ACADEMIC PERSPECTIVE ON THE USE OF RAW PERLITE AND AEROGEL IN LIGHTWEIGHT CONCRETE

Yasir PAZAR
Kırşehir Ahi Evran University, Institute of Science, Department of Civil Engineering, 40100 Merkez, Kırşehir
ORCID: 0009-0002-4052-6050
Hakan ÇAĞLAR
Kırşehir Ahi Evran University, Faculty of Engineering and Architecture, Department of Civil Engineering, 40100 Merkez, Kırşehir
ORCID: 0000-0002-1380-8637
Arzu ÇAĞLAR
Kırşehir Ahi Evran University, Faculty of Engineering and Architecture, Department of Architecture, 40100, Merkez, Kırşehir
ORCID: 0000-0003-3928-8059

ABSTRACT

Concrete is one of the indispensable building materials in the construction sector. Being economical, fire-resistant and easy to shape make it attractive. Concrete is classified according to its usage purposes. In this classification, one of the concrete types defined as special concrete is lightweight concrete. Lightweight concrete is a type of concrete that is frequently preferred among special concrete types. It is a very good alternative especially for those who want to use concrete with low unit weight and superior thermal properties. With the developing technology, lightweight concrete properties have begun to be improved. This improvement is sometimes done with waste materials and sometimes with nanotechnological materials. In addition, the use of natural lightweight aggregates in lightweight concrete production is an important step for improvement. This study aims to examine academic studies on the use of perlite and aerogel in lightweight concrete production. For this purpose, numerous national and international academic studies published have been examined. These studies examined are presented in summary form. As a result of the study, it was determined that the compressive strength and unit weights of lightweight concretes produced with perlite and aerogel decreased. It was observed that the porosity rates of the lightweight concrete samples with additives increased. In parallel, it was determined that the water absorption rate increased. In addition, it was understood that the thermal properties were improved and it exhibited better behavior under seismic loads.

Keywords: Perlite, aerogel, concrete, lightweight concrete

HAFİF BETONDA HAM PERLİT VE AEROJEL KULLANIMINA AKADEMİK BAKIŞ

ÖZET

Beton, inşaat sektörünün vazgeçilmez yapı malzemelerinden biridir. Ekonomik olması, yangına karşı dirençli olması ve kolay şekil verilebilmesi onu cazip hale getirmektedir. Beton kullanım amaçlarına göre sınıflandırılmaktadır. Bu sınıflandırmada özel beton olarak tanımlanan beton çeşitlerinden biri de hafif betondur. Hafif beton, özel beton çeşitleri arasında sıklıkla tercih edilen bir beton çeşididir. Özellikle birim ağırlığı düşük termal özelliği üstün beton kullanmak isteyenler için çok iyi bir alternatiftir. Gelişen teknoloji ile birlikte hafif beton özellikleri geliştirilmeye başlanmıştır. Bu iyileştirme bazen atık malzemelerle bazen de nanoteknolojik malzemelerle yapılmaktadır. Bunun yanı sıra, hafif beton üretiminde doğal hafif agrega kullanımı iyileştirmenin önemli bir adımı olmaktadır. Bu çalışmada, hafif beton üretiminde perlit ve aerojel kullanımı üzerine yapılan akademik çalışmaların irdelenmesi amaçlanmıştır. Bu amaç doğrultusunda yayımlanmış olan çok sayıda ulusal ve uluslararası akademik çalışma incelenmiştir. İncelenen bu çalışmalar özet şeklinde sunulmuştur. Çalışma sonucunda, perlit ve aerojel ile üretilmiş hafif betonların basınç dayanımı ve birim ağırlıklarının azaldığı tespit edilmiştir. Katkılı hafif beton numunelerinin porozite oranlarının arttığı görülmüştür. Buna paralel olarak su emme oranın da arttığı tespit edilmiştir. Bunun yanı sıra termal özelliklerin iyileştiği ve sismik yükler altında daha iyi davranışlar sergilediği anlaşılmıştır.

Anahtar Kelimeler: Perlit, aerojel, beton, hafif beton

1.INTRODUCTION

The continuous development of the construction industry forces concrete to change (Jiang et al., 2022). With the help of developing technology, the production of special concretes has accelerated in order to meet the needs and expectations in the construction sector (Yazıcıoğlu and Bozkurt, 2006). Lightweight and high-strength concrete is becoming increasingly important (Jiang et al., 2022). It is possible to give these properties to concrete by adding different building materials to the mixture, other than the traditional components of concrete (Gökçe et al., 2010). Lightweight concretes are classified according to their usage areas and properties (Topçu et al., 2023). While concretes with very low unit weight are called insulating concretes, concretes with a unit weight approaching 2000 kg/m^3 are called carrier lightweight concretes (Topçu and Uygunoğlu, 2021).

Lightweight concretes are produced using different lightweight aggregates. Sifan et al., (2021) reported in their study that natural and artificial aggregates were mostly preferred (Figure 1).

In addition, they stated that palm oil clinker and slag are also used as aggregate in the production of lightweight concrete.

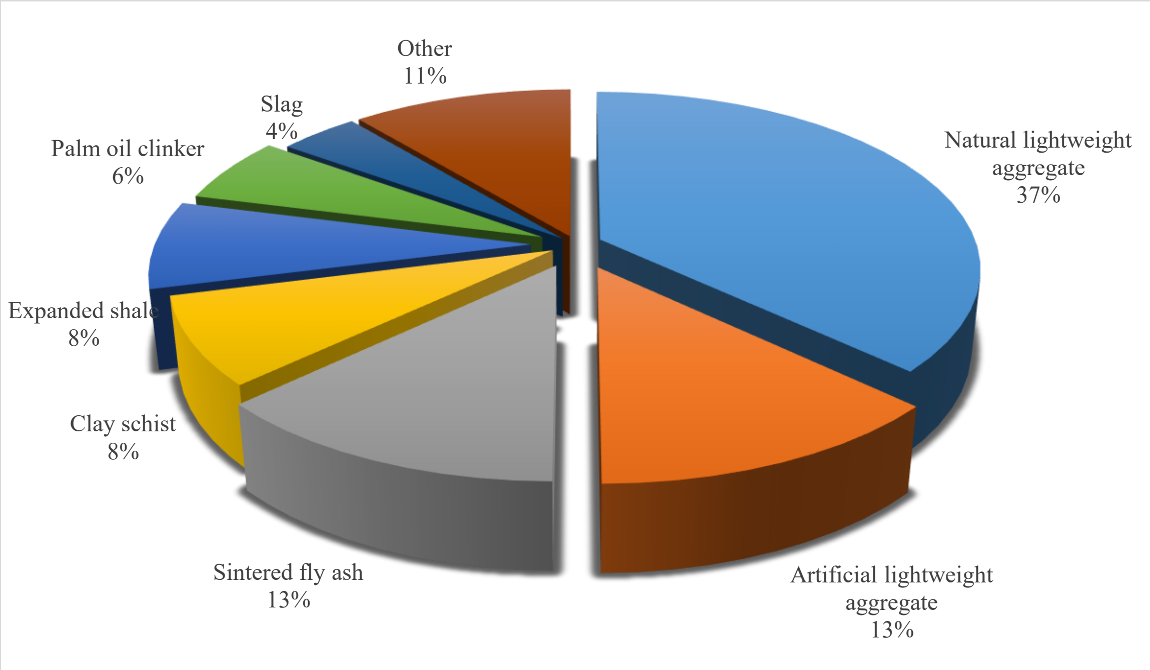

Figure 1. Aggregate ratios used in lightweight concrete production

One of the natural aggregates used in lightweight concrete production is perlite. Perlite is a naturally occurring silica-based volcanic rock. Raw perlite aggregate is obtained by breaking these rocks at certain intervals (Ulusu, 2007). It is thought that the effective use of perlite as concrete aggregate in the construction industry will contribute positively to the country's economy and global warming due to its thermal insulation properties and lightness. Thanks to the properties of perlite, in terms of thermal properties, the produced concretes provide better performance than normal concretes and provide energy efficiency (Gökçe et al., 2010). Perlite is frequently used in the production of lightweight concrete (Jedidi et al., 2015; Sriwattanapong et al., 2013; Benjeddou et al., 2023; Bakhshi et al., 2023; Sai et al., 2025).

Another material used in the production of lightweight concrete in the studies examined within the scope of the study is aerogel. Aerogels are solid materials in which the liquid in the pores has been replaced with air. Aerogel, which is quite light, has a porous structure and contains air instead of liquid in its pores (Bheekhun et al., 2013). When their surfaces are physically examined, it is seen that they consist of many small holes and resemble a sponge. Aerogels are a synthetic porous material with very low density and extremely low thermal conductivity as well as high specific surface area (Doğdu, 2022).

This study aims to examine academic studies on the use of perlite and aerogel in lightweight concrete production. For this purpose, many published academic studies were examined and presented in summary form.

2. RAW PERLITE AND AEROGEL

2.1. Raw Perlite

Approximately 74% of the world's perlite reserves are located in Turkey (Azizi, 2007). It is estimated that the world perlite reserves are approximately 6.6 billion tons, and the amount in Turkey is around 4.5 billion tons (DPT, 2001). Other countries with significant reserves are Greece, the USA, Japan, the Philippines, Russia, Hungary, Mexico and Italy (Çelik et al. 2014). The most common use of perlite is the construction sector, both in the world and in our country. Therefore, adverse situations in the construction sector significantly affect perlite consumption (Kaya, 2019). Significant advantages of perlite, such as its good insulation properties and its use in special-purpose concretes, will provide positive economic contributions to the construction sector (Ciminli, 2025).

The state of perlite in rock form after breaking and sizing is called raw perlite. The color of raw perlite can vary from transparent-light gray to shiny black. One of the most important properties of perlite is that it contains approximately 2.5% water (Baradan et al., 2022; General Directorate of Mineral Research and Exploration, 2022). The worldwide production of raw perlite, whose physical and chemical properties are given in Table 1, has increased steadily over the last decade (Olteanu et al., 2024). Raw perlite in gray tones is seen in Figure 2.

Figure 2. Raw perlite (Bergama Perlite, 2025)

Table 1. Physical and chemical properties of raw perlite (Kaya, 2019; Örüç, 2022)

Physical Feature	
Color	Black, grey and shades of grey
Softening Point	800 – 1100 °C
Melting Point	1325 – 1390 °C
PH	6,6 – 8, 0
Hardness	-
Specific Heat	0,2 kcal/ kg°C
Specific Gravity	2200 – 2400 kg/m3
Thermal Conductivity	-
Dissolution in Acid	They dissolve slightly in hot concentrated alkalis and mineral concentrated acids, but very little in dilute minerals or concentrated weak acids.
Chemical Properties	
SiO_2	73,8
Al_2O_3	13,9
Fe_2O_3	0,9
Ca	0,9
MgO	0,3
Na_2O	4,7
K_2O	4,3
H_2O	<1,0
As	<0,001
Ba	<0,1
B	<0,01
Cl	<0,0005
Cr	<0,007
Cu	<0,0015
Ga	<0,05
Pb	<0,001

2.2. Aerogel

Aerogel was first discovered by Kistler in the 1930s. In the following years, the Teichner group increased the production and popularity of aerogel using the sol-gel method. Its extraordinary properties and wide range of applications make aerogel stand out (Yılmaz, 2013). Aerogels are generally produced by the sol-gel method. The aerogels given in Figure 3 have different mechanical and physical properties depending on the production parameters (aging, initiators, drying, etc.) (Doğdu, 2022). Aerogels are divided into three categories: inorganic (metal and metal oxides), organic (synthetic polymers and biopolymers) and hybrid (organic–inorganic) materials (Meti et al., 2023).

Figure 3. Aerogel (Web Post, 2025)

The aerogels whose properties are given in Table 2 have poor mechanical properties. This makes the aerogel samples brittle, soft and fragile. These shortcomings limit the development and application areas of aerogels. Nowadays, some fibers and hard materials are added to aerogels to improve their mechanical properties (Huang et al., 2012).

Table 2. Properties of silica aerogels (Doğdu, 2022)

Feature	**Value**
Intensity	0.003 g/cm^3
Surface Area	500-1000 m^2/g
Porosity	%80-99.8
Pore Diameter	20-150 mm
Particle Diameter	2-5 nm
Thermal Conductivity	0.017-0.021 W/mK
Coefficient of Thermal Expansion	2.0-4.0*10-6
Speed of Sound	100 m/s
Dielectric Constant	1.1
Refractive Index	1-1.05

3. EVALUATION OF THE USE OF PERLITE AND AEROGEL IN LIGHTWEIGHT CONCRETE

In their work, ***Adhikary et al., (2021)*** investigated the effect of carbon nanotubes on the properties of lightweight aggregate concrete containing expanded glass and silica aerogel. Combinations of expanded glass (55%) and hydrophobic silica aerogel particles (45%) were used as lightweight aggregates. In the study, carbon nanotubes were sonicated in water containing polycarboxylate superplasticizer with ultrasonication energy for 3 minutes. As a result of the study, they reported that the incorporation of multi-walled carbon nanotubes significantly affected the compressive strength and microstructural performance of aerogel-based lightweight concrete. They detected that the addition of carbon nanotubes provided approximately 41% improvement in compressive strength. They reported that in the SEM image of lightweight concrete, carbon nanotubes were distributed homogeneously within the concrete structure. They also observed the agglomeration of carbon nanotubes and the presence of ettringites in the transition zone between the silica aerogel and cementitious materials.

In their study, ***Wang et al., (2018)*** produced concrete by replacing conventional aggregate with expanded perlite filled with Silica Aerogel granules in different proportions. They investigated the strength and thermal properties of the produced concrete. As a result of their studies, they reported that both the mechanical strength and thermal conductivity of the produced concrete were inversely proportional to the amount of expanded perlite filled with aerogel in the mixture. They also detected that the mechanical strength and thermal conductivity of produced concrete with ungraded aggregate were higher than that of concrete produced with graded aggregate.

In their study, ***Adhikary et al., (2020)*** prepared four different series of concrete samples using expanded glass aggregates, fly ash, prefabricated plastic bubbles and aerogel to investigate the mechanical properties of lightweight/ultra-lightweight concrete. To analyze the effect of aerogel particles on the hydration process of lightweight/ultra-lightweight concrete, scanning microscopy, thermography, semi-adiabatic calorimetry tests and XRD analysis of concrete samples were performed. As a result, they stated that up to 15% of the cement aerogel particles caused a decrease of more than 42% in the compressive strength of the concrete. They reported that when used with expanded glass aggregate with higher aerogel particle content, concrete density lower than 800 kg/m3 could be achieved. They noticed that there were separation gaps between the aerogel and the surrounding cementitious materials. They stated that this was an indication that the aerogel particles had lower bonding. They concluded that fly ash and precast plastic bubbles are quite useful in the production of fluid lightweight/ultra lightweight concrete.

In his thesis, **Çimen (2023)** synthesized silica aerogel (SA) with Bayburt Stone (BT) waste. It has investigated the effects of substituting SA in lightweight concrete at certain rates on properties such as heat and sound insulation, strength and porosity. Physical (unit weight, porosity, water absorption, thermal conductivity and ultrasound transmission speed) and mechanical (compressive strength) tests were applied to the samples. As a result of the study, it was determined that thermal insulation would be optimum with (3%, 350% and 0.40%) levels.

It was reported that (3%) SA replacement improved (46%) thermal conductivity value, increased porosity (31.48%) and caused a decrease in compressive strength (9.72 MPa). He found that SA is hydrophobic and has good adsorption properties and that a porous structure is formed around SA in concrete. He reported that the polycrystalline structure in concrete increases with the increase in SA concentration. He detected that this increase causes a decrease in the mechanical strength of the material.

In their study, **Jiang et al., (2022)** obtained Aerogel reinforced Epoxy Macrospheres (AR-EMS) using the ball rolling method. They prepared lightweight concrete by mixing AR-EMS, cement and hollow glass beads in the mold. In the experiment, they investigated the factors such as stacking volume ratio, inner diameter, wall thickness, different glass fiber (GF) content and length in the matrix of AR-EMS and different types of hollow glass microspheres (HGMS). As a result of the study, they detected that AR-EMS bonded well to the concrete matrix and the addition of long fibers improved the compressive strength of lightweight concrete. When lightweight concrete was prepared with 12 mm GF and 9–10 mm-2 layer-90% AR-EMS at 2% weight ratio, they achieved both high strength (11.46 MPa) and low density (0.897 g/cm3).

In addition, when comparing concrete without GF and concrete with EPS filler, they detected that the compressive strengths increased by 69% and 398%, respectively.

Shohan et al., (2024) developed ultra-high performance lightweight concrete by combining various levels (5-25%) of dehydrated cement powder (DCP) and aerogel (AG) with double hooked end steel fibers (DHE-SFs). In the study, they aimed to increase strength, durability, density and thermal/acoustic properties. As a result of the study, they found that fluidity decreased with higher DCP and AG content. 5%, 10% and 15% DCP and AG reported improved compressive strength (17.3%) through better packing and bond formation. They reported that modified mixtures resisted sulfate attack and increased compressive strength. They found that sound absorption and pore volume increased in modified mixtures.

In their study, **Chen and Yu (2024)** investigated the surface modification method of a bio-fiber (miscanthus) using hydrophobic silica aerogel. They evaluated the mechanical and insulation performance in lightweight concrete. As a result of the study, it was found that the silica aerogel modified miscanthus fiber increased both compressive and flexural strength. They also reported that it significantly improved the insulation performance of concrete.

In their study, **Mancı and Sarıışık (2019)** examined the effect of tincal waste in mixtures prepared with different amounts of cement. They produced samples with different cement dosages using pumice aggregate and ground tincal waste additives. They used 0-4 mm Nevşehir region acidic pumice aggregate and 1% tincal waste in the production of lightweight concrete mortars. They determined the 7 and 14-day compressive strength and post-freeze-thaw compressive strength values of concrete samples. As a result of the study;

- ✓ 7-day compressive strength value in the control sample with 176 kg/m^3 dosage is 1.60 MPa,
- ✓ The compressive strength value of the sample with 1% tincal waste added is 1.77 MPa,
- ✓ In the control sample with the same cement dosage, the 14-day compressive strength value is 2.00 MPa,
- ✓ The compressive strength value of the sample with 1% tincal waste additive is 2.03 MPa,
- ✓ They found that 1% tincal waste addition in samples with a dosage of 176 kg/m^3 slightly increased the compressive strength value at both ages.

In their study, **Şengül et al., (2011)** investigated the effects of expanded perlite on the mechanical properties and thermal conductivity of lightweight concrete. In the study, they used partially expanded perlite instead of natural aggregate. They determined the compressive strength, elasticity modulus, water absorption, thermal conductivity and capillarity coefficient of the mixtures. As a result of the experiments, they found that the compressive strength and elasticity modulus decreased with increasing perlite content. They reported that with the increase in perlite content, water absorption and sorptivity coefficient increased. They also stated that thermal conductivity was significantly improved with the use of perlite and that there was a strong relationship between thermal conductivity and unit weight.

In their study, **Topçu and Işıkdağ (2011)** investigated the properties of concrete containing expanded perlite aggregate (EPA) by considering cement types (CEM II 32.5R and CEM I 42.5R), dosages (300, 350 and 400) and substitution rates (0, 15, 30, 45 and 60). As a result of the study, they reported that expanded perlite aggregate concrete can be used as lightweight concrete at sufficient replacement rates despite some losses in mechanical properties.

In their study, **İbrahim et al. (2020)** produced durable structural lightweight concrete (LWC) by adding expanded perlite aggregate (EPA) in the range of 0% to 20% by weight. They produced the concrete with low water-cement ratio to ensure its durability when exposed to chloride environment. They replaced ordinary Portland cement (OPC) with 50% and 7% ground granulated blast furnace slag (GGBFS) and silica fume (SF), respectively. They evaluated the mechanical properties and durability of concrete, unit weight, compressive strength, flexural strength, drying shrinkage, and chloride permeability. The study results;

- ✓ The unit weight of concrete is reduced by 20% to 30% compared to normal weight concrete (NWC),
- ✓ The compressive strength of the developed LWC is sufficient to be used as structural concrete, especially in mixtures containing 10% and 15% perlite aggregate,
- ✓ LWC has superior thermal insulation properties compared to NWC,
- ✓ Increased incorporation of EPA into concrete has shown better behavior under seismic loading.

4. CONCLUSION AND RECOMMENDATIONS

In this study, the use of perlite and aerogel in widely used lightweight concrete was examined from an academic perspective. The results obtained are listed below.

- ✓ The use of perlite and aerogel reduces the compressive strength of lightweight concrete,
- ✓ There is a decrease in unit volume weight value by substituting perlite and aerogel into lightweight concrete,
- ✓ By substituting perlite and aerogel into lightweight concrete, porosity and water absorption values increase,
- ✓ By substituting perlite into lightweight concrete, it exhibits better behavior under seismic loading,
- ✓ Thermal properties of lightweight concrete samples with additives were improved,
- ✓ As the amount of aerogel in lightweight concrete increases, the compressive strength increases,
- ✓ The use of perlite in lightweight concrete production is an important step in terms of the use of our natural raw materials,
- ✓ It was concluded that perlite and aerogel can be used in the production of lightweight concrete.
- ✓ The use of perlite and aerogel not only in the production of lightweight concrete but also in the production of other building materials,
- ✓ It is recommended that these productions be supported by both universities and public institutions and organizations.

5. REFERENCES

Adhikary, S. K., Rudžionis, Ž., Tučkutė, S., & Ashish, D. K. (2021). Effects of carbon nanotubes on expanded glass and silica aerogel based lightweight concrete. Scientific reports, 11(1), 2104.

Çimen, S. (2023). Investigation of engineering properties of lightweight concrete with silica aerogel additives produced using volcanic tuff waste, PhD Thesis, Bayburt University, Institute of Science, Bayburt.

Liu, P., Jing, Q., Liu, Y., Wanga, W., Zhanga, Y., Li, Z. (2018). Strength properties and thermal conductivity of concrete with the addition of expanded perlite filled with aerogel, Construction and Building Materials, 188(2018) 447-457.

Adhikary, S. K., Rudžionis, Ž., & Vaičiukynienė, D. (2020). Development of flowable ultra-lightweight concrete using expanded glass aggregate, silica aerogel, and prefabricated plastic bubbles. Journal of Building Engineering, 31, 101399.

Jiang, T., Wang, Y., Shi, S., Yuan, N., Ma, R., Wu, X., ... & Yu, J. (2022). Compressive behavior of lightweight concrete using aerogel-reinforced expanded polystyrene foams. *Case Studies in Construction Materials*, *17*, e01557.

Shohan, A. A. A., Zaid, O., Arbili, M. M., Alsulamy, S. H., & Ibrahim, W. M. (2024). Development of novel ultra-high-performance lightweight concrete modified with dehydrated cement powder and aerogel. *Journal of Sustainable Cement-Based Materials*, *13*(3), 351-374.

Chen, Y. X., & Yu, Q. (2024). Surface modification of miscanthus fiber with hydrophobic silica aerogel for high performance bio-lightweight concrete. *Construction and Building Materials*, *411*, 134478.

Mancı, A., & Sarıışık, A. (2019). Investigation of the Effect of Cement Amount and Boron Waste on Early Strength of Pumice Aggregate Lightweight Concrete. *I CIVILTECH*, *124*, 2019.

Strzałkowski, J., & Garbalińska, H. (2016). Thermal and strength properties of lightweight concretes with the addition of aerogel particles. *Advances in Cement Research*, *28*(9), 567-575.

Sengul, 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*(2-3), 671-676.

Topçu, İ. B. & Işıkdağ, B. (2008). Effect of expanded perlite aggregate on the properties of lightweight concrete. *Journal of materials processing technology*, *204*(1-3), 34-38.

Ibrahim, M., Ahmad, A., Barry, M. S., Alhems, L. M., & Mohamed Suhoothi, A. C. (2020). Durability of structural lightweight concrete containing expanded perlite aggregate. *International Journal of Concrete Structures and Materials*, *14*, 1-15.

Yazıcıoğlu, S. & Bozkurt N. (2006). Investigation of Mechanical Properties of Load-Bearing Lightweight Concrete with Pumice and Mineral Additives, Journal of Gazi University Faculty of Engineering and Architecture, 21(4), 675-680.

Gökçe, H. S., Şimşek, O., Durmuş, G., & Demir, İ. (2010). The effect of using alternative expanded perlite on the properties of lightweight concrete with raw perlite aggregate. Polytechnic Journal, 13(2), 159-163.

Ulusu, İ., (2007). Investigation of the Produceability of High Strength Lightweight Concrete by Using Raw Perlite Aggregate, PhD Thesis, Ataturk University, Institute of Science, Erzurum.

Topçu, İ. B., & Uygunoğlu, T. (2021). Building Materials. Nobel Academic Publishing.

Sifan, M., Nagaratnam, B., Thamboo, J., Poologanathan, K., Corradi, M. (2023) Development and prospectives of lightweight high strength concrete using lightweight aggregates, Construction and Building Materials 362, 129628.

Topçu, İ. B., Hocaoğlu, İ., & Kara, İ. (2023). Current Developments in Ultra-Lightweight Concrete. International Journal of Engineering Research and Development, 15(2), 689-703.

Jedidi, M., Benjeddou, O., & Soussi, C. (2015). Effect of expanded perlite aggregate dosage on properties of lightweight concrete. Jordan Journal of Civil Engineering, 9(3), 278-291.

Sriwattanapong, M., Sinsiri, T., Pantawee, S., & Chindaprasirt, P. (2013). A study of lightweight concrete admixed with perlite. Suranaree J. Sci. Technol, 20(3), 227-234.

Benjeddou, O., Ravindran, G., & Abdelzaher, M. A. (2023). Thermal and acoustic features of lightweight concrete based on marble wastes and expanded perlite aggregate. Buildings, 13(4), 992.

Bakhshi, M., Dalalbashi, A., & Soheili, H. (2023). Energy dissipation capacity of an optimized structural lightweight perlite concrete. Construction and Building Materials, 389, 131765.

Sai, K., Srikanth, K., & Chaitra, K. (2025). Effect of natural perlıte aggregate and ıts powder on propertıes of lıght weıght concrete. International Journal of Advances in Agricultural Science and Technology, 12(4), 124-129.

Yılmaz, Y. (2013). Synthesis and characterization of monolithic silica airgel and silica airgel by sol-gel method using different starting materials, Master's Thesis, Gazi University Institute of Science and Technology, Ankara.

Doğdu, M. (2022). Development of lightweight ceramic sanitary ware with silica airgel addition, Master's Thesis, Yıldız Technical University, Institute of Science and Technology, Istanbul.

Meti, P., Wang, Q., Mahadik, D. B., Lee, K. Y., Gong, Y. D., & Park, H. H. (2023). Evolutionary Progress of Silica Aerogels and Their Classification Based on Composition: An Overview. Nanomaterials 2023, Vol. 13, Page 1498, 13(9), 1498.

Huang, L., Ehsan, S., & Haghighi, B. (2012). Feasibility study of using silica aerogel as insulation for buildings. Master of Science thesis, KTH School of Industrial Engineering and Management, Stockholm, Sweden.

Azizi, S. (2007). Mechanical Properties and Thermal Insulation of Lightweight Concretes with Perlite Additives. Master Thesis, Istanbul Technical University, Institute of Science, Istanbul.

DPT (State Planning Organization), (2001) Mining Specialization Commission Report, Eighth Five-Year (2001-2005) Development Plan, DPT: 2617-ÖİK: 628, Ankara, 73s.

Çelik, A., Kılıç, A. & Akkurt, F., (2014), Investigation of the usability of expanded perlite aggregate in construction material production, Journal of Gazi University Faculty of Engineering and Architecture, 29 (3), 1-18.

Kaya, E. S. (2019). Usability of Raw Perlite and Expanded Perlite as Pozzolanic Material. Master Thesis, Balikesir University, Institute of Science, Balikesir.

Ciminli, A.T. (2025). Investigation of Mechanical Properties of Polymer Concretes with Perlite Aggregate, Master Thesis, Erzincan Binali Yıldırım University, Institute of Science, Erzincan.

Baradan, B., Yazıcı, H. & Aydın, S., 2022, Concrete, Dokuz Eylul University Faculty of Engineering Publications, İzmir, 825s.

Maden Tetkik ve Arama Genel Müdürlüğü, ‘’Perlite’’, https://www.mta.gov.tr/v3.0/bilgi-merkezi/perlit, (Access date: 17.04. 2025).

Olteanu, I. Taranu, G., Bunea, G. vd. (2024). Effect of expanded perlite aggregates and temperature on the strength and dynamic elastic properties of cement mortar. Construction and Building Materials,438,137229.

Örüç, B. (2022). Production and Optimization of Lightweight Geopolymer Mortar with Expanded Perlite and Expanded Clay Aggregates, Master Thesis, Kocaeli University Institute of Science, Kocaeli.

Bergama Perlit, (2025). Perlite. https://www.bergamaperlit.com/hizmet/dokum-perlit. (Access date: 07.05.2025).

Web Message, (2025). Aerogel. https://www.amazon.com.tr/Par%C3%A7ac%C4%B1k-%C3%96rnekleri-Dondurulmu%C5%9F-Laboratuvar%C4%B1-Sifity/dp/B09LSJ34KQ. (Access date: 30.05.2025).