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DETERMINATION OF PHYSICAL, MECHANICAL, THERMAL PROPERTIES OF READY THERMAL INSULATION PLASTERS

HAZIR ISI YALITIM SIVALARININ FİZİKSEL, MEKANİK, ISI ÖZELLİKLERİNİN BELİRLENMESİ

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ABSTRACT

Thermal insulation in buildings is of fundamental importance in reducing energy consumption and ensuring environmental sustainability. This practice, which increases energy efficiency by minimizing heat transfer, both limits fossil fuel consumption and reduces greenhouse gas emissions. In addition, it improves thermal comfort conditions in interior spaces, increasing the quality of life and providing long-term economic savings. In this study, the compliance of some properties of thermal insulation mortars produced in our country, especially thermal conductivity coefficient and compressive strength, with the criteria were evaluated. Mortar samples were produced with five different plasters from different manufacturers. Fresh and hardened samples were tested, and their values were obtained. When the compressive strength values are examined, the highest compressive strength value belongs to product E. The lowest compressive strength value belongs to the insulating plaster samples of product C. When the heat resistance values that class T plasters should have are taken into consideration, it has been determined that the D, A, and F insulating plasters meet the CS I criterion, while the E and B insulating plasters meet the CS II criterion. When the thermal conductivity coefficient values are examined, the highest value belongs to the insulating plaster samples of product B. The lowest heat insulation value belongs to the insulating plaster samples of product C. When the thermal conductivity coefficient values that class T plasters should have been taken into consideration, it has been determined that the A, C, and D insulating plasters meet this criterion. As a result, it was seen that a significant part of the insulation plasters did not meet the values declared by the manufacturers.

Keywords: Thermal insulation plaster, thermal properties, mechanical properties

ÖZET

Yapılarda ısı yalıtımı, enerji tüketiminin azaltılması ve çevresel sürdürülebilirliğin sağlanması açısından temel bir öneme sahiptir. Isı transferini minimize ederek enerji verimliliğini artıran bu uygulama, hem fosil yakıt tüketimini sınırlamakta hem de sera gazı emisyonlarını azaltmaktadır. Bunun yanı sıra, iç mekânlarda termal konfor koşullarını iyileştirerek yaşam kalitesini artırmakta ve uzun vadeli ekonomik tasarruf sağlamaktadır. Bu çalışmada, ülkemizde üretilen ısı yalıtım harçlarının, ısı iletkenlik katsayısı ve basınç dayanımı başta olmak üzere bazı özelliklerinin kriterlere uygunluğu değerlendirilmiştir. Harç numuneleri farklı üreticilere ait 5 farklı sıva ile üretilmiştir. Numunelerin taze ve sertleşmiş haldeki deneyleri yapılmış ve değerleri elde edilmiştir. Basınç dayanımı değerleri incelendiğinde en yüksek basınç dayanımı değeri E firmasının yalıtım sıvası numunelerine aittir. En düşük basınç dayanımı değeri ise C firmasının yalıtım sıvası numunelerine aittir. T sınıfı sıvaların sahip olması gereken ısı

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dayanımı değerleri dikkate alındığında, D, A ve F yalıtım sıvalarının CS I kriterini, E ve B yalıtım sıvalarının ise CS II kriterini sağladığı tespit edilmiştir. Isıl iletkenlik katsayısı değerleri incelendiğinde en yüksek değer B firmasının yalıtım sıvası numunelerine aittir. En düşük ısı yalıtım değeri ise C firmasının yalıtım sıvası numunelerine aittir. T sınıfı sıvaların sahip olması gereken ısıl iletkenlik katsayısı değerleri dikkate alındığında, A, C ve D yalıtım sıvalarının bu kriteri sağladığı tespit edilmiştir. Sonuç olarak, yalıtım sıvalarının önemli bir kısmının firmanın beyan ettiği değerleri karşılamadığı görülmüştür.

Anahtar Kelimeler: Isı yalıtım sıvası, ısıl özellikler, mekanik özellikler

INTRODUCTION

The ability of the outer shell of the building to prevent moisture and water from the atmosphere, that is, its ability to release water, is extremely important for the safety and long-term usability of the building. One of the oldest known solutions in this regard is the plastering of building walls (Nascimento et al., 2020; Faria et al., 2016; Balovic et al., 2016). Plaster is a mortar-based continuous coating applied at a certain thickness to the interior and exterior wall surfaces and ceilings of the building. The use of unsuitable materials, such as plaster in buildings causes the expected efficiency to decrease, the building weight and heat losses to increase, and therefore the expected savings in energy costs cannot be achieved (Santos et al., 2019; Xu et al., 2022; Yi et al., 2023). The most important factor in fully meeting these features expected from plaster is the complexity value of the plaster mortar (Molnar & Manea, 2016; Mutouskova et al., 2021). Certainly, a plaster mortar with a high complexity will also provide strength and durability properties. In addition, if the plaster is used for various purposes such as adherence, easy workability, strength and impermeability, and obtaining decorative surfaces depending on the place where it will be applied in the structure, it is envisaged that the binder within the plaster will be selected to provide these properties (Çolakoğlu, 2004). Studies to increase awareness of water and heat insulation It is gaining momentum due to factors such as the adaptation of regulations and standards to current conditions and the implementation of finalized regulations within the sector (İzoder, 2002; Altuncı and Ocal, 2021; Yetkin et al., 2024). Çolakoğlu (2004) investigated the feasibility of making a plaster with thermal insulation properties using pumice and limestone. It was stated that the plaster sample complies with the TS 6433 standard. Davraz & Kılınçarslan (2014) aimed to develop a perlite aggregate plaster material that provides high-performance thermal insulation, has sufficient pressure and flexural strength, has low water absorption rate and capillarity, and is resistant to environmental effects such as freezing and thawing effects. They stated that since heat loss in buildings will be greatly reduced by perlite-added plaster produced by the standards, energy savings will be achieved by using our resources, and the economy of our country, which imports most of its energy, will be positively affected. Dilmaç & Kesen (2003) stated the importance of the heat permeability coefficient U-value of building elements (such as walls, windows, roofs) and especially transparent surfaces in the annual energy consumption of buildings. Dylewski et al. (2014) investigated whether it is beneficial to use thermally insulated pumice granules or EPS plaster instead of cement plaster on the exterior walls of a building. They determined that there was an improvement in the thermal insulation properties of pumice granule and EPS plastered walls, and as a result, savings in energy consumption were achieved. It has been claimed that this effect occurs in 2-5 years for pumice and EPS plaster, depending on the heat source, while this period exceeds 30 years for cement plaster. Barbero et al. (2014) made a general analysis of thermal insulation plasters in the European market, comparing existing products according to technical and economic features. The main aim of the research is to direct research in the field of thermal insulation plaster towards innovative applications and to create new plasters that can meet the demands of the real market and end users. It is explained that the three main factors defined according to European standards are the dry bulk mass of the mixture, the dry unit volume mass of the hardened plaster, and the thermal conductivity. Zach et al. (2013) explained the research results on the development of silica-based ultra-light thermal insulation plasters. It has been stated that the developed materials have a significant potential for use in the field of thermal insulation in buildings due to their high open porosity and low unit volume weight. In practice, the basic requirements of these materials are explained as dry conductivity $\lambda 10$, dry ≤ 0.08 W/mK, and minimum compressive strength fc $\geq$ 0.5 N/mm^2. Davraz et al. (2011) conducted a study on lightweight aggregate foam plaster. In the study, three different pumice and expanded perlite were used as lightweight aggregates. In foam plaster samples, dry unit volume mass varies between 338-487 kg/m^3, compressive strength 0.64-2.34 MPa, flexural strength 0.070-0.11 MPa, capillary water absorption coefficient 0.62-1.82 kg/m^2.min and thermal conductivity coefficient 0.068-0.088 W/mK.

To reduce heat loss and prevent condensation, it is possible to completely insulate all kinds of elements such as columns, beams, and beams, which are located on the exterior of the building and act as thermal bridges, by applying thermal insulation from the outside, based on the principle of continuity of insulation (Dylewski & Adamczyk, 2011; Papadopoulos & Giama, 2007; Manohar, 2012). However, since the structure is enclosed in a sheath, it is protected against external climatic conditions, preventing strong temperature changes and unwanted internal stresses, cracks, and structural damage in the main material that forms the wall. The external thermal insulation system helps keep the indoor temperature balanced in summer and winter by providing the structure with the ability to store sufficient heat. Additionally, the risk of condensation that may occur on the building envelope is minimized (Pasztory, 2021; Çomaklı &Yüksel, 2004; Tychanicz-Kwiecien et al., 2019).

When choosing the materials used for thermal insulation, attention is paid to whether they fulfill certain properties depending on where they are used (Papadopoulos, 2005; Bektaş et al., 2017; Davraz et al., 2020). While it is important that insulation materials are light and do not crumble against external impacts, it is also desirable that they be resistant to moisture and have a low coefficient of vapor permeability when working in humid environments (Al-Homoud, 2005; Davraz et al., 2011; Davraz et al., 2015). According to different usage areas, the specific volume of thermal insulation materials, low drying shrinkage, workability, ease of workmanship, deformation resistance against compression and tensile stress, chemical neutrality, resistance to decay and crumbling, thermal insulation function at continuous, periodic, or short-term temperatures. The selection is made by taking into account the relevant factors such as not changing the material, being suitable for the element to be applied, having high fire resistance and low thermal conductivity coefficient (Villasmil et al., 2019; Abu-Jdayil et al., 2019; Zach et al., 2013).

Plaster has functional functions other than aesthetics in the building. The most important function of the plaster is to maintain the relative humidity at the comfort level in the interior and reduce heat loss or to reduce the heat loss/gain ratio. Plaster is also a major factor in sound insulation and fire prevention. However, plaster is divided into types according to its usage area in the building, its structure, the type of binding material in its composition, the way its surface is used, and its construction. The goal of this study was to determine whether thermal insulation mortars made in our nation by TS EN 998-1 standard meet the other requirements listed in this standard, particularly those related to pressure resistance and thermal conductivity coefficient, and to compare the results with the declared values.

MATERIAL AND METHODS

Material

Samples from five different companies, including A, B, C, D, and E the most preferred T1 class ready-made thermal insulation plasters in the market, were obtained. The amount of mixture recommended by the companies was prepared by weighing the insulation plaster and water and mixed with a mixer. The amount of mixing water recommended by each company is different, and therefore the mixing amounts are not given so that the companies cannot be identified. Mixing was carried out until a homogeneous mortar was obtained (approximately 3-5 minutes). A total of 5 series of plaster mortars were produced and placed in sample molds. After being in the mold for twenty-four hours, the samples were taken out of it. Figure 1 displays the samples of plaster mortar that were manufactured.

Figure 1. Produced Plaster Mortar Samples

Experimental Test

In this study, five series of plaster mortars were produced. The produced plaster mortars were tested in fresh and hardened states. The consistency of the wet mortar mixtures to be prepared from each plaster sample was determined according to TS EN 1015-3 standard. Before the experiment, the inner and outer surfaces and edges of the circular plate and truncated cone-shaped mold were cleaned with a clean and damp cloth. The mortar was then filled into the mold and compacted. After the compression process was completed, the mold was pulled, and the mortar was spread by hitting it 10 times at fixed intervals. The pressure method in accordance with TS EN 1015-7 standard was used to determine air content. Spreading diameter measurement and air content determination experiments are shown in Figure 2.

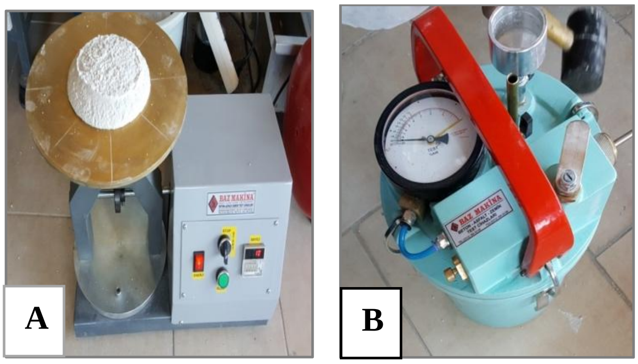

Figure 2. A: Spreading Diameter, B: Air Content Determination Experiment

For the fresh unit volume mass test, mortar was added until it overflowed the edge of the measuring cup. Excess mortar was scraped off so that the mortar surface was smooth and at the same level as the upper surface of the measuring cup. Mortar residues on the surface of the measuring cup were cleaned by wiping with a damp cloth. The total mass of the measuring cup filled with mortar was weighed. In dry unit volume mass tests, the drying method was applied until a constant mass was reached according to TS EN 1015-10. For this, the sample was dried in an oven set at 70°C ± 5°C until it reached a constant mass. If the sample masses determined by successive weighings at intervals of two hours during the drying process do not differ from each other by more than 0.2% of the dry sample mass, this indicates that the sample has reached a constant mass. After the sample reached a constant mass, the dry sample mass was immediately measured with an electronic balance with an accuracy of 0.01 g. Prisms with dimensions of 160×40×40 mm were produced for the capillary water absorption (capillarity) experiment (Figure 3A). The prisms produced were placed on the tray as shown in TS EN 1015-18. The masses of the samples placed in water were measured at the end of the 10th and 90th minutes. Flexural strength determination was subjected to a three-point loading test according to TS EN 1015-11 (2000) standard (Figure 3B). For this, each sample is placed on two cylinders with 100 mm between them, and the sample is loaded with the same size cylinder in the middle of the upper surface of the sample until it breaks. The flexural strength can be calculated from the breaking load found. For this experiment, a flexural strength test device with adjustable loading speed was used. To determine the flexural strength, 3 40×40×160 mm prism samples were produced from each mixture.

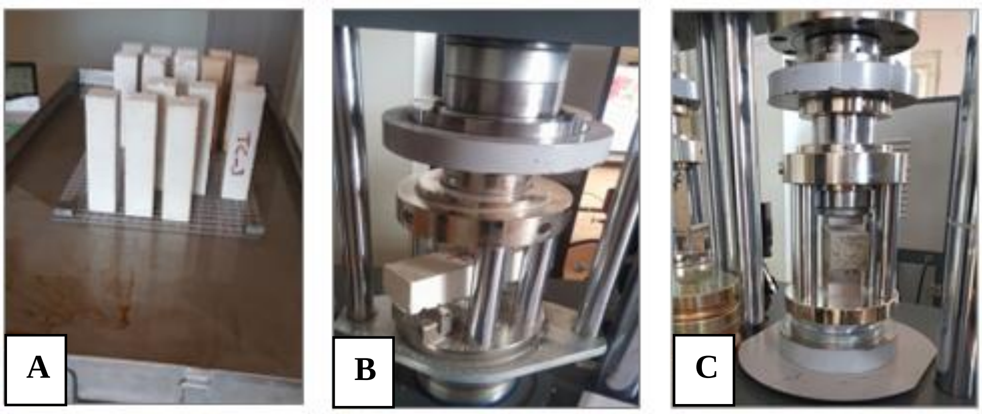

Figure 3. Performing The Experiments A: Capillary Water Absorption, B: Flexural Strength, C: Compressive Strength

The uniaxial compressive strength test, one of the destructive test methods, was performed (Figure 3C). A uniaxial compressive strength tester was used for this experiment. After the flexural strength test, compressive strength tests were performed on two pieces obtained from a prism sample. The compressive strength test of 28-day hardened plaster samples was carried out according to TS EN 1015-11. Lasercomp Fox 50 thermal conductivity device, which works with the heat flux measurement method, was used for the thermal conductivity coefficient determination experiment. It is designed for thermal conductivity coefficient measurements of materials with a thermal conductivity coefficient of less than 10 W/mK. Using this device, the thermal conductivity coefficient (λ) of samples up to 63 mm in diameter and 1-30 mm in thickness can be measured (Figure 4). Two samples were produced for each plaster series and thermal conductivity tests were carried out on a total of 10 samples.

Figure 4. Thermal Conductivity Coefficient (λ) Measurement

RESULTS AND DISCUSSION

Experimental Test Results

In this study, the test results of plaster mortars produced with plasters supplied by five different companies were compared with the standards given in TS EN 198-1. It has been compared with the standards given in TS EN 198-1. The properties that the plaster mortars of class T should have are given in Table 1.

Table 1. Properties that Plaster Mortars Belonging to T Class

Properties	Classes
Compressive strength	CS I: 0.4-2.5 MPa CS II: 1.5-5 MPa
Capillary water absorption	W 1
Thermal conductivity (W/mK)	T 1 : ≤ 0.10 T 2 : ≤ 0.20

Unit volume mass and air content values of fresh mortar for the plaster mixtures prepared within the scope of the study are given in Figure 5.

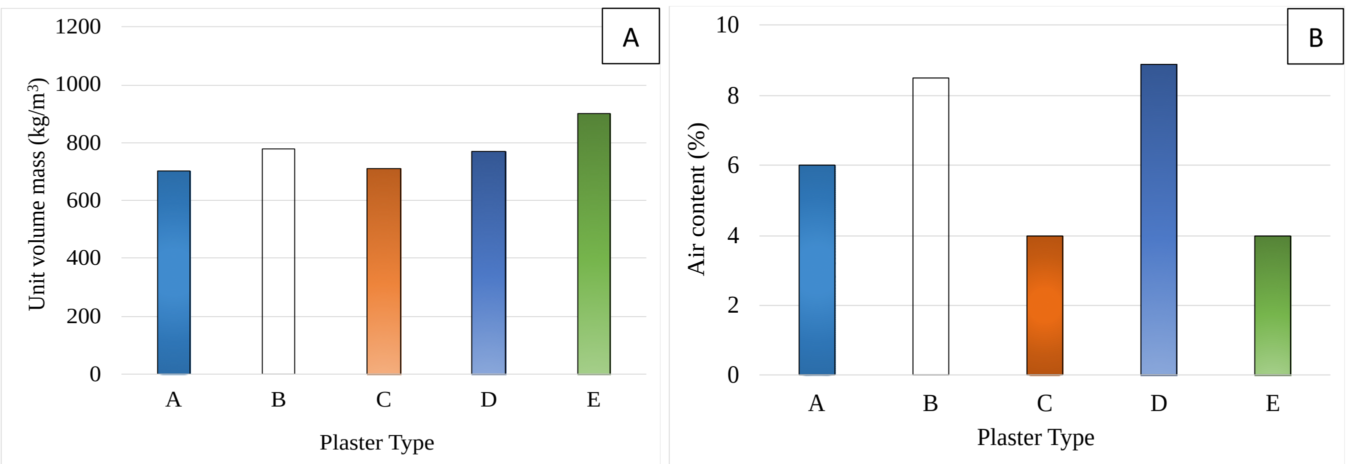

Figure 5. Properties of Fresh Mortar, A: Unit Volume Mass, B: Air Content

When the unit volume mass values shown in Figure 5 are examined, it is seen that the highest value belongs to the insulation plaster mortar of product E and the lowest value belongs to the insulation plaster mortar of product A. When the air content values are examined, it is seen that the highest value belongs to the insulation plaster mortar of products D, and the lowest value belongs to the insulation plaster mortar of companies E and C. Additionally, it improves the workability of fresh mortar. In this study, the consistency of 5 different plaster mortars was determined and their spreading diameters were determined. Spreading diameter values of insulation plasters are given in Figure 6.

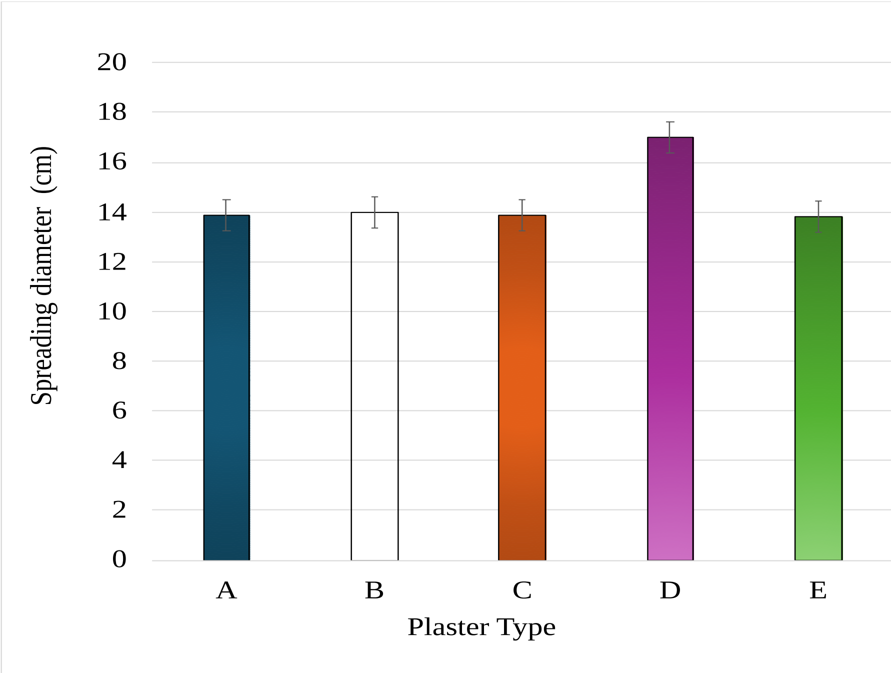

Figure 6. Spreading Diameter Values of Thermal Insulation Plasters

When the spreading diameter values are examined, it is seen that the highest value belongs to the insulation plaster mortar of product D and the lowest value belongs to the insulation plaster mortar of product A. The spreading diameter feature affects the processability. The w/c ratio of the mortar, air content, adherence additive content, and binder content affects the spreading diameter. While the spreading diameter makes a positive contribution up to a certain value, it is not desired as it will cause flow in plaster application afterward.

The dry unit volume mass values for the hardened plaster samples produced in the experimental study were determined according to the TS EN 1015-10 standard. For each series, 3 prismatic samples that completed the 28-day curing period were tested. The samples were dried in an air circulation oven until a constant mass was reached and weighed, and the arithmetic average of the weighing results was taken. Dry unit volume mass of hardened plaster samples is given in Figure 7.

In insulating plasters, dry unit volume mass is the most important parameter affecting the mechanical properties and thermal conductivity values of the plaster. When the dry unit volume mass values shown in Figure 7 were examined, it was determined that the highest value belonged to the insulation plaster samples of product B and the lowest value belonged to the insulation plaster samples of product A. The coefficients (c) obtained from capillary water absorption tests of prisms produced in dimensions of 160×40×40 mm according to TS EN 1015-112 are given in Figure 8.

c values are closely related to the sustainability of the thermal insulation properties of thermal insulation plasters. The thermal insulation performance of insulation materials with high C values also decreases. When the c values shown in Figure 8 are examined, it is seen that the highest value belongs to the insulation plaster samples of product E and the lowest value belongs to the insulation plaster samples of product B. Considering the c values that class T plasters must have, it has been determined that only B-code insulation plaster meets this criterion.

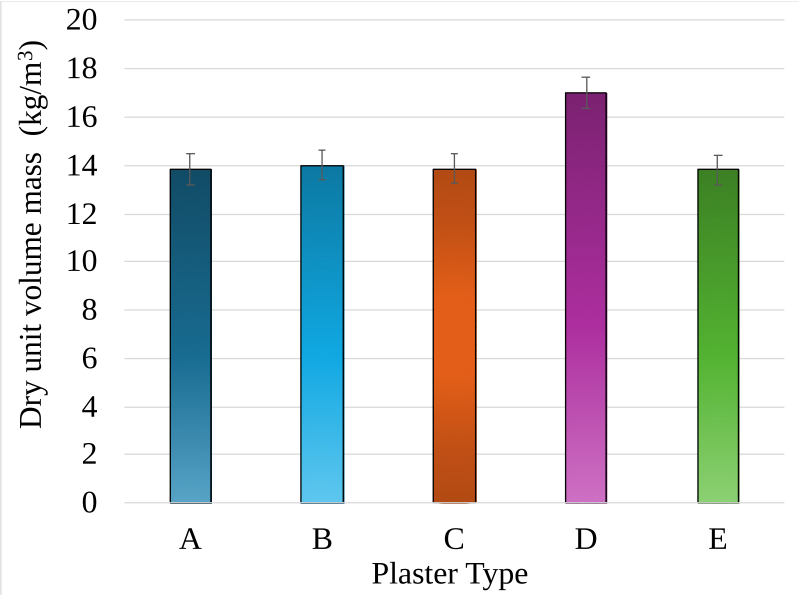

Figure 7. Dry Unit Volume Mass Values of Hardened Samples

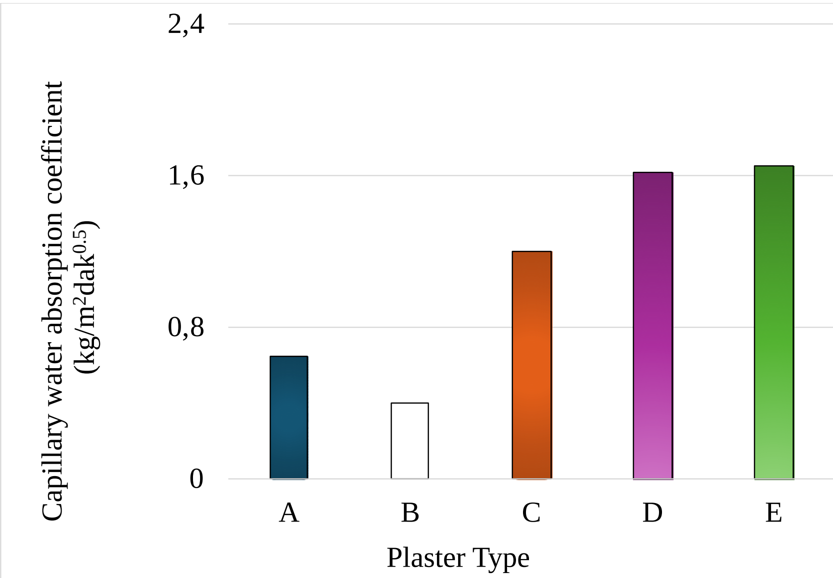

Figure 8. Capillary Water Absorption Coefficient Values of Insulation Plasters

In each series, 3 prismatic samples were subjected to flexural strength tests perpendicular to the casting direction, and the arithmetic average of the 3 test results was accepted as the flexural strength value. After the flexural strength test, compressive strength tests were carried out on two pieces obtained from a prism sample, and the arithmetic average of the test results obtained from 6 pieces was accepted as the compressive strength. Figure 9 shows the average flexural and compressive strength values of the plaster samples.

When the fc values shown in Figure 9 are examined, it is seen that the highest value belongs to the insulation plaster samples of products E and the lowest value belongs to the insulation plaster samples of products C. The compressive strength-flexural strength relationship of insulation plasters is given in Figure 10.

When the graph in Figure 10 is examined, it is seen that the R^2 value is determined as 0.98. fcf-28-day, 28-day flexural strength, MPa; fc-28-day, 28-day compressive strength is MPa.

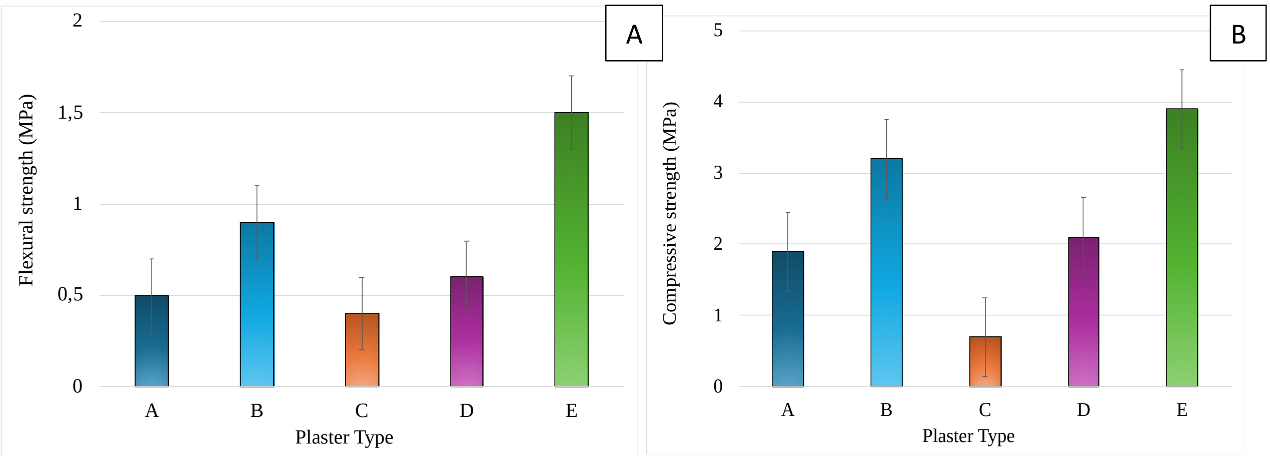

Figure 9. Strengths of Insulation Plasters, A: Flexural Strength, B: Compressive Strength

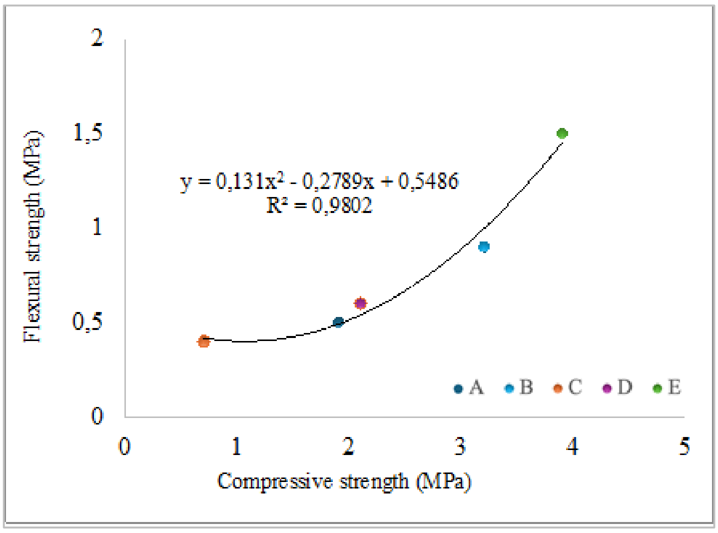

Figure 10. Compressive Strength-Flexural Strength Relationship of Insulation Plasters

For each series, 3 cylindrical samples with a diameter of 63 mm and a thickness of 25 mm were tested for determining thermal conductivity coefficients. Thermal conductivity coefficients (λ) of 28-day hardened plaster samples are given in Figure 11.

When the thermal conductivity coefficient values shown in Figure 11 are examined, it is seen that the highest value belongs to the insulation plaster samples of product B and the lowest value belongs to the insulation plaster samples of product C. When the values given in Table 1 are examined, it is seen that plasters with a heat transfer coefficient of 0.10 and below are in the T1 class, and plasters with a heat transfer coefficient of 0.20 and below are in the T2 class. When the results are examined, plasters A, C, and D are in the T1 class, and plasters B and E are in the T2 class.

CONCLUSIONS

This study analyzed the physical, mechanical, and thermal properties of insulation plaster mortars from various companies, identifying significant variations in performance and discrepancies between experimental results and manufacturer claims. The findings highlight the critical role of properties like unit volume mass, air content, spreading diameter, capillary water absorption, compressive strength, and thermal conductivity coefficient in determining insulation materials' overall effectiveness and functionality. The unit volume mass values ranged widely among the samples, with product E products showing the highest values, indicating greater density, while product A had the lowest. Air content, a key factor influencing thermal insulation, capillary water absorption, and workability, was highest in product D samples and lowest in products E and C. However, excessive air content negatively impacted compressive and flexural strength values, underscoring the need for balance to optimize performance. Spreading diameter significantly affects the processability of fresh mortar. While a larger diameter improves workability, excessive spreading can cause flow issues during plaster application. This metric, influenced by water-to-cement (w/c) ratio, air content, and binder additives, requires careful optimization to balance application efficiency with structural integrity.

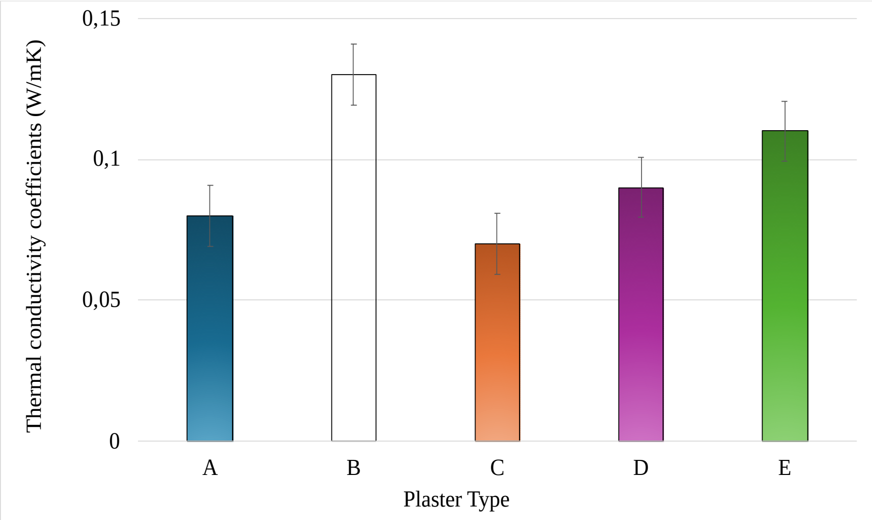

Figure 11. Thermal Conductivity Coefficients of Insulation Plasters

The study revealed discrepancies in capillary water absorption and compressive strength values. Product B had the lowest water absorption and highest adherence to standard requirements, while product E exhibited the highest absorption. Compressive strength values varied similarly, with product E mortars achieving the highest performance and product C the lowest. Only certain products met the required class T plaster standards for compressive strength and capillary water absorption, indicating a need for quality improvement across many samples.

Thermal conductivity, crucial for energy efficiency, was highest in product B and lowest in product C. Several products, including those from Companies A, C, and D, met the required standards, but discrepancies between manufacturer claims and experimental results were common. For instance, product A declared thermal conductivity and capillary water absorption values were unmet, while compressive strength was consistent. A strong correlation was observed between unit volume mass and flexural strength, compressive strength, and thermal conductivity, suggesting that denser materials generally perform better. However, the study highlighted that many insulation plasters did not meet the stated manufacturer specifications, emphasizing the need for stricter regulatory oversight and regular quality control inspections.

The growing demand for energy-efficient, environmentally friendly building materials offers significant opportunities for innovation. With abundant perlite reserves, the focus in Turkey should shift toward developing eco-friendly insulation materials that serve as alternatives to expanded polystyrene (EPS). Enhancing R&D efforts to create sustainable, energy-saving, and high-performance products is critical for advancing the industry. In conclusion, aligning the actual performance of insulation plasters with declared standards is vital for fostering consumer trust and promoting energy conservation. By intensifying inspections and supporting innovative R&D initiatives, the construction industry can deliver next-generation insulation solutions that combine environmental benefits with superior quality and durability. This approach will contribute to more sustainable building practices, reducing energy consumption and environmental impact.

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