



MECHANICAL PROPERTIES OF THE COMPOSITE MATERIAL PRODUCED BY THE MIXTURE OF EXPANDED PERLITE, WASTE MARBLE DUST AND TRAGACANTH

Şermin KOÇYİĞİT^{1*}, Vedat Veli ÇAY²,

¹ Technical Sciences Vocational School, Dicle University, Diyarbakır, Turkey

² Civil Aviation High School, Dicle University, Diyarbakır, Turkey

Corresponding author; sermin.kocyigit@dicle.edu.tr

Received: 10 November 2018; Accepted: 29 December 2018

In this study, the strength characteristics of the expanded perlite aggregate, waste marble dust and tragacanth added cement based composite material were investigated. A composite construction material was prepared using expanded perlite aggregate with a particle size of 0-2 mm and 2-4 mm at the ratio of 10%, 30% and 50% by weight, waste marble powder produced by sieving through 0.25 mm sieve at the ratio of 10% and 20%, tragacanth at the ratio of 0%, 0.5% and 1% and CEMI 42.5 N type Portland cement. Density, compressive strength, abrasion loss, water absorption tests were performed on these prepared composite samples. It was seen that compressive strength and density values have decreased and abrasion loss and water absorption values have increased as expanded perlite particle size, expanded perlite ratio, tragacanth ratio have increased and waste marble powder ratio has decreased on the prepared samples.

Key words: expanded perlite, waste marble dust, tragacanth, mechanical properties

1. Introduction

It is clear that increasing population density, resource consumption and environmental pollution across the world negatively affect the ecology of our planet. The construction sector is responsible for 50% of the material resources in nature, 40% of energy consumption and 50% of total waste. This will further increase due to the increasing number of buildings in parallel with the increase in world population and will cause irrecoverable damage to the ecosystem [1]. Low-density, in other words, lightweight concretes should be used for earthquake resistant buildings. [2]. The density of lightweight concretes produced by adding low density aggregates to it is between 0.8 g/cm³ and 2 g/cm³. The use and investigation of lightweight concretes are increasing with each passing day due their low density,

low thermal conductivity coefficient value and architectural flexibility characteristics. Lightweight concretes with superior properties such as heat and sound insulation have significant advantages over normal concretes due to energy saving and comfort they provide. These studies have mainly focused on the addition of different aggregates into the cement [3]. One of the materials used as an aggregate in the production of lightweight concrete is the expanded perlite. The thermal conductivity coefficient of expanded perlite is given as 0.40-0.45 W/mK. It is important to keep the internal temperatures of indoor spaces at the desired level, to save energy in heating cooling operations against external climatic conditions, to solve environmental problems, to reduce air pollution, and most importantly, to take heat insulation measures in the structures with expanded perlite. [4]. Due to its high heat and sound insulation and economy, the market share of expanded perlite in our country's construction sector has increased by 4 times in the last 10 years [5-7]. For mortar or concrete production, great numbers of worldwide studies have been carried out on natural (such as diatomite, pumice, slag, sawdust, palm oil shells and lower ash) or artificial (such as expanded clay, gravel, slate, perlite and vermiculite) aggregates. [8-14]. Tragacanth has an adhesion property and is used as a binding material when it is mixed with cement and waste marble powder. The utilization of marble wastes, which have technological and economic value, along with expanded perlite is an important raw material in the production of composite constructional components in terms of the compliance of our country with the environment and recycling strategies. An increase is observed in the number of marble processing plants in our country in order to meet the increasing demand for marble. As a natural consequence of this, it is seen that the marble waste sites, which form a negative reaction in the public eye due to environmentalism and since it destroys natural beauty, has become widespread in the regions where the marble processing plants have become intense [15-17]. Powder wastes that arise from marble factories as production wastes cannot be evaluated in general, and their storage or disposal into the natural environment may lead to environmental pollution and the problems such as the pollution of natural resources. Waste marble powders, which can be used in various industrial branches, can be a much cheaper input when they are used instead of their alternatives. Powder wastes reduced to different size fractions are used in many areas apart from their use as a construction material in the literature studies on the utilization of materials thrown to waste sites in marble processing plants [18]. Soykan and Özel [19] investigated the use of marble waste as an aggregate in polymer concrete technology. Gündüz et al. [20] mixed various waste marble powders with doped Portland cement at various dosages and investigated the techno-mechanical properties of the obtained samples at different curing times. Türker et al. [21] examined the effects of waste marble powders on hydration and microstructure of cement. In their experimental study, Şengül et al. [22] replaced expanded perlite with natural aggregate in lightweight concrete mixtures and investigated its effect on heat insulation property. Since the tragacanth used in the experiments was a natural and local resin, its effects in the samples desired to be produced at different ratios and the thermal and mechanical behavior with different proportions of expanded perlite aggregate were examined, and its effect on the strength of the samples was investigated with waste marble powder substitution.

2. Material and method

For the preparation of samples, raw perlite was obtained from perlite deposits in Izmir Bergama region, and it was made usable by crushing in the business and expanding at 800°C in the factory furnaces and sieving at the desired ratios. The samples were divided into two groups in 0-2 and 2-4, mm grain size, as it is seen Figure 1. As a waste marble powder additive, the aqueous wastes obtained during

the production of marble types produced by Diyarbakır Beden Mermer ve Maden İşletmesi San. ve Tic. A.Ş. were used by drying and grinding them. CEM I 42.5 N Portland cement produced in Diyarbakır Ölmezler Concrete Plant was used as the cement. Diyarbakır's city water supply was used as the mixing water in accordance with the standards specified in TS EN 1008. In the study, the leaf tragacanth was powdered with an electric motor grinder for a better and faster melting. In the preliminary studies carried out, it was determined that 100 g tragacanth was fully soluble in approximately 5 liters of water. 100 g powdered tragacanth, which was weighed with precision scales, was placed in a 5 liter water container and 2 liters of water was added to the beaker and mixed thoroughly. The mixing process was maintained at certain intervals for 1 day. After the tragacanth was thoroughly cracked and swelled, 1 liter of water was added to the mixture at intervals of 1-2 hours with beaker and it was continued to mix it. After the completion of 5 liters of water, the tragacanth mix was filtered 2 times and transferred to another container [23]. The samples produced were evaluated as a new building material and their usage areas were determined according to the test results. The expanded perlite aggregates which were divided into three groups of with a particle size of 0-2 mm, 2-4 mm at the ratio of 10%, 30% and 50% by weight, waste marble powders produced by sieving through 0.25 mm sieve at the ratio of 10% and 20%, and 0%, 0.5% and 1% tragacanth and cements were added into the mixtures for the preparation of samples



Figure 1. Expanded Perlite Aggregates Sized as 0-2 and 2-4 mm

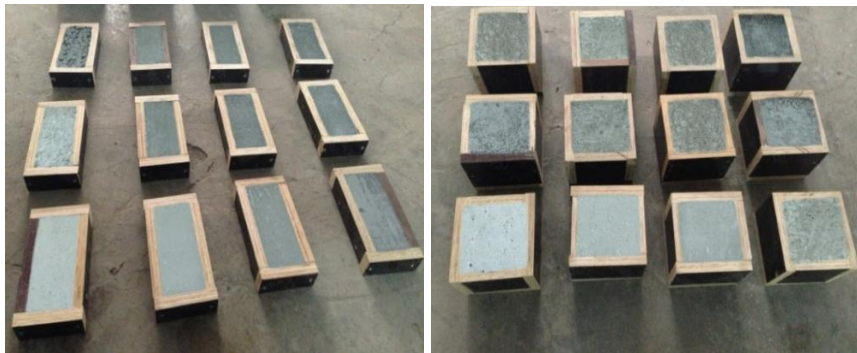


Figure 2. Samples Cast into Plywood Molds

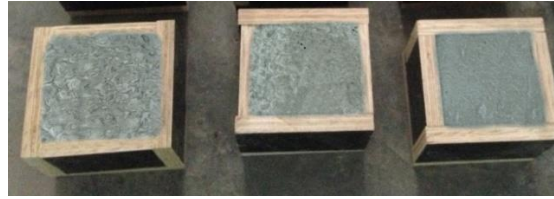


Figure 3. Samples Prepared for Compressive Strength, Abrasion Loss, High Temperature and Freezing-Thawing Compressive Strength Tests

The waste marble powder sieved through 0.25 mm sieve that was used in the experiments is presented in Figure 4. The leaf form of tragacanth used in the experiments and its appearance after it was melt in water and filtered is seen in Figure 5



Figure 4. Waste Marble Powder Sieved Through 0.25 mm Sieve



Figure 5. Leaf Form of Tragacanth (a) Its Appearance After it (b) was Filtered

2.1. Mechanical Tests

The compressive strength and abrasion loss tests were applied to the samples obtained from cube shaped plywood molds with dimensions of 100x100x100 mm. Ele International brand device, used for compressive strength tests applied to samples, is equipped with a capacity of 3000 kN, with a digital control panel, with adjustable loading speed and a single-axis force. In the determination of the abrasion loss by friction in the samples, the measurement of weight reduction was preferred and it was done with the Böhme instrument. Abrasion loss (AL) values were calculated using formula (1).[23-25]

$$\% AL = \frac{Firstmass - Lastmass}{Firstmass} \times 100 \quad (1)$$

While water absorption test was performed, 20x60x150 mm test samples were first placed in drying oven set at $(105\pm 5)^{\circ}\text{C}$ temperature and dried until constant weight was achieved. The powders on the samples, which were provided to be in constant weight in this way, were cleaned with a brush and then weighed at a precision of 0.1 g, and then dry sample weights (W_d) were determined. Thus, the dried samples were placed in a container with water at a depth of $\frac{1}{4}$ of the sample height and at room temperature. Water was added to the container so that samples would be in water by half an hour later and $\frac{3}{4}$ water at the end of the second hour. Water was added 24 hours after the beginning of the experiments so that the samples were completely in water.[26-28]. In this case, the samples, which were removed from the water after 24 hours, were wiped with a piece of wetted cloth, weighed at a precision of 0.1 g, and water-soaked weights were found (W_w). By taking the ratio of these two weights, the percentage of water absorption was calculated by formula (2) in % with the following expression.

$$\text{WA \%} = \frac{W_w - W_d}{W_d} \times 100 \quad (2)$$

The density measurement of 20x60x150 mm samples was made with Isomet 2104 heat transfer analyzer of Applied Precision Company. The device has been developed especially for the determination of the thermophysical properties of constructional components, natural stone and soil. The device works according to the hot wire method.

3. Result and discussion

Density is one of the important parameters that can control the amount of construction materials and many physical properties in the production of lightweight concrete. It was determined that density values decreased from 1.889 to 0.939 depending on the ratio of expanded perlite aggregates in the samples produced, the expanded perlite particle size and tragacanth ratio, and the waste marble powder ratio. The results of density, porosity, compressive strength, abrasion loss, and water absorption rate measurements are presented in Table 1. The pressure values decreased in the samples in which the expanded perlite particle size, the expanded perlite ratio and tragacanth ratio were same but the waste marble powder ratio increased. This is due to the fact that the waste marble powder filled the porosities in the sample and that the amount of cement decreased. The excess of these porosities makes it possible to produce samples with lower density. However, this causes the gases in porosities to be replaced by water or water vapor in humid environments. The increase in expanded perlite particle size, expanded perlite ratio and tragacanth ratio and the decrease in waste marble powder ratio increased the amount of porosity.

Lower porous samples will be produced depending on the decrease in expanded perlite particle size and expanded perlite ratio as the waste marble powder and cement ratio used in the sample increase. The compressive strengths, abrasion loss ratios and water absorption rates of the samples with expanded perlite with 0-2 and 2-4 mm particle sizes, waste marble powder and tragacanth-cement binder are presented in Table 1. When Table 1 is examined, it is seen that the compressive strength of the samples with 0-2 mm particle size varies between 17.36 - 31.67 MPa and that the compressive strength of the samples with 2-4 mm particle size varies between 15.97 - 29.60 MPa.

The sample encodings in Table 1 are as the following.

Number One expanded perlite diameter

X: (0–2) mm.

Y: (2–4) mm.

Z: Cement

Number three waste marble % mixture ratio

1: 10%

2: 20%

Number two expanded perlite % mixture ratio

1: 10% expanded perlite (\cong 80% cement ratio)

3: 30% expanded perlite (\cong 60% cement ratio)

5: 50% expanded perlite (\cong 40% cement ratio)

Number four tragacanth % mixture ratio

0: 0.0%

1: 0.5%

2: 1%

Table 1. Mechanical Test Results Of The Composite Samples Produced

Sample code	Density (g/cm ³)	Porosity (%)	Compressive strength (MPa)	Abrasion loss (%)	Water absorption (%)
Samples with 0 % tragacanth ratio					
X110	1.789	0.305	31.67	0.65	19.57
X310	1.567	0.321	27.82	0.82	19.85
X510	1.517	0.352	25.05	1.01	21.26
X120	1.889	0.251	28.94	0.75	18.63
X320	1.678	0.271	26.01	0.92	19.76
X520	1.583	0.293	24.41	1.11	20.17
Y110	1.611	0.414	29.60	0.74	20.48
Y310	1.489	0.442	25.92	0.94	21.25
Y510	1.439	0.465	24.10	1.15	22.26
Y120	1.661	0.339	27.90	0.81	20.19
Y320	1.567	0.392	25.18	0.96	20.98
Y520	1.517	0.408	23.02	1.24	21.43
Samples with 0.5 % tragacanth ratio					
X111	1.639	0.311	26.75	0.87	24.17
X311	1.539	0.329	22.90	1.04	24.45
X511	1.394	0.368	20.13	1.23	25.86
X121	1.694	0.259	24.02	0.97	23.23
X321	1.556	0.283	21.09	1.14	24.36
X521	1.456	0.299	19.49	1.33	24.77
Y111	1.444	0.421	24.68	0.96	25.08
Y311	1.406	0.450	21.00	1.16	25.85
Y511	1.283	0.477	19.18	1.37	26.86
Y121	1.550	0.348	22.98	1.03	24.79
Y321	1.478	0.404	20.26	1.18	25.58
Y521	1.378	0.415	18.10	1.46	26.03
Samples with 1 % tragacanth ratio					
X112	1.500	0.317	23.62	1.05	29.84
X312	1.400	0.338	20.77	1.22	30.12
X512	1.256	0.379	18.00	1.41	31.53
X122	1.556	0.263	21.89	1.15	28.90
X322	1.417	0.294	18.96	1.32	30.03
X522	1.317	0.303	17.36	1.51	30.44
Y112	1.306	0.429	22.55	1.14	30.75
Y312	1.267	0.461	18.87	1.34	31.52
Y512	1.144	0.488	17.05	1.55	32.53
Y122	1.411	0.353	20.85	1.21	30.46
Y322	1.339	0.417	18.13	1.36	31.25
Y522	1.239	0.423	15.97	1.64	31.70

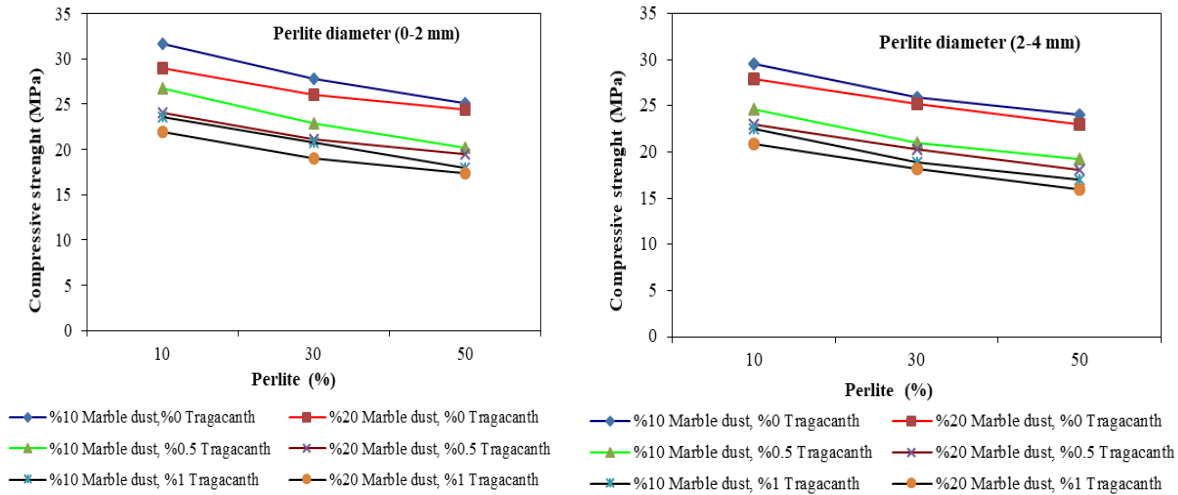


Figure 6. Change in compressive strength depending on the expanded perlite, waste marble powder and tragacanth ratios

When Figure 6 was examined, it was seen that the expanded perlite in the samples could not provide an adequate adhesion with the waste marble powder and decreased the compressive strength by increasing the waste marble powder ratio in the sample for all three types. Furthermore, compressive strength decreased depending on the increase in tragacanth ratio in the sample. This shows that the waste marble powder with low particle size increased the pore ratio in the sample and decreased the strength values and that the compressive strength of the samples decreased along with the increase in expanded perlite particle size.

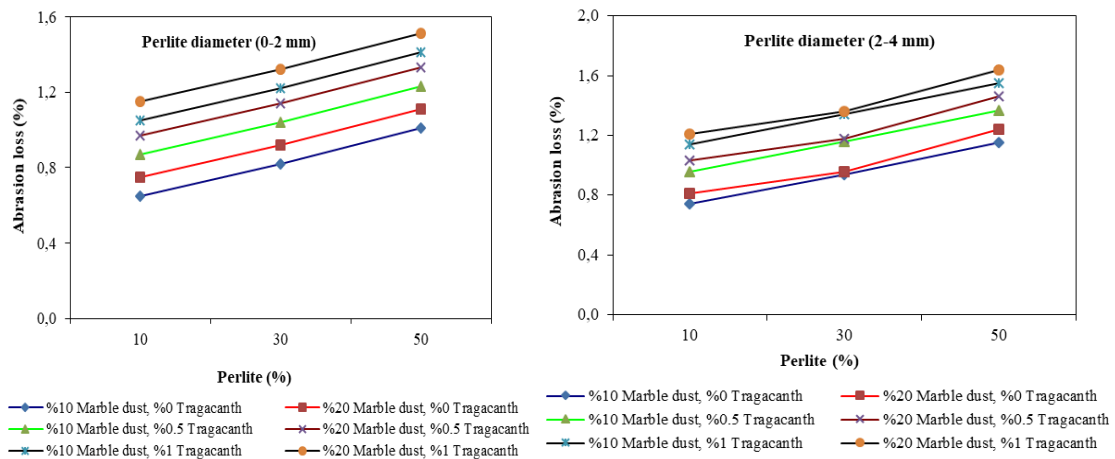


Figure 7. Abrasion Loss Change depending on the expanded perlite, waste marble powder and tragacanth ratios

The results in Table 1 show that the samples with a large expanded perlite particle size and high waste marble powder ratio and tragacanth ratio are not resistant to abrasion. It is seen that the abrasion resistance decreased along with the increase in waste marble powder ratio. The abrasion loss with friction was compared in Figure 7, and the effect of expanded perlite, waste marble powder and tragacanth on abrasion loss with friction was investigated. It was determined that the samples with an expanded perlite particle size of 0-2 and 2-4 mm and the sample with tragacanth ratio of 1%, expanded perlite ratio of 50% and waste marble powder ratio of 20% had no resistance to abrasion. The abrasion

loss ratio of the samples produced with expanded perlite aggregates with a 0-2 mm particle size varied between 0.65 and 1.51. The abrasion loss of the samples produced with expanded perlite aggregates with a 2-4 mm particle size varied between 0.74 and 1.64. The abrasion loss of the samples produced with expanded perlite aggregates with a -8 mm particle size varied between 0.88 and 1.95. The water absorption ratios of some of the produced samples were determined to be above 30% of the critical value. The samples produced have a porous structure, and the porosity ratio varies within the whole structure depending on the expanded perlite particle size, expanded perlite ratio, and waste marble powder ratio. This increases the water absorption capacity and the water absorption values of the samples by allowing water to be retained in these pores when the samples come into contact with water. When the samples' water absorption ratios according to the changes in expanded perlite particle size, expanded perlite ratio, waste marble powder ratio, and tragacanth ratio in Figure 8 are examined, the water absorption ratio increases as the expanded perlite particle size, expanded perlite ratio and tragacanth ratio increase, and the water absorption ratio increases as the waste marble powder ratio increases since the waste marble powder will fill the pores in the sample.

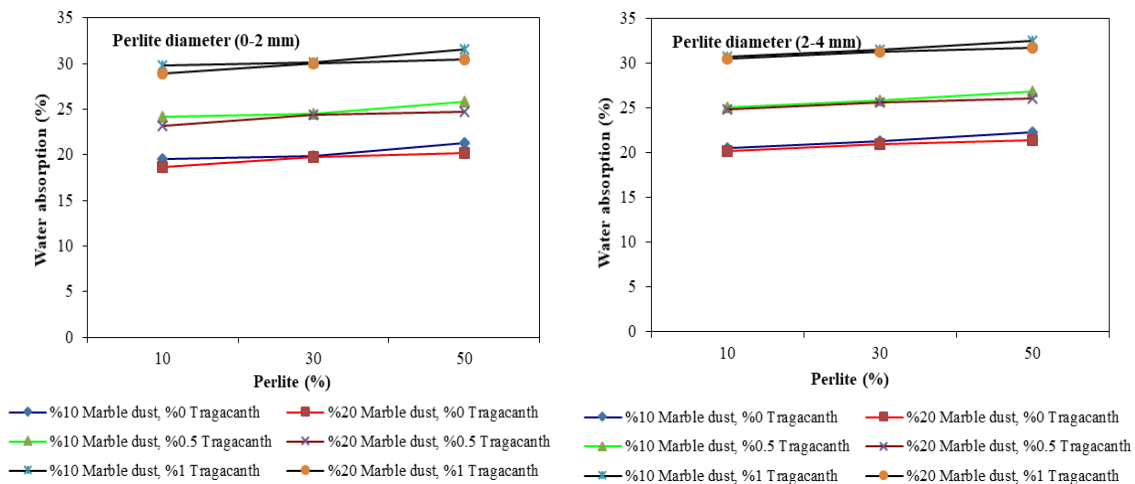


Figure 8. Change in Water Absorption Ratio depending on the expanded perlite, waste marble powder and tragacanth ratios

As it is seen in water absorption graphics, the water absorption ratios of the samples with a particle size of 0-2 mm vary between 18.63% - 22.64% and the water absorption ratios of the samples with a particle size of 2-4 mm vary between 23.23% - 27.24%.

4. Conclusions

In this study, density, water absorption, compressive strength and abrasion loss were performed respectively on the composite samples prepared, and the following conclusions were obtained.

- ✓ The amount of porosity in the sample changed depending on the waste marble powder ratio. The waste marble powder filled the pores caused by the expanded perlite and tragacanth in the samples and increased the abrasion loss since it could not provide adhesion, and it reduced the compressive strengths. The abrasion loss can be significantly improved by the addition of cement. The water absorption ratio increased by the reduction of waste marble powder. Because water easily reached these pores through capillary channels since the pores could not be filled by decreasing the waste marble powder ratio.

- ✓ As the expanded perlite particle size, expanded perlite ratio, tragacanth ratio and waste marble powder ratio in the composite samples prepared decreased, the compressive strength and the abrasion loss and water absorption values increased.

In conclusion, expanded perlite, waste marble powder and tragacanth can be used as alternative raw material sources for the production of porous construction materials. It should be considered that these type of lightweight concretes produced are weaker under load compared to normal concretes. They cannot be used in the places that are directly exposed to water. To coat the surfaces of the samples produced with waterproofing materials may inhibit the capillary absorption of water, and it should not be forgotten that such measures lead to additional costs.

Referances

- [1] <http://ec.europa.eu/enterprise/construction/suscon/tgs/tg1/efcmfin.htm>
- [2] Neville, A.M., 1975. "Properties of concrete", Pitman publishing, London, 606-607
- [3] Ortak Geleceğimiz, 1987. London: Oxford Üniv. Yayınları, WCED Raporu, <http://www.worldsummit2002.org/guide/brundtland.htm>.
- [4] Doğan, H., Şener, F., 2004. Hafif Yapı Malzemeleri (Pomza - Perlit - Ytong - Gazbeton) Kullanımının Yaygınlaştırılmasına Yönelik Sonuç ve Öneriler, Haber Bülteni, 1, 51-53.
- [5] Çiçek, Y. E., 2002. Pişmiş toprak tuğla, bimsbeton, gazbeton ve perlitli yapı malzemelerinin fiziksel, kimyasal ve mekanik özelliklerinin karşılaştırmalı olarak incelenmesi, Yüksek Lisans Tezi, İTÜ Fen Bilimleri Enstitüsü, İstanbul.
- [6] TS 3681, 1982. Genleştirilmiş perlit agregası, Türk Standartları Enstitüsü, Ankara.
- [7] Azizi, S., 2015, Perlit Katkılı Hafif Betonların Mekanik Özellikleri ve Isı Yalıtımı. (Yüksek Lisans Tezi). İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü. İstanbul.
- [8] Bouguerra A, Ledhem A, De Barquin F, et al. Effect of microstructure on the mechanical and thermal properties of lightweight concrete prepared from clay, cement, and wood aggregates. *Cem. Concr. Res.* 1998;28:1179–1190.
- [9] Hossain KMA. Blended cement using volcanic ash and pumice. *Cem. Concr. Res.* 2003;33:1601–1605.
- [10] Hossain KMA, Lachemi M. Development of volcanic ash concrete: strength, durability and micro-structural investigations. *ACI Mater. J.* 2006;103:11–17
- [11] Hossain KMA, Ahmed S, Lachemi M. Lightweight concrete incorporating pumice based blended cement and aggregate: Mechanical and durability characteristics. *Constr. Build. Mater.* 2011;25:1186–1195.
- [12] Gavligi HA, Tragacanth gum: structural composition, natural functionality and enzymatic conversion as source of potential prebiotic activity [PhD thesis]. Technical University of Denmark, Department of Chemical and Biochemical Engineering; 2012.
- [13] Hemmings RT, Cornelius BJ, Yuran P, et al. Comparative study of lightweight aggregates. In: *Proceedings of the World of Coal Ash (WOCA); 2009 May 4–7; Lexington (KY): Ash Library; 2009.*
- [14] Bicer Y, Yılmaz S. Producing new composite materials by using tragacanth and waste ash. *World Acad. Sci. Eng. Technol.* 2013;7:5–24.
- [15] Töre I. Uses of pumice as alternative flux for floor tile products. *Int. J. Sci. Mod. Eng. (IJISME)*2013;1: 16–19. ISSN: 2319-6386.
- [16] Serin, G., 1999. "Pomza'nın hafif beton blok duvar elemanı olarak kullanılmasının araştırılması", Yüksek Lisans Tezi, Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü, Isparta, 100.
- [17] Ağırdu, L.M., 1989. "Altınapa bims agregasından TS 3234'e uygun hafif beton briket imali", Yüksek Lisans Tezi., Selçuk Üniversitesi Fen Bilimleri Enstitüsü, Konya, 69.
- [18] Dincer, İ., (2002), "Thermal energy storage and phase-change materials", Course on Porous Media, Evora, Portugal.



- [19] Soykan, O. ve Özel, C., 2012. Mermer Tozu Tane Boyutunun Polimer Beton Özelliklerine Etkisi, International Construction Congress-ICOCNC2012, October 11-13, Isparta/Turkey.
- [20] Gündüz, L., Sarıışık, A., Davraz, M.U. ve Çankıran, O., 1998. Pomza Teknolojisi, Cilt 3, SDÜ-ISBAS, 14-31, Isparta.
- [21] Türker, P., Erdoğan, B., Katnaş, F. ve Yağınobalı, A., 2003. Türkiye'deki uçucu küllerin sınıflandırılması ve özellikleri, Türkiye Çimento Müstahsilleri Birliği Yayınları, Ankara, 76 s.
- [22] Sengül O., Azizi S., Karaosmanoglu F., Tasdemir M. A., 2011. Effect of expanded perlite on the mechanical properties and thermal conductivity of lightweight concrete, Energy and Buildings. 43: 671–676.
- [23] Demirboğa, R. ve Gül R., 2003. Thermal conductivity and compressive strength of expanded perlite aggregate concrete with mineral admixtures. Energy and Buildings. 35: 1155-1159.
- [24] Öztürk M., 2012. Pomza ve Perlit İçerikli Hafif Betonların Fiziksel ve Mekanik Özelliklerin İncelenmesi. (Yüksek Lisans Tezi). Namık Kemal Üniversitesi, Fen Bilimleri Enstitüsü, Tekirdağ.
- [25] Demirboğa, R. ve Gül, R., 2003. "The effects of expanded perlite aggregate, silica fume and fly ash on the thermal conductivity of lightweight concrete", Cement and Concrete Research, 33, (5): 723-727.
- [26] Kocıyigit F. Kitre Katkılı Bims ve Çimento Karışımlarının Yeni Bir Yapı Malzemesi Olarak Değerlendirilmesi [Evaluation of pumice and cement mixture with tragacanth as a new building materials] [PhD thesis]. Firat University; 2012. Turkish.
- [27] Beden Mermer ve Maden İşletmeleri San. ve Tic. A.Ş.
- [28] Mehta, P.K., 1986. Concrete, structure properties and materials, Printice Hall, USA 152-158.