness	+	+	+
Water Absorption (by Weight)	-	-	-
Effect of Freeze-Thaw on Compressive Strength	+	+	+
Compressive Strength	+	+	+
Splitting Tensile Strength	+	+	+

At the end of the study, the results obtained are listed below.

- In the dry unit volume weight experiment applied to the samples, it was observed that the dry unit volume weight value decreased as the RHA ratio increased. It was determined that the porosity value decreased with increasing RHA substitution. The lowest porosity value was get from the RLC30 sample. When looking at the compactness value, the compactness value increased with the increase in the amount of RHA.
- As a result of the water absorption (by weight) experiment, it was observed that the water absorption rate decreased with the increase of RHA substitution. The lowest value was get from the RLC30 sample with 7.1%.
- When the compressive strength values after freezing and thawing were examined, it was seen that there was a decrease in the compressive strength after freezing and thawing as the RHA substitution increased. It was determined that the highest effect was get from the RLC30 sample with 9.3%. After the freeze-thaw experiment, fine cracks appeared on the surface of the RLC30 sample.
- It has been observed that the compressive strength of LC samples is directly proportional to the RHA substitution rate. The lowest compressive strength belongs to the reference sample, and the highest compressive strength belongs

to the RLC30 sample. All RHA substituted LC samples produced according to the ACI 213R-87 standard are in the load-bearing LC class. It was observed that the splitting tensile strength value of the samples increased with the increase of RHA substitution.

- It has been observed that there is no harm in using RHA in the production of LC. It has been observed that the use of natural raw materials such as pumice in the most preferred building materials such as concrete is beneficial.
- Actively use of agricultural waste in the construction sector should be encouraged. Wastes with high silicon content, such as rice husks, should be brought into the construction industry.
- It is thought that the use of natural raw materials such as pumice and agricultural wastes such as RHA in the construction sector will be very effective in the production of sustainable building materials. Using waste such as RHA in different sectors will be an effective way for waste disposal.

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