Evaluation of a Cost-Effective Interior Flooring System Using Burnt Clay Brick for Residential Buildings

HDS Asoka[#1], HT Rupasinghe[1]

1Department of Architecture, Faculty of Built Environment and Spatial Sciences, General Sir John Kotelawala Defence University, Sri Lanka

[#] <asokahds@kdu.ac.lk>

Abstract— *Price escalation of construction materials and the economic crisis faced by the construction industry call the attention of building related professionals to experiment with cost effective material inventions. This research is initiated with the aim of developing a cost effective and an innovative interior flooring system using burnt red brick. The paper presents the findings of the initial step of the pilot study of the experimental research conducted to identify the potential of developing the proposed and to assess the feasibility interior flooring system using burnt red bricks. The proposed system involves laying tiles on a well-compacted quarry dust layer, filling grout gaps with fine-grinded brick powder mixed with a binder gum, and applying multiple layers of grinded brick and binder gum paste to achieve a mirror finish. The economic benefits of the burnet red brick flooring system were explored in comparison to traditional flooring options. Among the various flooring options, the brick flooring system stands out for its remarkable cost-effectiveness. Priced at Rs. 570.00 per square foot, it offers an affordable solution that combines sustainability and energy efficiency. The use of locally available materials, such as burnt clay bricks, contributes to its cost-effectiveness. These bricks are produced at lower firing temperatures compared to porcelain or ceramic tiles, resulting in significant energy savings during the manufacturing process. By utilizing red bricks, which are widely accessible, the system reduces the need for resource-intensive materials and minimizes the environmental impact associated with their extraction and production. The findings of this research provide valuable insights into the viability of this cost-effective flooring system within the field of architecture.*

Keywords— **Burnt clay brick, Interior flooring, cost-effectiveness, water absorption, architectural appearances.**

I. INTRODUCTION

The choice of flooring material greatly influences the overall aesthetics, functionality, and cost of residential buildings. Traditional options such as cement rendered floor, ceramic tiles, or hardwood flooring can be expensive and may not be sustainable in certain regions. This research aims to explore a cost-effective interior flooring system utilizing burnt clay bricks, which are widely available and have potential benefits in terms of cost effectiveness and physical properties.

The construction industry is very vital to the socioeconomic development and, in many countries, the yardstick for the measurement of national progress is hinged on the degree of contributions of the construction industry. The building materials sector is also a major contributor to the construction industry plays a crucial role in the socioeconomic development of many nations, often serving as a key gauge for measuring national progress. Additionally, the building materials sector significantly contributes to the construction industry of every nation, as materials represent the largest input in construction, typically constituting approximately half of the total cost of construction projects. Notably, around 60% of the total expenses for house construction are allocated to the acquisition of construction materials. The importance of materials in construction is immense, as they form the foundational basis for various other factors within the industry. A report from the United Nations categorizes the building materials sector into three distinct production groups:

1. Modern or Conventional Building Materials:

These materials, produced using contemporary methods such as concrete, steel, and glass, rely on modern conventional production techniques.

2. Traditional Materials:

This category encompasses materials that have been locally produced for centuries using small-scale rudimentary technologies, including laterite, gravel, thatch, straw, stabilized mud, Azara, and raphia palm.

3. Innovative Materials:

These materials are developed through research efforts aimed at providing alternatives to import-based materials. Examples include fiber-based concrete and ferrocement products.

One prominent building material is clay bricks, widely utilized in various construction applications, including building, civil engineering, and landscape design. Burnt brick, in particular, holds significant importance as a widely used building material globally. The origins of brick technology can be traced back to ancient Egyptian and Babylonian empires, with bricks being an integral part of the construction industry since approximately 8300 years BC (before Christ). Over the course of 10,000 years, bricks have evolved to play a pivotal role in structural constructions, facilitating the construction of multi-story buildings. Bricks seamlessly combine functionality with aesthetics, shifting the construction industry from a position subordinate to weather influences to one capable of withstanding the test of centuries. Bricks are recognized for their recyclability, health-friendly attributes, anti-allergenic properties, fire resistance, and chemical resistance. They have served as the cornerstone of construction since the 19th century and continue to be extensively utilized in various construction projects, offering resistance against weather conditions while simultaneously contributing functional and aesthetic value.

The quality of a good brick is characterized by its hardness, proper burning, uniformity in texture and colour, and precision in shape and dimension. It should also withstand impacts, such as being struck against another brick or dropped from a height of approximately one meter. Achieving certain desirable properties in burnt clay bricks is essential for their use in construction, including compressive strength, density, thermal stability, porosity, sound insulation, fire resistance, and overall durability. Compressive strength, a key mechanical property, is easily determinable and holds great importance due to its influence on other properties such as flexural strength and resistance to abrasion. Compressive strength depends on factors including the raw materials used, the manufacturing process, and the shape and size of the brick. Generally, compressive strength decreases with increasing porosity but is also influenced by clay composition and firing (Gopi,2009; Okunade,2008; Adeola,1977; Emmitt and Gorse,2005; Okunade,2008).

Density, describing the ratio of dry brick weight to the volume of the clay brick, reflects the proportion of matter (clay) within the volume. Higher density results in denser bricks, which exhibit enhanced mechanical and durability properties. Bricks generally exhibit better thermal insulation properties than other building materials like concrete. Perforation can improve thermal insulation to some extent. The mass and moisture of bricks help maintain stable internal temperatures. Thermal conductivity of bricks varies between 0.7 and 1.3 w/mk. Porosity, defined as the ratio of void spaces (pores and cracks) to the total volume of the specimen, is vital in clay bricks due to its impact on properties such as chemical reactivity, mechanical strength, durability, and overall quality. Pore characteristics are influenced by factors such as raw clay quality, additives, impurities, water content, and firing temperature (Fernandes et.al,2009; Clay bricks & Tiles, 2010).

Studies have shown that the firing temperature significantly affects pore size distribution, with higher temperatures increasing larger pores (3–15 μm) and reducing pore connectivity while diminishing smaller pores. Carbonates in raw clay and firing temperatures between 800 and 1,000°C promote the formation of small pores, below 1 μm in diameter, which negatively impact brick quality by increasing water absorption and retention. A similar conclusion was given by Winslow et al., for bricks with a pore size smaller to 1.5 μm. Brick has excellent fire resistance. 100 mm brickwork with 12.5 mm normal plastering would provide a fire-resistance of 2 hours and 200 mm non-plastered brickwork would give a maximum rating of 6 hours for non-load bearing purposes. The durability of a material is its ability to withstand a particular recurrent weathering effect without failure. Burnt clay bricks are known for their exceptional durability, as evidenced by numerous ancient brick buildings that have stood for centuries, showcasing the enduring nature of burnt-clay bricks.

However, the construction industry faces environmental challenges, including carbon impact and finite resource depletion associated with materials like concrete, steel, and bricks. The carbon impact and problem of finite resource depletion associated with concrete, steel and bricks need to be addressed to align with national and international requirements and legislations, the construction industry must prioritize reducing its negative environmental impact. In this regard, research experiments with new materials and innovative usage of existing materials is vital. As discussed above, burnt red clay brick is a common material in both local and international context. This research aims to investigate the use of this material as an internal flooring system for residential purpose in local context.

The objective of this research is to evaluate the properties and cost-effectiveness of the proposed interior flooring system using burnt clay bricks for residential buildings. The study will investigate water absorption, wear and tear resistance, strength, architectural appearances, and overall cost effectiveness.

II. METHODOLOGY

Materials:

The primary materials used in the flooring system include burnt clay bricks, quarry dust, finely ground burnt brick powder, and binder gum. These materials were selected based on their availability, cost-effectiveness, and potential performance as an alternative flooring solution.

Construction Process:

The cost-effective interior flooring system using burnt clay bricks was constructed following a specific procedure. The construction process involved the following steps:

a) Selection of Materials:

- Burnt Clay Bricks: The bricks used in the flooring system were of size 215mm x 102.5mm x 65mm, obtained from a reliable source.
- Quarry Dust: A well-compacted layer of quarry dust with a thickness of 75mm was prepared as the base layer for the flooring system.
- Finely Grinded Brick Paste: A brick paste was prepared by finely grinding burnt clay bricks, which was then mixed with binder gum to create a homogeneous mixture. The thickness of the brick paste layer applied between the bricks was maintained at 3-4mm.

b) Construction of the Flooring System:

- The sample area for the flooring system construction was prepared with dimensions of 1200mm x 1200mm.
- The compacted quarry dust layer was evenly spread and compacted to achieve a uniform and stable base for the flooring.
- The bricks were laid in a desired pattern on the compacted quarry dust layer, ensuring proper alignment and spacing between them.
- The gaps between the bricks were filled with the prepared finely grinded brick paste mixed with binder gum. The paste was evenly spread and leveled to fill the gaps completely.
- The top surface of the flooring system was cut and smoothed to achieve a uniform and level finish.
- After the initial construction, the flooring system was kept for curing for a period of 12 hours to enhance the bonding and strength of the materials.

c) Sanding and Finishing:

- Following the curing period, the top surface of the flooring system was sanded using appropriate sanding equipment. This process helped in achieving a polished and mirrored finish.
- Multiple layers of brick powder mixed with binder gum were applied to the sanded surface to enhance the architectural appearance and durability of the flooring system.

III. TESTING AND EVALUATION:

a) Water Absorption: As this interior flooring system using burnt clay bricks was constructed in-situ, testing the water absorption for the entire construction was not feasible. To overcome this challenge, a specific approach was adopted. A sample brick treated with three finishing layers of the same brick powdered paste. The surface was then sanded to achieve the same surface quality as the rest of the construction. This treated brick sample was used to test the water absorption property. The water absorption test was conducted on the treated brick sample according to the appropriate standard procedures.

b) Wear and Tear Resistance: Due to limitations in resources and equipment, an abrasion resistance test was not conducted for this research. Therefore, the wear and tear resistance of the flooring system was evaluated through visual inspection and observation over time. The flooring system was monitored for any signs of wear, scratches, scuffs, or loss of material during the course of the study. The performance and durability of the flooring system were assessed based on its ability to withstand normal usage conditions and resist damage caused by foot traffic and regular activities.

c) Architectural Appearances: The architectural appearances of the flooring system were evaluated based on visual inspection and subjective assessments. The finished surface of the flooring system was observed for its overall aesthetics, including texture, color, and surface finish. The quality of the applied finishing layers and their ability to enhance the architectural appearance of the flooring system were considered.

IV. RESULTS & DISCUSSIONS

Water Absorption: The water absorption property of the cost-effective interior flooring system using burnt clay bricks was evaluated. The bricks used in this construction had a water absorption level of 19%. However, by incorporating a finely grinded brick powder layer on the surface, the water absorption level was significantly reduced to 5.7%. This reduction in water absorption level is remarkable and surpasses even the water absorption level of terracotta tiles, which typically range between 8-10%. The invented flooring system exhibits a water absorption level similar to commercially used tiles. This can be attributed to the small size particles of the crushed bricks used in the construction. Additionally, since the bricks used were fired, the clay body has comparatively low water absorption. The incorporation of binder gum in the construction process not only improves the binding capacity but also enhances the water resistance properties of the flooring system.

The reduction in water absorption achieved by adding the finely grinded brick powder layer and binder gum improves the overall durability and longevity of the flooring system. Lower water absorption reduces the risk of water damage, such as warping, cracking, or deterioration, which is critical for maintaining the structural integrity and appearance of the flooring system over time.

The findings highlight the effectiveness of the proposed method in enhancing the water resistance properties of the cost-effective interior flooring system. The combination of crushed brick particles and binder gum creates a surface that is more resistant to water penetration, making it suitable for various residential applications.

Cost effectiveness: Construction costs for the experimental flooring system were as follows.

Table 1: Construction costs for the experimental flooring system

	Cost type	Qty	Unit of Measure	Total cost (Rs)
1.0	Material Cost			
1.1	[illegible] charges of the machine [illegible]	[illegible]	Cube	[illegible]
[illegible]	Supplying [illegible] bricks	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Sanding Paper	[illegible]	[illegible]	[illegible]
[illegible]	Equipment	3.00	Hour	[illegible]
2.0	Labour Cost			
2.1	Skill Labour	[illegible]	Hour	[illegible]
2.2	Unskilled Labour	3.00	Hour	[illegible]
	Total Amount			[illegible]
	Per sq ft rate			[illegible]

According to the above data, square foot rate for the brick flooring system is Rs. 570.00. it is the most affordable flooring system when it compared with the other conventional flooring materials.

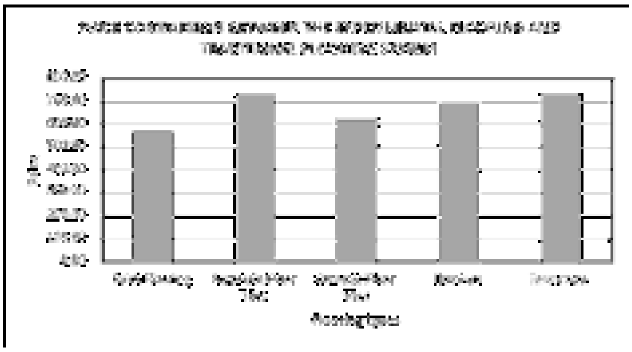

Figure 1: Price comparison between the experimental flooring and traditional flooring system

Among the various flooring options, the brick flooring system stands out for its remarkable cost-effectiveness. Priced at Rs. 570.00 per square foot, it offers an affordable solution that combines sustainability and energy efficiency. The use of locally available materials, such as burnt clay bricks, contributes to its cost-effectiveness. These bricks are produced at lower firing temperatures compared to porcelain or ceramic tiles, resulting in significant energy savings during the manufacturing process.

Furthermore, the brick flooring system aligns with sustainable practices. By utilizing red bricks, which are widely accessible, the system reduces the need for resource-intensive materials and minimizes the environmental impact associated with their extraction and production. Additionally, the construction process incorporates finely ground brick powder mixed with binder gum, enhancing water resistance and durability without relying on resource-intensive alternatives.

This cost-effective flooring option not only saves on manufacturing costs but also promotes a sustainable approach to construction. It reduces energy consumption, minimizes reliance on imported or specialized materials, and supports the local economy. By highlighting these factors, it becomes evident that the brick flooring system offers a compelling combination of cost-effectiveness, energy efficiency, and sustainability in comparison to other flooring options available in the market.

V. CONCLUSION

water absorption poses a significant challenge in the context of flooring systems. Conventional flooring materials, such as impervious porcelain tiles, exhibit an exceptional water absorption rate of less than 0.5%. Vitreous porcelain ranges from 0.5% to 3%, while ceramic tiles range from 3% to 7%. Achieving such minimal water absorption rates necessitates the synthesis of raw materials at exceedingly high temperatures. Porcelain tiles, for instance, require firing temperatures ranging from 1200 to 1500 degrees Celsius. Even ceramic tiles, which are comparably lower in firing temperature than porcelain, still surpass the firing temperature of red bricks. This energy-intensive manufacturing process of porcelain or ceramic tiles presents significant sustainability concerns.

In contrast, the proposed cost-effective interior flooring system utilizing burnt clay bricks offers a sustainable and viable alternative. The primary material employed in this system is red brick, a widely available resource fired at lower temperatures than porcelain or ceramic. Red bricks typically undergo firing temperatures ranging from 800 to 1000 degrees Celsius. By leveraging red bricks as the fundamental component, the flooring system achieves energy savings during manufacturing, rendering it an environmentally-friendly choice.

The findings of this research project demonstrate that incorporating a finely ground brick powder layer and binder gum substantially reduces the water absorption of the flooring system. The achieved water absorption level is comparable to that of commercially-used tiles, signifying excellent water resistance properties for the flooring system. This successful mitigation of a critical challenge in flooring systems is accompanied by the utilization of sustainable materials.

The cost-effective interior flooring system not only enhances water resistance but also showcases architectural appearances akin to commercially available tiles. The application of multiple layers of brick powder mixed with binder gum results in a polished and mirrored finish that enhances the overall aesthetic appeal of the flooring system.

In summary, the proposed cost-effective interior flooring system utilizing burnt clay bricks offers a sustainable and innovative solution to combat the issue of water absorption in flooring systems. By harnessing the advantages of widely accessible red bricks fired at lower temperatures, the system reduces energy consumption during the manufacturing process. Furthermore, the incorporation of a finely ground brick powder layer and binder gum significantly elevates water resistance, creating a durable and visually captivating flooring option for residential buildings. Future research endeavors can explore additional optimizations and applications for this groundbreaking flooring system.

According to the findings, the cost-effective interior flooring system utilizing burnt clay bricks demonstrates promising prospects, combining exceptional water resistance, sustainability, and architectural allure in a cost-effective manner.

REFERENCES

Kibert, C. J. (2008). Sustainable Construction: Green Building Design and Delivery.

Calkins, M. (2011). Materials for Sustainable Sites: A Complete Guide to the Evaluation, Selection, and Use of Sustainable Construction Materials.

Chiras, D. D. (2004). Sustainable Construction and Design.

Ashworth, A. (2019). Cost Studies of Buildings.

S. Gopi, Basic Civil Engineering, Pearson Education, Delhi, India, 2009

Trotter, C. G. (2001). Flooring Handbook: Planning, Installation, and Maintenance.

Allen, E., Iano, J., & Zalewski, A. (2020). Fundamentals of Building Construction: Materials and Methods.

Reznikoff, S. J. (2015). Construction Waterproofing Handbook.

Magee, B. (2016). Green Building: Project Planning & Cost Estimating.

Plevin, R. J. (2019). Sustainable Construction: Green Building Design and Delivery.

Pan, W. (2018). Building Construction: Principles, Materials, and Systems

E. A. Okunade, "Engineering properties of locally manufactured burnt brick pavers for Agrarian and rural earth roads," American Journal of Applied Sciences, vol. 5, no. 10, pp. 1348– 1351, 2008.

J. O. Adeola, A review of masonry block/brick types used for building in Nigeria [M.S. thesis], University of Benin, Benin City, Nigeria, 1977.

S. Emmitt and C. A. Gorse, Barry's Introduction to Construction of Buildings, Wiley Blackwell, 2nd edition, 2005

F. M. Fernandes, B. M. Paulo, and C. Fernando, "Ancient clay bricks: manufacture and properties," in Materials, Technologies and Practice in Historic Heritage Structures, M. Bostenaru Dan, R. Pˇrikryl, and A. T ´ or¨ ok, Eds., pp. 29–48, Springer, 2009. ¨

Claybricks & Tiles, 2010, http://www.claybricks.comAvailable at Accessed 19/05/14.

G. Cultrone, E. Sebastian, K. Elert, M. J. de la Torre, O. Cazalla, ´ and C. Rodriguez-Navarro, "Influence of mineralogy and firing temperature on the porosity of bricks," Journal of the European Ceramic Society, vol. 24, no. 3, pp. 547–564, 2004.

K. Elert, G. Cultrone, C. Rodriguez Navarro, and E. Sebastian´ Pardo, "Durability of bricks used in the conservation of historic buildings—influence of composition and microstructure," Journal of Cultural Heritage, vol. 4, no. 2, pp. 91–99, 2003.

D. N. Winslow, C. L. Kilgour, and R. W. Crooks, "Predicting the durability of bricks," Journal of Testing and Evaluation, vol. 16, no. 6, pp. 527–531, 1988.