Strategies to Mitigate Efflorescence in Walls Constructed Using Clays Bricks; A Review Article

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استراتيجيات للتخفيف من ظاهرة الترسيب في الجدران المبنية باستخدام الطوب الطيني: دراسة مرجعية

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Abstract

The construction of buildings, especially residential housing for communities, is a significant industry on a global scale. Masonry units such as bricks, blocks, and stones are often utilized materials. Bricks are highly regarded because to their widespread availability, cost-effectiveness, and excellent insulating capabilities. Nevertheless, the presence of efflorescence presents a difficulty in the construction of brick walls. Efflorescence refers to the process in which salts move to the outer layer of the brick, resulting in the formation of white deposits and negatively impacting its visual appeal. Efflorescence is caused by various circumstances, such as the existence of salts in bricks, the utilization of fossil fuels during the burning process, and constructing in regions with soluble salts in the soil. The presence of salts in the raw materials utilized in brick manufacture is a notable factor contributing to this problem. However, taking measures to remediate the soil before to the manufacturing process can effectively mitigate this issue. In addition, there are other measures that can be employed to reduce the occurrence of efflorescence, including the use of efflorescence-resistant bricks and the application of sealants to limit the migration of salt.

Keywords: Bricks, Efflorescence, Salt Solutions, Chemical Compositions

المستخلص

إن بناء المباني، وخاصة المساكن السكنية للمجتمعات، هو صناعة مهمة على نطاق عالمي. وكثيراً ما يتم استخدام وحدات البناء مثل الطوب والكتل والأحجار كمواد. ويحظى الطوب بتقدير كبير بسبب توفره على نطاق واسع وفعاليته من حيث التكلفة وقدراته العازلة الممتازة. ومع ذلك، فإن وجود الترسبات يشكل صعوبة في بناء الجدران المصنوعة من الطوب. يشير الترسبات إلى العملية التي تنتقل بها الأملاح إلى الطبقة الخارجية من الطوب، مما يؤدي إلى تكوين رواسب بيضاء والتأثير سلباً على جاذبيته البصرية. ويحدث الترسبات بسبب ظروف مختلفة، مثل وجود الأملاح في الطوب، واستخدام الوقود الأحفوري أثناء عملية الحرق، والبناء في مناطق تحتوي التربة على أملاح قابلة للذوبان. إن وجود الأملاح في المواد الخام المستخدمة في تصنيع الطوب هو عامل بارز يساهم في هذه المشكلة. ومع ذلك، فإن اتخاذ تدابير لإصلاح التربة قبل عملية التصنيع يمكن أن يخفف بشكل فعال من هذه المشكلة. بالإضافة إلى ذلك، هناك تدابير أخرى يمكن استخدامها للحد من حدوث التزهير، بما في ذلك استخدام الطوب المقاوم للتزهير وتطبيق المواد المانعة للتسرب للحد من ظهور الملح.

الكلمات المفتاحية : طابوق ,التزهر ,محلول ملحي ,التركيب الكيميائي

1. Introduction:

Brick is one of the most performable used masonry units in the world because it has many desirable properties, such as light weight, easy availability, thermal insulation, and sound insulation [1–3]. For the first time, bricks were discovered in Mesopotamia, which was used nine thousand years before chrisms. From that time until today, many changes have been made in its shape, composition, texture, and properties [2]. Today, the world produces approximately one thousand five hundred billion bricks annually [4, 5], resulting in the use of approximately three hundred fifty million tons of clay in this industrial process [5]. The properties of produced bricks are determined by three factors: the raw materials, the production process, and the location of use [2]. Two properties determine the durability and life time of clay bricks: compressive strength, which is responsible for withstanding external stress, and porosity, which is the most important property. An increase in porosity in bricks increases water absorption, moisture content, and efflorescence, which in turn decreases compressive strength and shortens the brick's lifespan [2, 6]. In Uganda, over 80% of living place walls are constructed from bricks [1]. Similarly, in Pakistan, masonry units are the most commonly used for construction [5]. Clay, which is obtained from the ground through the deterioration of various types of rocks, is one of the main compositions of clay bricks, containing a variety of chemical elements and salt amounts [2]. The main chemical compositions of clay bricks are silicon oxide, aluminum oxide, iron oxide, ferrous oxide, potassium oxide, titanium oxide, sodium oxide, calcium oxide, and magnesium oxide [2, 7]. Aluminum oxide and silicon oxide are two main compositions of clay in the range of 40–95% [2, 7, 8]. Each element in the brick composition influences

its behavior; carbonate elements increase the brick's porosity after burning, while alkaline elements like potassium and sodium cause an increase in efflorescence due to chemical reactions after placement, and quartz acts as a filler [5, 8, 9]. The chemical composition of clay generally determines the color of the produced brick; a high content of organic material results in a dark color, a high content of iron oxide results in a red color, and a high content of limestone results in an orange color [2]. Masonry is important, especially for the building's decoration and architectural purpose [7], which is many times affected by the efflorescence phenomenon [10, 11]. As depicted in Figure 1 below, the efflorescence phenomenon involves the movement of soluble salts and gypsum from the brick to the surface, where they absorb heat from the evaporation of the moisture that contains these salts and gypsums [7, 12, 13].

Figure.1 Brick Masonry wall subjected to efflorescence [10]

Most of these salts are composed of alkaline sulfate or sodium chloride [1, 7, 12].The efflorescence caused by the salt appeared shortly after the

masonry walls were placed, whereas the efflorescence caused by gypsum took longer, possibly even more than a year, to appear on the face of the walls [2, 12, 14], a phenomenon primarily observed in older buildings [11]. Due to the high usage of natural raw materials, many trials have been conducted to modify brick compositions [15–17]. Khan *et al*. [4] used marble waste as a partial replacement of clay in bricks, varying the ratios from zero to thirty percent by 5%. They observed an increase in porosity as the replacement rate increased, leading to increased water absorption, decreased strength, and increased efflorescence. Argha and Bari [7] conducted an investigation into efflorescence on the partition walls in garages. They found that the lower part of the walls had a higher chloride content, and they recommended using a low alkaline cement in the mortar to reduce the reaction between the available soluble salt in the brick and the external weather that causes efflorescence. Shahidi, [10], used a computer program simulation to predict the efflorescence in bricks based on their chemical composition. Khitab *et al*. [5] conducted an investigation into the use of waste brick and ceramic powder as a substitute for clay in bricks. They found that 12% of ceramic powder, combined with 15% of clay powder, or 27% of waste, can serve as a partial replacement for clay without significantly impacting the main brick requirements. This article discusses the factors that lead to efflorescence in masonry brick walls, as well as the strategic measures to minimize its occurrence and impact.

2. Research Significant

This article discusses the following topic

1. Study on Efflorescence Mitigation Techniques: Examining and assessing existing methods employed to reduce efflorescence in

brick building, including the use of sealants, surface treatments, or alterations to the materials

2. .Evaluating the Efficacy of Efflorescence Prevention Methods: Assessing the effectiveness of various techniques to prevent efflorescence in real-world scenarios by conducting tests and analyzing the results.
3. Creating Innovative Solutions: Suggesting new approaches or adjustments in the use of materials and manufacturing methods to tackle the issue of efflorescence.

3. Methodology

After reviewing previous experimental work and discussing efflorescence, we have discussed the factors that cause the appearance of efflorescence. We have also discussed the solutions for each factor, as shown in the following Figures:

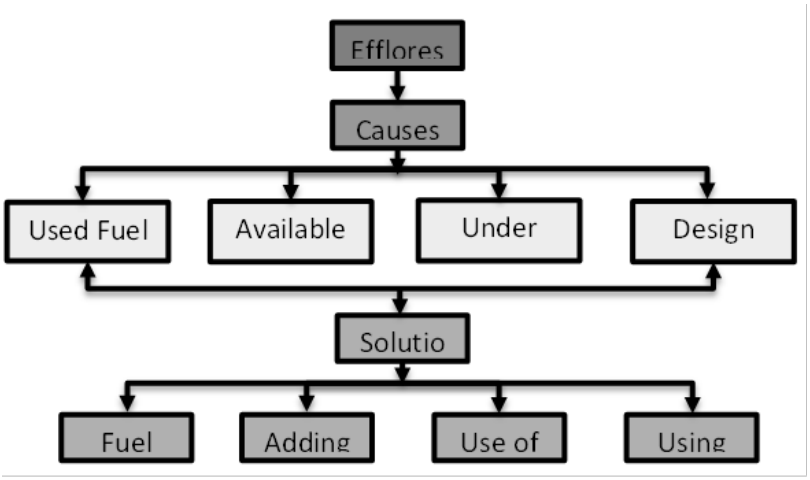

Figure.2 Methodology steps

4. Causes of Efflorescence

Efflorescence can occur through various intricate methods. Efflorescence is the result of water with dissolved salts rising to the surface of brickwork, where the water evaporates and leaves behind the salts. The salt solutions can move across the surfaces of masonry units, between the mortar and brick units, or via the pores of the mortar or brick units.

Efflorescence can only occur if specific circumstances are present simultaneously:

- The brickwork must contain or be in touch with soluble salts. These salts can be found in various components such as mortar ingredients, backing materials, trim, neighboring soil, brick, and so on.

- The user did not provide any text. The salts need to be in touch with a water source for a sufficient duration to dissolve.

- The user did not provide any text. The brickwork must have a pore structure that enables the movement of salt solutions to the surface or other areas where water can evaporate. A driving force, such as difference in temperature or humidity, guides the movement of moisture through the pore structure.People who are unfamiliar with efflorescence often mistakenly believe that it is caused by the substance on which it is found, typically the brick. The primary source of soluble chemicals that cause efflorescence on brick surfaces is typically the materials that come into contact with the brick, such as mortar, grout, concrete masonry, concrete, soil, or other substances. Nevertheless, soluble chemicals can also arise from within brick units. Efflorescence, being predominantly white in hue, tends to be more noticeable when contrasted with darker shades. According to John Sanders and Denis Brosnan, the misconception . that brick causes efflorescence is often based

on the fact that the soluble compounds are more easily seen on the brick's darker surface. This is because brick has a porous structure that allows water to be transported through it, which is necessary for the bond between brick and mortar to form [18].

4.1 Used Fuel In Burning Process

During the burning process of the bricks, an amount of gas is released into the air, containing a high amount of sulfate. This gas reacts with the available moisture or water on the brick surface, producing an effective acid. This acid then reacts with the available lime or magic in the brick, resulting in the formation of efflorescence [19–21].

4.2 Available Salt in Raw Material

All types of clay contain different types and amounts of salt since the clay is formed from the decomposition of different types of rock. Available salts in the clay may be sulfate of iron, hydrated silica, or aluminum salt, which vary in amount and particle size [19, 22]. Abilities of available salts for solution in the water vary, which show their effect on creating efflorescence, which means the high soluble salt in moisture is a higher maker of efflorescence [19]. One of the available salts that is little soluble in the water is iron pyrites, which are available in most types of clay and react with air when exposed to weather that causes the formation of iron sulfate. By the solution of iron sulfate in the water or available moisture in the brick, the yellow efflorescence will be produced. If the bricks are subjected to heat, the iron sulfate will dissolve, and the obtained sulfate will attach to available limestone or magnesia [19, 23]. The activity of these salts in the clay is

affected by many factors, which are the ability to dissolve in water, size of the salt particle, temperature of the subjected weather to the wall face, and capillary of the walls [19, 24, 25].

4.3 Under Ground Salty Water

As shown in Figure 3, when the wall is in contact with the ground and the underground water contains soluble salt, the water will rise in the wall due to the capillary action, and due to the different weather conditions on both surfaces of the wall, the soluble salt will dry on the heated surface of the wall [26].

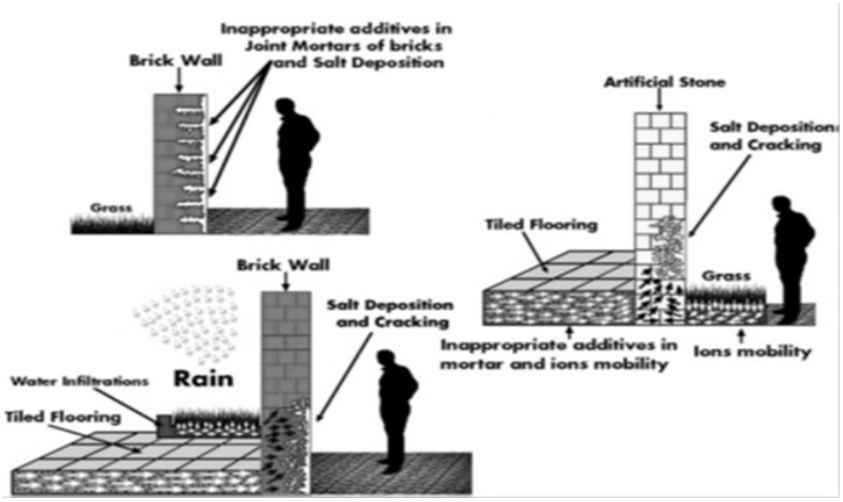

Figure. 3 Capillary effects on the efflorescence [27]

4.4 Design and Detailing

Poor wall that dissolves soluble salts. Rainwater that infiltrates or makes contact with masonry is the main source of moisture responsible for the occurrence of efflorescence material selection or craftsmanship can undermine even the most exquisite design and detailing. Conversely, it

should be noted that even if appropriate materials and good workmanship are employed, a structure will not necessarily be successful and enduring if the design is flawed. Efflorescence occurs when there is water in the masonry is the main source of moisture responsible for the occurrence of efflorescence. shown in Figure 4.

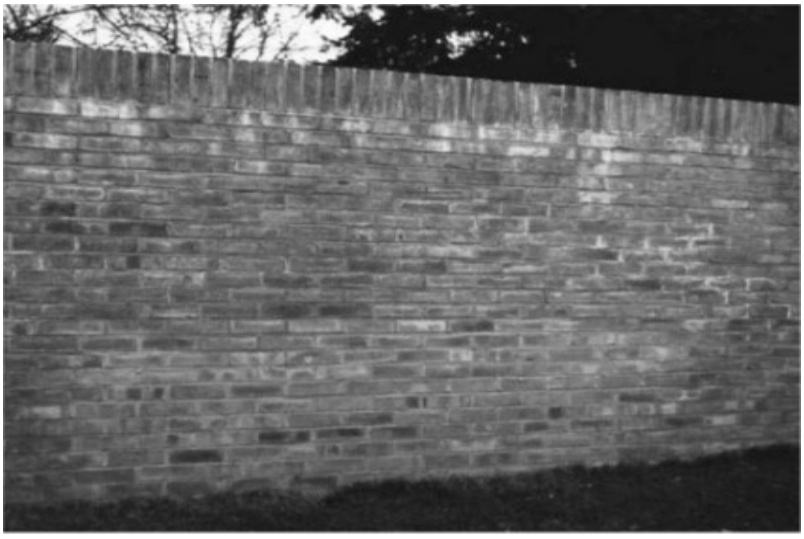

Figure. 4 Efflorescence from Water Penetrating Wall Top

Precipitation will infiltrate all masonry walls to varying extents, particularly if they are inadequately built or constructed.Restricting the presence of moisture effectively inhibits the formation of efflorescence. Consequently, the success of the project relies heavily on the careful design and meticulous consideration of specific crucial elements, especially those related to the prevention of moisture infiltration into the brickwork and the proper drainage of water from the tops of walls and horizontal surfaces [28].

5. Solutions of Efflorescence

5.1 Fuel Change

Most fuel types available in the burning process, with the exception of wood, anthracite cool, and coke, produce sulfur. Therefore, using these materials during the burning process will be more efficient [19].

5.2 Adding Salt

This technique involves adding types of salt, such as barium carbonate, to react with soluble salts found in clay, such as calcium sulfate, resulting in the creation of insoluble salts, including barium sulfate and calcium carbonate [29].

This approach is designed to reduce the amount of soluble salts, ultimately minimizing efflorescence on the surface of bricks or construction materials. This process's chemical reactions can be represented as follows:

$BaCO_3 (aq) + CaSO_4 (aq) \rightarrow BaSO_4 (s) + CaCO_3 (s)$

This reaction results in the formation of barium sulfate ($BaSO_4$) and calcium carbonate ($CaCO_3$), both of which are relatively insoluble in water. As a result, the brick's efflorescence is reduced. It's crucial to emphasize that while this method has been contemplated for managing efflorescence, its practical implementation and efficacy can be influenced by diverse factors. These factors include the clay's exact composition, current environmental conditions, and the concentration of soluble salts. Furthermore, the use of barium compounds necessitates careful consideration due to potential environmental and health-related concerns about barium [30].

5.3 Use of Nano coatings

Many researchers have tried to use the coating method of the brick wall surface to prevent the evaporation effect on the surface of bricks [19, 31]. The rapid evolution of nanotechnologies in construction emerged soon after their discovery, giving rise to an innovative generation of specialized building materials capable of addressing emerging market demands [32]. Nanotechnology integration facilitated the combination of these nanosized particles with organic components. This utilization aimed to create surface roughness while concurrently lowering surface free energy, leading to the development of materials with super hydrophobic properties [33]. Ginchitskaia *et al*. [34] used carbon nanotubes in the coating cover, which increased the mechanical properties by 30–35%. Another study coated the brick surface with ZnO nanoparticles through chemical deposition and modified it with silver nanoparticles to impart hydrophobic, photocatalytic, and antibacterial properties. The modified brick nanocomposites demonstrated increased flexural strength. The efflorescence test revealed that the flexural strength of the brick modified by ZnO/Ag was almost 1.8 times greater than that of the non-coated brick, and the modified brick exhibited reduced efflorescence on the surface [35]. The findings indicated a significant improvement in the efflorescence properties of the brick, leading to an increased interest in the utilization of nanomaterials.

5.4 Using new Technique

Efflorescence poses a major challenge for clay bricks due to its adverse environmental effects. This issue has a significant impact on the quality of the bricks and therefore is a challenge to address. This research presents a

way for a precise, efficient, and cost-effective technique to measure efflorescence. This has been accomplished by the development of an innovative, cost-effective, and high-performing electrical apparatus that delivers precise measurements of the salinity ratio. This technology has greatly decreased the typical duration for assessing efflorescence from 7-10 days to around one to three hours [36].

5.5 Using Additional Materials

Using new materials from available solid waste in the land is considered one of the methods for reducing waste in the environment [37–41]. For effect on the efflorescence phenomenon, much research has been done to use new materials in the clay brick composition to find their effect on the efflorescence [27]. Nhabih *et al*. [42] investigate the usage of silica fume. When adding silica fume by 15% of soil weight to the sample, it reduces the efflorescence by 92.3%. Riaz *et al*. [43] used brick kiln dust as a partial replacement for clay, which obtained that decrease in unit weight with a reduction of mechanical properties while increasing the resistance to the efflorescence. Zanelli *et al*. [44] investigate the usage of construction and demolition residual in the brick production. The obtained results indicate a decrease in the mechanical properties and increase the porosity in the brick with a reduction in the efflorescence. Argha and Bari [7] used fly ash in the mortar to react with some kind of available salt in the bricks moisture, which caused the reduction in the efflorescence.

6. Conclusions

Brick is one of the most used masonry units in wall construction. One of the primary challenges associated with using brick in wall construction is the efflorescence phenomenon. This article concludes with a strategic approach aimed at reducing the impact of factors that cause this phenomenon and mitigating their impact on the wall. The review yielded the following findings:

1. The main source of the problem in clay brick production is the availability of salt in the raw material; treating the soil before its use in the production industry could potentially solve part of the issue.
2. At the same time, more than one solution may be required for using the produced brick in external load-bearing walls.
3. When fine cementitious materials like silica fume are used in place of some clay, the efflorescence effect is reduced accurately and satisfactorily.
4. If the masonry wall is located on the external surfaces of the building, it may be more practical to use a coating material for these surfaces.

7. Summary of Recommendations

General

- Develop and build brickwork with the aim of optimizing its ability to withstand water infiltration.

- Accurately recognize the presence of efflorescence.
- Ascertain whether the efflorescence is a result of a new building bloom.
- Utilize the provided troubleshooting list to identify the underlying factors contributing to efflorescence, and address these reasons prior to attempting its removal.
- Take into account materials with lower levels of soluble salts.
- Coatings should not be relied upon as the only method to manage efflorescence.

Design

- Separate the outer layer of bricks from the rest of the structure by creating a gap filled with air.
- Apply a waterproofing treatment to the outer surface of walls that extend below ground level.
- To address walls that lack an air space, it is advisable to use a damp proof coating to create a separation between the brick and the backing.

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