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Water absorption, capillarity action, and materials composition of different bricks and panels as part of the external coating of buildings. Case study: Tirana, Albania.

Klodjan Xhexhi[1,*] and *Besnik Aliaj*[2]

[1]Department of Architecture and Engineering, Polis University, Tirana, Albania
[2]Urban Planning Department, Polis University, Tirana, Albania

Abstract. The article aims to provide insight into the water absorption, capillarity action, and material composition of various bricks and panels used as external coatings for buildings. The materials analyzed include silicate brick, red clay brick, normal clay hollow brick, concrete block, and EPS fibre cement composite wall panel. These types of bricks and panels are widely used in buildings in Albania, making their water absorption characteristics and hygroscopic moisture levels important factors to consider for future applications. The study is based on an experiment involving five material samples. Initially, the samples are dried and then partially submerged in water for 12, 24, and 36 hours. Afterward, they are removed from the water and dried indoors for 12, 24, and 36 hours. The moisture content is measured at three intervals for each sample category. The experiment also analyzes the capillarity action of water within the materials to evaluate their overall performance. Based on the results, red clay brick and normal clay hollow brick were identified as the most vulnerable materials due to their composition, high capillarity action, and significant water absorption. These findings are crucial for determining the suitability of these materials in construction practices.

1 Introduction

Building materials' ability to absorb moisture is becoming widely acknowledged for its effects on interior environments. This is linked to material longevity, occupant comfort, and health [1]. The water content of the materials has a direct impact on the building's thermal performance [2].

Building exterior coatings are the first line of protection against weather conditions, therefore understanding how various materials absorb water during construction is essential. The most often utilized materials are bricks and panels because of their strength, visual appeal, and thermal properties. However, the amount of water they can absorb varies substantially depending on their chemical composition and manufacturing manners.

The external coatings of buildings function as a barrier that prevents the outside factors including moisture, humidity, and rain. The effectiveness and longevity of these coatings are significantly impacted by the absorption capacity of building materials, particularly bricks and panels. This work aims to clarify the water absorption behaviour of EPS fibre cement board panels, silicate bricks, clay bricks, clay hollow bricks, and concrete blocks using a rigorous experimental procedure.

By analysing the samples' moisture content and capillary activity, researchers hope to provide meaningful information regarding the samples' potential for exterior coating applications. Capillary rising is a phenomenon that occurs in hydrophilic materials that have pores, with a range in diameter from 10^{-3} mm to 10^{-2} mm. The height of capillary ascending moisture is mostly determined by the capillary pores' radius; the smaller the radius, the higher the rising height [3].

Capillary action is a phenomenon associated with surface tension, whereby liquids can travel – horizontally or vertically (against the force of gravity) in small spaces within materials. It is sometimes referred to as capillary action.

Smaller pores usually produce greater capillarity. The reason behind this is that smaller pores provide more space for the liquid to interact with thus increasing the adhesive forces between the liquid and the material. Therefore, these materials with smaller pores tend to have an increased capillary action facilitating a larger rise or movement of liquid on them. On the other hand, porous materials with bigger pore sizes will have very minimal surface areas which are suitable for capillarity action. Hence the capillarity action will be lower.

Hola 2020, in her research, explores the moisture content of brick walls in wet historical buildings. The author uses non-destructive methods to determine moisture and salinity in brick walls [4].

According to a study conducted by McGregor, et al., the findings show that unfired clay masonry works better at controlling interior humidity than traditional materials.

* Corresponding author: klodjan_xhexhi@universitetipolis.edu.al

This characteristic can lessen the risk of mould formation, use less energy, and increase the longevity of materials. Choosing the right soil is essential since mineralogy and particle size distribution maximize the building's ability to buffer humidity [5].

Osanyintola, and Simonson (2006) investigate the effect of hygroscopic materials and energy consumption in buildings. It was found that energy consumption can be reduced by 5% up to 30% by applying hygroscopic materials [6].

Kuteli et al (2022) analysed the moisture content and temperature level of different typologies of brick walls in the city of Tirana. The authors analyse silicate bricks, clay hollow bricks with and without insulation, and concrete blocks. Measurements were applied to all the building facades. He concluded that silicate bricks provide better protection than red clay bricks, and insulated hollowed brick walls provide better protection against moisture [7].

Another experiment was conducted by Kalaja et al (2022). The authors analyse the amount of water absorbed by different types of wood considering their initial state and their state after water immersion. The natural woods selected were: pine, oak, beech, and fir (the most popular woods in use in the Albanian context). The study concluded that Oak absorbs and loses water more easily than the other samples. Meanwhile, Pine contains more water after 48 hours of drying than the other samples [8].

According to Xhexhi and Aliaj (2023), the moisture level of the external walls influences the indoor air quality. They concluded that the moisture level in masonry walls equipped with ventilated façade is lower than standard masonry walls as well as their coefficient of thermal performance (U-value). The moisture level on most of the building materials should not exceed 15%, otherwise, health problems due to mould may be present [9].

This research endeavours to clarify the properties of water absorption and capillarity action of silicate bricks, clay bricks, normal clay hollow bricks, concrete blocks, and EPS fibre cement board panels — all of which are frequently employed in the external coating of buildings.

2 Materials composition and their physical, mechanical, and thermal proprieties

Masonry and cementitious building materials play a fundamental role in construction, providing structural stability, insulation, and aesthetic appeal to buildings [10]; [11]. Because they can be obtained easily, they are versatile as well. They are also reasonably priced, including: silicate bricks, clay bricks, regular clay hollow bricks, concrete blocks, and cement board panels. So, they are some of the most often used materials. [12].

2.1 Silicate bricks

Sand, lime, and water are the ingredients used for producing silicate bricks, commonly referred to as sand-lime bricks [12]. After combining the raw ingredients in specified amounts, the mixture is pressed into moulds [13]. The bricks are autoclaved at high pressures and temperatures so that they can gain strength and last for long periods [14].

Silicate bricks have good compressive strength and excellent dimension stability, so they are suitable for load-bearing applications in masonry constructions.
Both clay and silicate bricks are durable construction materials with a long lifespan and low maintenance requirements.

2.2 Clay bricks

Clay bricks are usually made from natural clay minerals comprising clay, shale, and water. These materials are mined, pulverized, mixed with water, and then formed into bricks using molds [13]. After formation, the bricks are dried and fired to vitrify the clay particles at high temperatures to produce strong and durable bricks [15].

Clay and silicate-bricks have moderate thermal conductivity; they provide insulation and thermal mass for buildings. Because of their excellent thermal insulating qualities and compressive strength, clay bricks are perfect for both structural and non-structural uses.

2.3 Normal clay hollow bricks

Normal clay hollow bricks, also known as clay hollow blocks, are similar in composition to clay bricks but are characterized by voids or cavities within the brick structure [15]. These voids reduce the weight of the bricks and improve thermal insulation properties [14].

Typical clay hollow bricks are ideal for walls and partitions in both residential and commercial constructions because they are lighter and provide better thermal insulation than solid clay bricks.

Due to the voids between the bricks, regular clay hollow bricks provide better thermal insulation.

Typical clay hollow bricks are quite resistant to deterioration from the elements and weather.

2.4 Concrete blocks

Concrete blocks, also referred to as concrete masonry units (CMUs), are composed of cement, aggregates, and water [10]. Portland cement is commonly used as the binder, while aggregates provide bulk and stability to the blocks [16]. Concrete blocks are formed by pouring the concrete mixture into moulds and allowing it to cure [10].

Although the heat conductivity of concrete blocks is rather high, it can be enhanced by adding insulating coatings or additives.

Concrete blocks are frequently used in foundation systems, retaining walls, and load-bearing walls because of their exceptional durability and compressive strength.

Because of its extreme durability and resistance to fire, moisture, and insects, concrete blocks may be used in a variety of building applications.

2.5 Cement board panels

Cement board panels are composite materials typically composed of Portland cement, cellulose fibres, and reinforcing additives [10]. These panels are manufactured by mixing the ingredients with water to form a slurry, which is then poured onto sheets and compressed under high pressure [10].
Because of their low heat conductivity, cement board panels help make building envelopes more energy-efficient.

The experiment in this article will take into consideration the EPS fibre cement composite wall panel of 10 mm. The matrix of this composite panel is composed of two layers of fibre reinforced with cement 2 mm each and an EPS layer of 6 mm in the middle.

Because of its excellent moisture resistance and flexural strength, cement board panels may be used as external sheathing, wall cladding, and flooring underlayment.

Since cement board panels are resistant to microbial growth, moisture, and termites, they contribute to building durability and sustainable buildings. Their weight compared to the other samples is very low.

2 Methodology

Five samples of each type of brick and panels were considered, letting them first dry completely. The study used several architectural typologies and urban dwelling units in Albania's capital Tirana as references for brick selections such as: "Partizani" and "Brryli" silicate-brick housing units; "Ekspozita Shqiperia Sot" mould-brick housing unit; "Dinamo Stadium" housing cement-brick housing units; as well as the historic "Pallatet Shallvare & Agimi" housing units, which are built with different kinds of bricks. Buildings at Bathore informal area, at Kamza Municipality, were also subject to sample preparation, especially for cement-block samples.

Afterward, the samples taken were partially immersed in water to mimic moisture exposure. Following the duration of immersion, the samples were left and taken out of the water and dried in the indoor area for 12, 24, and 36 hours, respectively.

Using the Silverline Digital Moisture Meter, the moisture content of every sample was determined after each drying and submersion cycle. Furthermore, a qualitative analysis of the capillary action level in the samples was conducted using ocular observations of water movement through the material structure.
In compliance with ASTM guidelines, several tests were carried out to evaluate the water absorption capabilities of the chosen construction materials. The samples were conditioned in a controlled atmosphere to reach moisture equilibrium before testing.

During the water absorption test, the samples were submerged in water for a predetermined amount of time, and the weight increase was then tracked during that period. Also, the following formula was used to determine the percentage of water absorption per sample:

$$\text{Absorption of Water (\%)} = (W_{final}) - (W_{initial}) / (W_{initial}) \times 100 \quad (1)$$

where "$W_{initial}$" is *the initial weight* of the specimen and "W_{final}" is *the weight after submersion*.

In addition to experimental research, each sample's material composition is analysed in order to determine the water absorption affecting the capillarity level.

3 Experiment

The samples were first weighed in a dry state as seen in Figure 1 using the electronic weighting machine (Emos Digital Scale EV023). At the end of the experiment, the samples were totally submerged into water in order to be reweighed again.

Fig. 1. Weighing of the samples in a dry state

The temperature of the indoor environment was 21.6°C at the time the samples were weighed.

Table 1. The initial and final weight of the samples and their water absorption.

Samples	Initial weight (g)	Final weight after total submersion (g)	Water absorption, according to Formula (1) (%)
Silicate brick	3344	3672	9.8%
Clay red brick	3084	3507	13.71%
Normal hollow brick	4253	4875	14.62%
Concrete block	2586	2666	3.09%
EPS fiber cement composite wall panel	260	295	13.46%

The water absorption results per sample according to the Formula (1) are shown at Table 1.

The samples were initially left totally submerged in the water for 10 minutes each and then weighed again.

It was observed that concrete blocks and silicate bricks recorded the lowest level of water absorption. Meanwhile, normal hollow bricks, clay red bricks, and EPS fibre cement composite panel recorded the highest level of water absorption when totally submersed in water. This is due to their material composition of the outer fiber cement layers. Meanwhile, considering the closed-cell structure of expanded polystyrene (EPS), its capillarity is usually low. This structure makes it difficult for water to be absorbed by or pass through EPS

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materials via capillary action since they have restricted interconnectedness as far as pores are a concern.

Table 2. The initial moisture content of the samples, and after partial water immersion (using Silverline Digital Moisture Meter).

Samples	Initial moisture content (%)	Moisture content 12 hours After immersion (%)	Moisture content 24 hours After immersion (%)	Moisture content 36 hours After immersion (%)
Silicate brick	6%	19%	24%	26%
Clay red brick	5%	17%	17%	18%
Normal hollow brick	5%	19%	24%	26%
Concrete block	4%	14%	15%	15%
EPS fiber cement composite wall panel	4%	13%	14%	15%

The samples were partially immersed in water. The water level provided was 2.7cm per sample.
The moisture content was measured at the highest part of the sample, taking into account the capillarity action of the water as seen in Figure 3.

It was observed that after 12 hours the normal hollow brick was almost totally wet due to the capillarity action, while other samples were not, as seen in Figure 3. Meanwhile, the materials with large pore spaces such as concrete blocks have better permeability and poor capillarity as seen in Table 3.

Table 3. Water capillarity action of the samples after immersion

Samples	Water capillarity, 12 hours Min/Max (cm)	Water capillarity, 24 hours Min/Max (cm)	Water capillarity, 36 hours Min/Max (cm)
Silicate brick	9/10cm	11/12cm	14/15cm
Clay red brick	13/15cm	16.5/17cm	20/21cm
Normal hollow brick	21/25cm	25/25cm (+)	25/25cm (+)
Concrete block	7.5/9cm	8/9cm	8/9cm
EPS fiber cement composite wall panel	5/6.5cm	5.5/6.5cm	5.5/6.5cm

It was observed that the capillarity level at the first moment of the immersion is higher in normal hollow-brick, due to: the material composition; the porosity; and the bigger contact surface of water (because of the holes). The normal hollow-brick absorbs water more quickly than the other samples. In contrast, the capillarity action was lower in the other samples because of their bigger pores and different material composition.

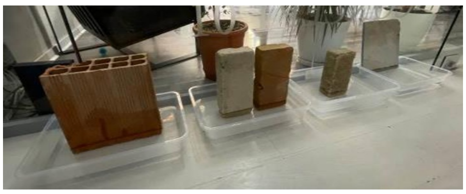

Fig. 2. The first moment of the sample immersion.

Fig. 3. Water capillarity action of the samples after 12 hours of immersion.

After 12 hours of immersion, the capillarity level of the normal hollow-brick was higher than the other samples. The height of the capillarity-rise depends also on the continuity of the material pores. The clay-brick had the second highest value, due to its material composition and porosity level. The third and fourth highest values were: the silicate-brick and the concrete-block. Meanwhile, the lower value of the capillarity level goes in favour of EPS fibre cement composite wall panel due to the EPS (expanded polystyrene foam), as well as its ability to absorb a minimum amount of water, while having almost no capillarity action. The minimal capillarity action of this composite panel is mostly due to the fibre cement layers implemented on both sides of the matrix.

Fig. 4. Water capillarity of the samples after 24 hours of immersion.

After 24 hours it was observed that clay-based materials absorb the water quicker than the other samples as seen in Figure 4, and Table 3. There was also observed very little capillarity action in concrete blocks and EPS fibre cement composite panel.

Fig. 5. Water capillarity of the samples after 36 hours of immersion.

Table 4. Moisture content during the drying process of the samples.

Samples	Moisture content after total submersion	Moisture content 12 hours	Moisture content 24 hours	Moisture content 36 hours
Silicate brick	27%	23%	18%	17%
Clay red brick	26%	25%	19%	17%
Normal hollow brick	30%	24%	19%	15%
Concrete block	16%	9%	7%	6%
EPS fiber cement composite wall panel	20%	8%	7%	5%

After the total water submersion, the samples were left to dry and then their water content was measured as seen in Table 4. Comparing: EPS fibre cement composite panels and concrete blocks -to- other samples, it was found that their moisture content is reduced. It was also observed that normal hollow brick, concrete block, and EPS fibre cement panels lose water more quickly than the other samples during the drying process.

4 Results and discussions

The water absorption test results showed notable differences between the various construction materials. Concrete-blocks and silicate-bricks showed the lowest rate of water absorption, with an average absorption of 3.09% and 9.8%. Concrete-blocks showed a lower rate of water absorption depending on their mixed design and curing circumstances.

Depending on the heating process temperature, and clay composition, red clay-brick, and normal clay-hollow brick showed moderate water absorption levels, ranging from 13.71% to 14.62%. Because of their hollow cores and larger surface area, regular clay-hollow brick exhibited more water absorption than solid-clay brick.

The EPS fibre cement board panel, being a composite material, showed comparatively moderate water absorption rates compared to silicate-brick and concrete block. This is due to its outer layers of fiber cement. Being a composite material, the water is absorbed mainly by the fibre cement layers implemented in both parts of the matrix. These panels absorb the water faster and, in the meantime, release the water faster, as a result of their small thickness.

The material composition investigation supported the patterns in water absorption that were observed, emphasizing the impact of capillary action, porosity, and pore structure on moisture infiltration.

The testing of the capillary action reveals different indications of the water activity in all of the samples. It can be observed that clay-based activity showed more capillary activity when compared to EPS fibre cement board panel, concrete-block, and silicate-brick.

Table 5. Overall results

Samples	Mean capillarity action (cm)	Mean moisture content	Water absorption
Silicate brick	11.83 cm	20%	9.8%
Clay red brick	17.08 cm	18%	13.71%
Normal hollow brick	24.33 (+) cm	20.25%	14.62%
Concrete blocks	8.42 cm	10.75%	3.09%
EPS fibre cement composite wall panel	5.92 cm	10.75%	13.46%

The mean capillarity level is calculated for all minimum and maximum values, considering the timelines as seen in Table 5. The mean capillarity level of the normal hollow brick is marked with (+) because, at the time frame of 24 and 36 hours, the brick was totally wet because of the capillarity action. This shows that the capillarity level could be even greater in this case.

The mean moisture content is calculated for all the values; beginning from the initial moisture content, from the moisture content after partial immersion, and the moisture content during the drying process; considering all time frames.

It was revealed that moisture content is higher in normal hollow-brick, silicate-brick, and red clay-brick compared to concrete-blocks, and EPS fibre cement-wall panels.

Conclusions

How bricks and other materials absorb water, is a complex process that depends on many factors, including: i) the characteristics of the material, ii) the surface of contact with water, iii) and its porosity. Hollow clay-bricks, red clay-bricks, silicate-bricks, and concrete-blocks, due to the capillarity action, absorb water significantly and more rapidly than EPS fibre cement panel when partially immersed in water.

On the other hand, concrete-blocks and silicate-bricks have a lower level of water absorption when totally submerged in water compared to the other samples.

These findings show how crucial it is to choose the appropriate construction materials for the specific local climate and the intended use; in order to extend: i) the longevity of structures; ii) and improve their resilience to the environment. However, more complex compositions of materials, and surface treatments, may be researched in order to decrease the capillarity and increase the durability, in favour of water resistance to the building materials.

The most vulnerable samples considering water absorption, water content, and capillarity action, were: the normal hollow-brick, and red clay-brick. Meanwhile, the best sample according to the experiment was the EPS fibre cement wall panel, due to the lower value of the water capillarity action and moisture content. These types of panels must be prevented by the total submersion in water because they show high water absorption due to the material composition (external fibre cement layers), despite the fact that they dry faster than others. These panels are the most recommended in terms of moisture content and water capillary activity for the external coating of buildings. They are also resistant to water and moisture from the outside environment due to the EPS. They weigh less, as well as provide moderate thermal insulation for the building.

The conclusion of this research might be useful to the authorities, developers, and residents for the maintenance, restoration, and reuse of such historic buildings and techniques in Tirana, in order to prolong the life of buildings and maintain the social cohesion of the areas under study. This is a pressing political and decision-making issue while considering the rapid/dramatic transformation of Tirana, Albania (including redevelopment, densification, verticalization, and gentrification of urban units).

More research is to be done to explore the relation of high-water tables, and the dry/humid climate of Tirana city, in relation to these types of bricks.

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