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Research Article

Investigation of the Effect of Ulexite Additive on the Mechanical Strength and Thermal Conductivity of Cement Mortar

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ABSTRACT

In this study, the effect of ulexite substitution in cement mortar and its physical and mechanical properties on cement mortar properties were investigated. First of all, the pozzolanic activity of the ulexite material was determined. Then, cement mortars with ulexite additives at different rates (0.5%, 1%, 2%, 4%); Specific gravity, specific surface, setting start and end times, consistency and expansion tests, as well as 7 and 28 days flexural and compressive strength of the mortar samples were determined and compared with the control sample. As a result of the study, with the increase of the ulexite substitution ratio, the set start and set expiration times were extended, and all of the ulexite-substituted cement mortars provided the lowest mechanical strength required in related standard. It was observed that the cement mortars with 0.5%, 1%, 2% ulexite substituted cement mortars exceeded the reference sample and the best replacement rate was in the mortars with 0.5% replacement. However, depending on the increase in the ulexite substitution ratio, a decrease in mechanical strength was detected among themselves. According to the results obtained from the thermal conductivity tests, the thermal conductivity values of the cement mortars decreased with the ulexite substitution. Depending on the ulexite substitution rate, the thermal conductivity value decreased by approximately 50%. The lowest thermal conductivity value was measured in the test sample with 4% ulexite substitute.

1. Introduction

Cement production is one of the important industrial activities in terms of its contribution to greenhouse gas emissions, and approximately 5% of global carbon emissions originate from cement production. Various studies are carried out for an alternative binder or cement substitute materials to reduce the greenhouse effect of cement production. As a result of the studies, it is understood that pozzolanic materials can be a good alternative as a substitute material [1]. In addition, it is predicted that the use of pozzolanic materials will be effective in reducing the CO_2 emissions caused by the production of Portland cement. One of the characteristics of pozzolanic materials is that they are light and heat resistant. It is also known that pozzolanic materials increase the fire resistance of concretes. In recent years, the use of fly ash, blast furnace slag (BFS) and silica fume as mineral additives in mixtures to provide high temperature resistance has become widespread [2].

Naturally, the element boron does not exist freely in nature; it typically combines with oxygen and other elements to form salts, commonly referred

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to as "borates." Over 250 boron-bearing minerals have been identified worldwide, with the most common ones being sodium, calcium, or magnesium salts. Boron is a rare element in nature (with an average content of 10 ppm in the Earth's crust); however, extraordinary concentrations can be found in specific regions. The formation of borate deposits can be attributed to different groups; and borates, in an academic context, refer to compounds containing boric oxide. The most significant ones commercially include borax, kernite, ulexite, and colemanite [3]. Notable results have been obtained in some studies on cement mortars produced with boron mineral substitution. It has been evaluated that the materials with new properties to be produced can be used in different areas of the industry.

In a study in the literature, colemanite and ulexite were used separately as fillers in the preparation of epoxy composites. The effects of filler amount, hardener type and plasticizer addition on the properties of new composites were investigated by instrumental analyzes and tests. Improvements in tensile properties were achieved up to 5% wt filler content in composites. Compared to pure epoxy, water absorption decreased significantly with increasing filler amount. Excellent corrosion resistance and strong adhesion properties were observed in all composites. The cold resistance of the composites was quite high. Given these inherent advantages, it is conceivable that composites could find successful applications across a range of industries including construction, coating, and flooring [4].

Another study, specifically investigated the impact of borogypsum and calcineborogypsum on the physical properties of ordinary Portland cement (OPC). The results showed that increasing the borogypsum level from 5% to 7% in Portland cement resulted in an increase in setting time and a decrease in strength expansion and compressive strength. It was found that the cement prepared with borogypsum (5%) had similar strength properties to those obtained with natural gypsum, and a mixture containing 5% hemihydrate borogypsum developed 25% higher compressive strength than the OPC control mixtures in 28 days. Thus, the exploration of using calcined borogypsum in cement applications is expected to yield superior outcomes compared to unprocessed borogypsum. Additionally, the utilization of hemihydrate borogypsum as a retarder for Portland cement holds promise in contributing to the reduction of environmental pollution [5]. A different study conducted an investigation into light concrete production using boron waste at varying ratios (1, 3, 5, 7, and 9%) as a substitute material.

The aim of this study was to achieve a water-resistant and lighter material with enhanced physical and mechanical properties compared to lightweight concrete. The findings of this study indicated that the physical and mechanical properties of the material improved with increasing boron waste content, with the most favorable results observed at the 9% boron waste substitution level. This suggests that by recycling environmentally harmful boron wastes commonly used in construction, a contribution to sustainability can be made [6]. Furthermore, an experimentally and analytically focused study was conducted to assess the impact of incorporating commercial boron carbide (B_4C) powder, with an average particle diameter of 2.64 μm, on the hydration reaction of Portland cement, along with the resulting mechanical and radiation shielding properties of concrete.

The findings indicated that the presence of sassolite in the studied B_4C powder led to a delayed hydration reaction for the initial 24 hours, followed by significant improvements in concrete strength with increasing boron carbide content, attributed to the filler effect. Furthermore, the incorporation of boron carbide was found to measurably enhance the neutron shielding capabilities of concrete mixes [7]. The compressive strength is widely recognized as one of the most vital parameters influenced by the addition of boron to concrete mixtures. The impact of boron addition on concrete compressive strength and other physical properties has been investigated through various studies [8-12]. In line with these findings, numerous studies have explored the applicability of boron wastes in cement production. For instance, one study indicated that the inclusion of tincal ore wastes in cement at a 1% displacement

level led to an enhancement in the qualities of Portland cement (PC), despite causing a delay in setting time. This suggests that tincal ore waste could potentially serve as an additive, replacing cement up to 5% [13]. Another experimental study noted that the 90th-day strength of concrete samples incorporating 4% colemanite waste, 5-15% natural pozzolan, and 81-96% Portland clinker ground cements achieved 90% of the strength observed in control samples. Furthermore, it was observed that concretes produced with higher levels of pozzolan cements exhibited superior 28th-day strength compared to those with lower levels of pozzolan content [14].

A different study delved into the properties of concretes containing varying percentages (0%, 3%, 5%, 10%, and 15%) of boron chips, evaluating parameters such as setting time, volumetric expansion, unit weight, consistency, compressive strength, and splitting tensile strength. This study explored the potential of boron chips as a concrete admixture. The findings suggested that concrete samples containing 3-5% boron chips exhibited higher compressive strength than control samples, and that 5-10% boron chips could be effectively used as an additive. The study also identified that the inclusion of borogypsum led to reduced concrete consistency and delayed setting in C52 concrete, indicating its potential use as a set retarder [15]. In their research, Bothe and Brown [16] examined the formation of a hydration product called ettringite. They identified two different compounds formed with the influence of boron-containing compounds: high boron ettringite and low boron ettringite.

The high boron ettringite is associated with the formula $C_3A{\cdot}2Ca(B[OH]_4)2{\cdot}Ca(OH)_2{\cdot}30H_2$, whereas the low boron ettringite has the formula O and $C_3A{\cdot}Ca(B[OH]_4)_2{\cdot}2Ca(OH)_2{\cdot}36H_2O$.

This study demonstrates that boron-containing compounds can affect the chemical composition of hydration products. While research related to ulexite in construction materials and the building sector is limited, specific studies indicate that ulexite can be utilized within cement [17, 18]. Collectively, the aforementioned studies underscore the beneficial impact of boron additives on various properties of cement mortars. The present experimental study seeks to contribute to this body of knowledge by preparing test samples incorporating ground ulexite at different weight ratios into CEM I 42.5 R Portland cement, with a focus on investigating their mechanical and thermal properties. The study encompasses compression and flexural tests, along with measurements of thermal conductivity for the resulting samples. This research aims to provide further insights into the potential of boron-containing composites in enhancing the performance of cement-based materials.

2. General Methods

The ulexite boron mineral provided by Eti Maden General Directorate, exhibits a high boron content (%37 B_2O_3) compared to other boron minerals, and is notably rich in calcium (CaO) as its dominant component with a calcium content of 19%, data sourced from Eti Maden Operations General Directorate. The study's ulexite mineral and the technical attributes of the CEM I 42.5 R Portland cement used in mixture preparation are detailed in Table 1.

Table 1. Technical properties of CEM I 42.5 R cement and ULEXITE

Elements (%)	CEM I 42.5 R	ULEXITE
SiO_2	21.01	4
Al_2O_3	5.39	0.25
Fe_2O_3	3.23	0.04
CaO	62.11	19
MgO	1.97	2.5
$Na_2O+ K_2O$	0.121	3.5
SO_3	3.10	-
B_2O_3	-	37
Physical Properties		
Specific Weight (g/cm^3)	3.17	2.52
Blaine Fineness (cm^2/g)	3351	3850
Ignition Loss (%)	2.36	32.46

Experimental studies were carried out in two main parts as mechanical experiments and thermal conductivity measurement experiments. First, the “Puzolanic Activity” of ulexite, which was determined in terms of its compressive strength with water and slaked lime $Ca(OH)_2$,

was determined. For this purpose, sieve analysis, specific surface area produced in accordance with TS EN 196-6 [19] standard and produced according to TS EN 196-1 [20] standard, taking into account the mixture amounts of slaked lime, standard sand, ulexite and water specified in the TS 25 [21] standard and density tests and compressive strength test in accordance with TS EN 196-1 standard.

After determining the pozzolanic activity of ulexite, cement mixtures were prepared by substituting ground ulexite at 0.5%, 1%, 2%, 4% by weight into CEM I 42.5R cement. The specific gravity, specific surface, setting times, consistency and volume expansion tests of the mixtures are based on the test methods in TS EN 196-1, TS EN 196-2 [22] and TS EN 196-3 [23] standards. It was done in a laboratory environment where it was 60±5%. The material mixture design for the compressive strength test is given in Table 2.

Table 2. Material mix design

Material	Cement (g)	Ulexite (g)	Sand (g)	Water (g)
U-0 (Reference)	450	0.00	1350	225
U-0.5	447.75	2.25	1350	225
U-1	445.50	4.50	1350	225
U-2	441.00	9.00	1350	225
U-4	432.00	18.00	1350	225

Flexural and compressive strength test specimens of ulexite substituted cement mortars were prepared in accordance with TS EN 196-1. 40×40×160 mm samples, which were kept in normal water for 7 days and 28 days for flexural strength, were removed from the curing pool and subjected to a flexural test with a flexural press at a loading speed of (50±10) N/s. Compressive strength was determined from 40×40×40 mm samples. The compressive strength device was adjusted at a suitable capacity for the test and a loading speed of (2400 ±200) N/s in accordance with TS 196-1. Photographs taken during the compression and flexural tests are given in Figure 1.

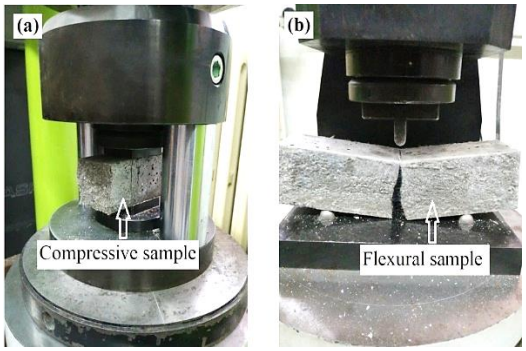

Figure 1. Compression test (a), Flexural test (b)

For the thermal conductivity tests in the second stage, test samples in the form of plates of 15×150×150 mm were prepared in the mixing ratios given in Table 2 and subjected to the same curing process. The images of the prepared samples are given in Figure 2.

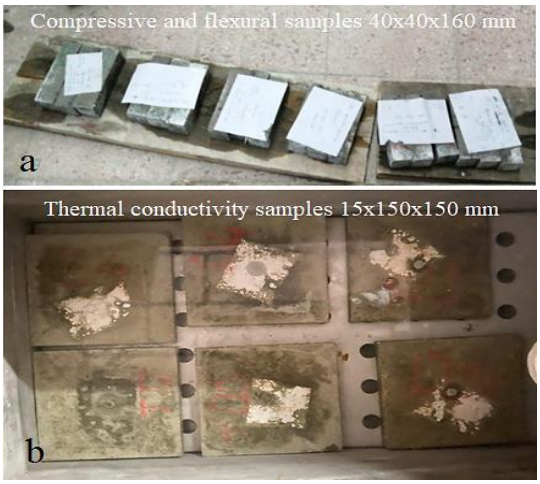

Figure 2. Compression and flexural test specimens (a), Thermal conductivity test specimens (b)

Thermal conductivity tests were carried out in Kırıkkale University Scientific and Technical Research Application and Research Center Machinery and Materials Laboratory, which is within the scope of accreditation according to TS EN 12667 [24] standard. The samples were first kept in an oven at 105°C until the change in mass (m, kg) reached a constant weight. Drying was continued until the mass change [$\Delta m=(m_1-m_2)/m_2$] reached constant weight ($\Delta m<0.005$). After drying, they were kept under laboratory conditions (23 ±1°C and (50 ±10)% RH) for one day and then tested. Laser Comp. for thermal conductivity tests. Company's Fox-314 device was used. Measurement ranges and other test parameters in the thermal conductivity measurement of the device (Thermal conductivity range 0.01 - 0.2 W/m.K, Accuracy

~1%, Repeatability ~0.2%, Reproducibility ~0.5%, Maximum temperature of hot plate 75 °C, Minimum temperature of cold plate -20°C, Temperature control stability ±0.03°C, Thickness measurement accuracy ±0.025 mm, Cooling - water flow ~18°C rate 57-75 liters per hour). As can be seen in Figure 3, the thermal conductivity measurement in the device is made with the principle of one-dimensional heat transfer based on the Fourier Heat Conduction Law. In the device, the heat flux (q'', W/m^2) is determined by keeping a temperature difference (ΔT) of the sample with a thickness (L, m) in a way that one surface is hot and the other surface is cold. The thermal conductivity ($\lambda = q''.L / \Delta T$, W/m.K) value was calculated by using the entered temperature difference, measured heat flux and thickness. In addition, in such measurements, the results may be affected as the sample thicknesses are too high (L>20 mm) will increase the edge heat losses. For this reason, the sample thickness was determined as 18 mm.

3. Results and Discussion

3.1. Evaluation of mechanical properties

As a result of the experiments, it was observed that the setting times of the mixtures prepared with different ulexite additive ratios were also different. In Table 3, setting times and some physical properties of the test samples without ulexite additive and with 0.5% - 1.0% - 2% - 4% ulexite additive by weight are given. the graph created according to the obtained values is given in Figure 3.

Table 3. Setting time and physical properties of cement with and without additives

	U-0	U-0.5	U-1	U-2	U-4
Density (g/cm^3)	3.09	3.08	3.07	3.08	3.06
Specific Surface (cm^2/gr)	3955	3982	3945	3944	3930
Setting Time (İnitial) (min)	185	215	2095	365	565
Setting Time Final (min)	205	235	315	390	565
Water Required for Standard Consistency (%)	26.6	26.6	26.8	27.1	28.0
Volume Expansion (mm)	7	7	6	7	7

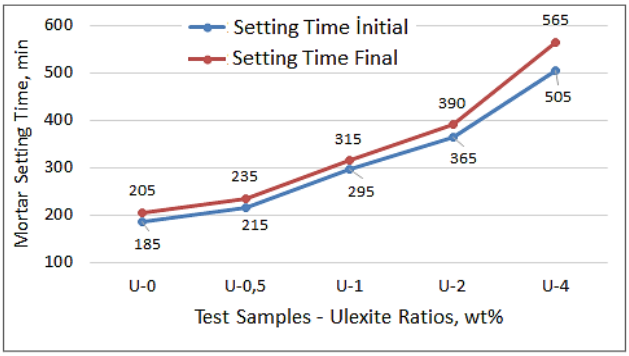

Figure 3. Setting time of cement with and without ulexite additives

Looking at the graph in Figure 3, it is understood that the setting time is prolonged due to the increase in the rate of ulexite substituted into the cement. Looking at Table 3, it is seen that the time between the beginning and the end of the setting was equal to 20 minutes in the samples numbered U-0, U-0.5, U-1, U-2 and U-4, but increased to 60 minutes in the sample numbered U-4. It is understood that ulexite, which is substituted up to 2% in cement, does not make a difference between the beginning and the end of the setting, but it also significantly increases the time between the beginning and the end of the setting with the increase in the rate of ulexite to 4%. With the increase of the ulexite content in the cement, both the total setting time and the time between the beginning and the end of the setting increased. In a study in the literature, it is stated that boric acid substituted into cement increases the setting initiation and setting end times by 2-4 times [25].

Likewise, in another study, it is reported that colemanite substituted into cement both delays the setting time and reduces the mechanical properties of concrete [26]. Improvements and additional properties of boron compounds to concrete and cementitious composites are closely related to the boron trioxide (B_2O_3) concentration of the boron compound used. However, as the B_2O_3 concentration increases, it is a well-known and intensively researched phenomenon that cement hydration slows down or even stops, and accordingly, the setting time is prolonged. In a study in the literature, borates were very briefly

referred to as cement hydration retarding compounds, possibly resulting from a precipitation mechanism [27]. In this study, inorganic material was ground and a paste was formed that hardened by hydration reactions compared to water. This cement paste preserved its strength and stability thanks to the stable hydrated phases formed after hydration. This definition fully complies with the cement definition in TS EN 197-1. The physical analyzes of the test samples prepared with a lime-ulexite mixture in the pozzolanic activity test, the 7-day compressive strength value and the values that must be met in the standard are given in Table 4.

Table 4. Physical analysis of ulexite and compressive strength test result

Features		TS 25
Density (g/cm^3)	2.52	-
Specific Surface (cm^2/g)	3850	4000 ± 25%
Residue on 90µm Sieve (%)	0.2	≤ 8%
Compressive Strength (MPa) 7 Days	4.3	≥ 4
Compressive Strength (MPa) 28 Days	4.6	-

The graphs created according to the values obtained from the compression and flexural tests performed to determine the mechanical properties of the prepared ulexite cement mortar samples are given in Figure 4 and Figure 5.

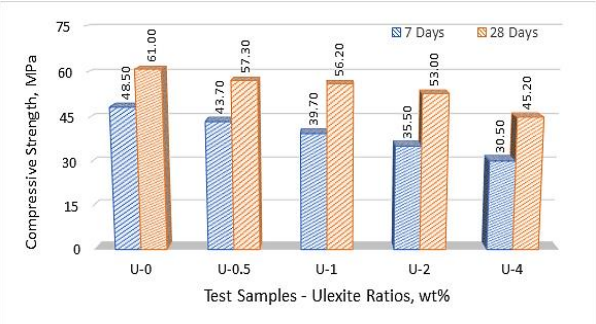

Figure 4. Compressive strength of mortar samples after 7 and 28 days of waiting period

When Figure 4 is examined, it is seen that the compressive strengths decrease as the ulexite substitution ratio increases. Another important point is that higher compressive strength was obtained in the samples in 28 days of waiting time compared to 7 days of waiting time. The highest compressive strength was determined as 61.0 MPa in the control sample, which was kept for 28 days. Among the ulexite added samples, the highest compressive strength was measured as 57.3 MPa in the U-0.5 coded sample with 0.5% substitution, which was also kept for 28 days. The graph created according to the flexural strength test results of ulexite substituted cement mortars in accordance with TS EN 196-1 is given in Figure 5.

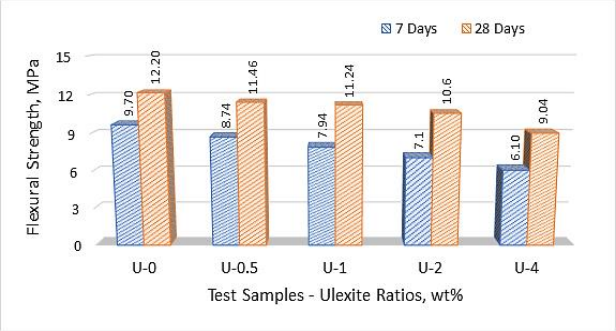

Figure 5. Flexural strength of mortar samples after 7 and 28 days of waiting period

Looking at Figure 5, it is understood that the flexural strength of the samples decreases as the ulexite substitution ratio increases. The flexural strength values of the samples that waited for 28 days were higher than the samples that waited for 7 days. These general results are in agreement with the compression test results. In these two test methods in which the mechanical properties were examined, it was observed that the ulexite substitution had a negative effect on the mechanical strength of the cement mortars. The highest flexural strength value among the ulexite added samples was obtained as 12.20 MPa from the U-0.5 coded sample, which was waited for 28 days and replaced with 0.5% ulexite.

The study conducted by I. Ustabaş (2011) demonstrates that the addition of ulexite has negative effects on fundamental mechanical properties such as flexural strength and compressive strength [28]. Piotrowski et al. (2019) [17] revealed that a significant amount of ulexite content in cement almost completely hindered hydration; simultaneously, samples containing 3% ulexite exhibited successful long-term performance. Studies reporting similar results for concretes with different boron compounds are available in the literature [1, 27, 29-31]. In a study in the literature, it is stated that

colemanite and barite added samples have lower compressive strength values than 7 days reference samples. This was explained by the delay in the hydration process caused by the pozzolanic mineral additives [32, 33]. During the hydration reaction, calcium oxide (CaO) reacts with water (H_2O) to form calcium hydroxide ($Ca[OH]_2$). During this reaction, the pore water quickly turns into an alkaline solution. While the concentration of calcium (Ca_2+) cations and hydroxyl (OH-) anions increase in the pore water that turns into alkaline solution, $B[OH]_3$ dissolves rapidly. $B[OH]_3$ ions and OH- anions in the mixture react to form $B[OH]_4$- compound.

Afterwards, Ca+ cations react with $B[OH]_4$-. The resulting calcium di borate (CBH_6) compound precipitates and covers a portion of the cement particle surface on all or part of it. The hydration reaction of cement particles, whose surface is completely or partially covered with an impermeable layer of CBH_6, either stops completely or is rather delayed. This causes the particles to agglomerate (cut-coagulate) and pseudo-setting occurs. A decrease in Ca2+ occurs due to the formation of CH and CBH_6 in the pore solution. However, when alkalis (Na_2O, K_2O etc.) are released as a result of cement hydration, sodium (Na+), potassium (K+) cations are formed in the pore solution and OH- anions increase in parallel. Depending on the increase of OH- anions, the pH value of the pore water increases again, and after a while, CBH_6 can dissolve again to form the Ca+2 cation. As the CBH_6 crystal layers covering the cement particle surface dissolve, the hydration reaction will accelerate and the above-mentioned chemical cycle will be renewed. If there is pore water in the environment to maintain hydration, these reversible reactions will continue until cement hydration is complete. As the soluble B_2O_3concentration in the medium increases, the initial CaO solubility also increases. However, after a while, the concentration of Ca+2 cations and OH anions decreases in the pore solution to form CBH_6 compound. As a result, the CBH_6 compound quickly covers the surface of the cement particles and hydration stops. Depending on the increasing B_2O_3 concentration, the solubility of the CBH_6 compound is also delayed. This phenomenon weakens bond formation between binder grains. Therefore, while the hardening time after the hydration reaction is prolonged depending on the B_2O_3 concentration, the strength of the cement matrix decreases [33]. In some studies investigating the properties of the cement produced by using the wastes from colemanite and tincal production together with fly ash, natural pozzolan and bottom ash in cement, it has been found that the setting time is delayed with the use of additives in cement, bentonite increases strength at early ages, natural pozzolana has the same positive effect, and high It was determined that the use of tincal and colemanite (over 5%) resulted in decreases in compressive strength [8, 13]

As a result, it was evaluated that ulexite was effective on the performance of cement mortars. With this study, it was understood that ulexite substitute would be beneficial for concrete and cement and could be used as a mineral additive.

3.2. Evaluation of thermal conductivities

Thermal conductivity measurements were made on test samples that were kept for 28 days. The graph created with the values obtained as a result of the thermal conductivity measurements of the ulexite substituted and unsubstituted samples is given in Figure 6.

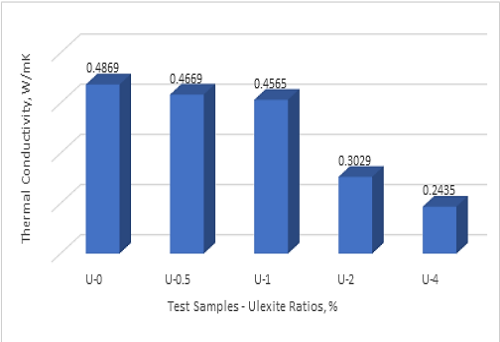

Figure 6. Graph of thermal conductivity values of mortar samples with 7 and 28 days waiting time

The thermal conductivity coefficients of the test samples without ulexite additive and with 0.5%-1.0%-2%-4% ulexite by weight were 0.4869 W/m.K 0.4669 W/m.K, 0.4565 W/m.K, 0.3029 W/m.K and 0.2435 W/m.K respectively and the lowest thermal conductivity was found in cement mortar with 4% ulexite. This situation affects the strength values of the material as expected. When

the thermal conductivity values of the additives in mixed materials are low, the effective thermal conductivity values of the material must also decrease. Here, since the density of ulexite is lower than the mortar material, its thermal conductivity is also partially low. For this reason, it has been observed that the ulexite additive decreased the thermal conductivity positively, but negatively affected and reduced the strength values of the material. When the thermal conductivity values of the additives in composite materials are low, the effective thermal conductivity values of the material must also decrease. It is very important that the material has a homogeneous structure in order to obtain the values in the thermal conductivity measurements with the least error.

The homogeneous distribution of the pores in the material is one of the parameters that affect the thermal measurement results. When the values obtained from the thermal conductivity measurements of ulexite added cement mortars are evaluated among themselves, it is thought that the pores inside the structure increase with the increase in the ulexite additive ratio. Because, although there was a double difference between the 0.5% ulexite added sample and the 1% ulexite added sample, the difference between the thermal conductivity values was 2%. However, with the increase of the ulexite substitution ratio from 1% to 2%, the difference between the thermal conductivities became 50%.

With the increase in the ulexite ratio from 2% to 4%, this difference emerged as 24%. It can be seen from these results that the amount of porosity in cement mortars increased with ulexite substitution. However, there is no direct correlation between these porosity rates and ulexite substitution rates, and the pores in the structure are not homogeneously distributed. The thermal conductivity values decrease with the effect of the air in the building. Therefore, it is considered that whether it is distributed as homogeneously as the amount of pores in the cement mortar plays an important role in determining the thermal conductivity values.

4. Conclusion

Pozzolanic Activity, Compressive Strength, Flexural Strength, Thermal Conductivity of ulexite-substituted cement mortars according to the research results of its properties;

- As stated in the TS 25 Standard, it can be said that ulexite has pozzolanic activity, since the 7-day minimum compressive strength value meets 4 MPa. The fact that it contains C-S-H gels with high binding properties provides an increase in strength and increases the resistance of concrete against external effects by decreasing the paste void ratio. Therefore, in accordance with TS 25 limit values, it is similar to some pozzolanic materials used in the cement industry.

- With the increase of ulexite substitution in the cement mortar, decreases in specific gravity and specific surface areas were observed.

- With ulexite substitution, the rate of substitution increased as the set start and set end times increased. It is slightly longer than the setting time and volume expansion limits of cements with additives given in TS EN 197-1. It shows us that it will be very ideal for cements used in mass concrete. Therefore, it can be said that ulexite will have a setting retarding effect. This situation is closely related to the B_2O_3 (boroxide) concentration in ulexite. As the B_2O_3 concentration decreases, the curing delay and strength decrease will also improve in direct proportion.

- As the ulexite substitution rates increased, the compressive strength of ulexite added cement mortars decreased. It was concluded that this situation weakens the bond formation between the binder grains. Therefore, it is thought that while the hardening time after the hydration reaction is prolonged depending on the B_2O_3 concentration, the strength of the cement matrix decreases.

Although it is the control sample with the highest compressive strength, it has been observed that ulexite added cement mortars have values close to the control sample.

It has been observed that the substitution of ulexite in cement reduces the thermal conductivity coefficient of the mortars. It was found as 0.2435 W/m.K in the mortar. When the thermal conductivity values of the additives in composite materials are low, the effective thermal conductivity values of the material must also decrease.

It has been determined that the thermal conductivity values increase accordingly with the increase in the ulexite substitution ratio. The lowest thermal conductivity value was obtained in 4% ulexite substituted mortars. In addition, as a result of this study, it was evaluated that ulexite substituted cement mortars could be used in thermal barrier development studies.

In addition, considering the CO_2 emission and energy consumption, it will be possible to contribute to sustainability by minimizing the negative impact on the environment during cement production and by recycling boron wastes that harm the environment.

Understanding the importance of ulexite in the field of construction materials should be seen as a step forward. Attention should be drawn to the positive effects of ulexite on the strength, thermal properties, and environmental sustainability of cement mortar. The interaction of ulexite with different dosages and various cement compositions should be examined more thoroughly. Furthermore, further research is needed to explore the economic and environmental impacts of ulexite's industrial-scale usage. Therefore, future studies should be expanded to better understand the role of ulexite in the construction materials industry and fully assess its potential.

These results show that ulexite can be developed with more use in experimental researches and different usage areas for ulexite may emerge.

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This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics
The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

References

[1] T. Mutuk, B. Mesci, “Analysis of mechanical properties of cement containing boron waste and rice husk ash using full factorial design,” Journal of Cleaner Production, vol. 69, pp. 128–132, Apr. 2014.

[2] B. Dündar, E. Çınar, “Farklı Mineral Katkılı Hafif Harçların Mekanik ve Fiziksel Özelliklerine Yüksek Sıcaklığın Etkisi,” Türk Doğa ve Fen Dergisi, vol. 9, no. 2, pp. 42–49, 2020.

[3] C. Helvaci, “Borate deposits: An overview and future forecast with regard to mineral deposits,” Journal of Boron, vol. 2, no. 2, pp. 59–70, 2017.

[4] G. Guzel, O. Sivrikaya, H. Deveci, “The use of colemanite and ulexite as novel fillers in epoxy composites: Influences on thermal and physico-mechanical properties,” Composites Part B: Engineering, vol. 100, pp. 1–9, Sep. 2016.

[5] I. Y. Elbeyli, E. M. Derun, J. Gülen, S. Pişkin, “Thermal analysis of borogypsum and its effects on the physical properties of Portland cement,” Cement and Concrete Research, vol. 33, no. 11, pp. 1729–1735, Nov. 2003.

[6] A. Aldakshe, H. Çağlar, A. Çağlar, Ç. Avan, “The investigation of use as aggregate in lightweight concrete production of boron wastes,” Civil Engineering Journal., vol. 6, no. 7, pp. 1328–1335, 2020.

[7] S. E. Chidiac, M. G. El-Samrah, M. A. Reda, M. A. E. Abdel-Rahman, “Mechanical and radiation shielding properties of concrete containing commercial boron carbide powder,” Construction and Building Materials, vol. 313, no. June, p. 125466, 2021.

[8] Ç. Targan, A. Olgun, Y. Erdoğan, V. Sevinç, “Effects of supplementary cementing materials on the properties of cement and concrete,” Cement and Concrete Research, vol. 32, no. 10, pp. 1551–1558, Oct. 2002.

[9] Y. Erdoğan, M. S. Zeybek, A. Demirbas, “Cement Mixes Containing Colemanite from Concentrator Wastes,” Cement and Concrete Research, vol. 28, no. 4, pp. 605–609, Apr. 1998.

[10] B. Çomak, A. Bideci, Ö. Salli Bideci, “Effects of hemp fibers on characteristics of cement based mortar,” Construction and Building Materials, vol. 169, pp. 794–799, Apr. 2018.

[11] R. Boncukcuoğlu, O. Içelli, S. Erzeneoğlu, M. Muhtar Kocakerim, “Comparison of radioactive transmission and mechanical properties of Portland cement and a modified cement with trommel sieve waste,” Cement and Concrete Research, vol. 35, no. 6, pp. 1082–1087, Jun. 2005.

[12] A. Filazi, M. Pul, “Effect of Borax Pentahydrate Substitution on Sound proofing and Mechanical Properties of Cement Mortar,” Uluslararası Muhendislik. Araştırma ve Geliştirme Dergisi, vol. 14, no. 2, pp. 604–610, Jul. 2022.

[13] I. Kula, A. Olgun, V. Sevinc, Y. Erdogan, “An investigation on the use of tincal ore waste, fly ash, and coal bottom ash as Portland cement replacement materials,” Cement and Concrete Research, vol. 32, no. 2, pp. 227–232, Feb. 2002.

[14] Ş. Targan, A. Olgun, Y. Erdoğan, V. Sevinç, “Influence of natural pozzolan, colemanite ore waste, bottom ash, and fly ash on the properties of Portland cement,” Cement and Concrete Research, vol. 33, no. 8, pp. 1175–1182, Aug. 2003.

[15] U. K. Sevim, M. Özturk, M. B. Bankir, U. Aydin, “Utilization of Colemanite waste in Concrete Design,” International Journal of Advanced Engineering Research and Science, vol. 4, no. 12, pp. 172–175, 2017.

[16] J. V. Bothe, P. W. Brown, “Phase formation in the system CaO–Al2O3–B2O3–H2O at 23±1°C,” Journal of Hazardous Materials, vol. 63, no. 2–3, pp. 199–210, Dec. 1998.

[17] T. Piotrowski, J. Glinicka, M. A. Glinicki, P. Prochoń, “Influence of gadolinium oxide and ulexite on cement hydration and technical properties of mortars for neutron radiation shielding purposes,” Construction and Building Materials, vol. 195, pp. 583–589, Jan. 2019.

[18] Standard, B. (2003). British Standard Methods of testing cement.

[19] TS EN 196-6. (2010). Methods of testing cement–part 6: determination of fineness.

[20] Turkish Standard Institute-TSE. (2002). TS EN 196-1: methods of testing cement: part 1: determination of strength.

[21] TSE, T. (2011). Natural pozzolan (Trass) for use in cement and concrete-Definitions, requirements and conformity criteria. Turkish Standard Institute. Ankara, Turkey.

[22] TSE, (2002). TS EN 196-2: Methods of testing cement. Part 2: Chemical analysis of cement.

[23] EN, T. (2017). 196-3. Methods of testing cement-Part, 3.

[24] EN, T. (2003). 12667 Turkish Standards Institute. Thermal performance of building materials and products.

[25] H. E. Pehlivanoğlu, M. Davraz, Ş. Kılınçarslan, "The effect of boron compound to settıng time of cement and controllability," International Journal of Technologic Sciences, vol. 5, no. 3, pp. 39-48, 2013.

[26] O. Gencel, W. Brostow, C. Ozel, M. Filiz, "An investigation on the concrete properties containing colemanite," International Journal of Physical Sciences, vol. 5, no. 3, pp. 216–225, 2010.

[27] N. Yaltay, C. E. Ekinci, "Investigation Of Compression Strength Of Lightweight Concrete, Subjected To Elvated Temperature, Produced With Pumice Agregate And Colemanite Addition By Non-Destructive Method," Süleyman Demirel University International Journal of Technologic Sciences, vol. 5 no. 2, pp. 30-41, 2013.

[28] Ustabaş, İ., "Investigation of the Usability of Colemanite and Ulexite in Cement", Ready-Mixed Concrete Congress, Istanbul, 2011.

[29] H. F. W Taylor, "Cement chemistry," 2nd ed., Thomas Telford publishing, London, 1997.

[30] E. Erdogmus, "Combined effect of waste colemanite and silica fume on properties of cement mortar," Science and Engineering of Composite Materials, vol. 21, no. 3, pp. 369–375, 2014.

[31] İ. Yakar Elbeyli, "Utilization of Industrial Borax Wastes (BW) for Portland Cement Production," The Turkish Journal of Engineering & Environmental Sciences, vol. 28, pp. 281-287, 2004.

[32] O. Aksoğan, H. Binici, E. Ortlek, "Durability of concrete made by partial replacement of fine aggregate by colemanite and barite and cement by ashes of corn stalk, wheat straw and sunflower stalk ashes," Construction and Building Materials, vol.106, pp.253-263, 2016.

[33] M. Davraz, "The effect of boron compound on the properties of cementitious composites," Science and Engineering of Composite Materials, vol.17, no. 1, pp. 1-17, 2010.