Research on using brick and colored glass wall waste to make decorative ventilation bricks

Nguyen Le Duy Dang[1,*], Nguyen Thanh Thao[2], Le Thi Thu Hang[3] and Le Quoc Tien[3]

[1] Class XD22D04 - Faculty of Civil Engineering - Mien Tay Construction University;
[2] Class XD23D04 - Faculty of Civil Engineering - Mien Tay Construction University;
[3] Faculty of Civil Engineering - Mien Tay Construction University;
*Corresponding author: nlddangxd22d04@mtu.edu.vn

■ Received: 19/08/2025 ■ Revised: 08/09/2025 ■ Accepted: 13/10/2025

ABSTRACT

This study proposes a solution to recycle brick and colored glass waste to produce decorative ventilation bricks, in order to reduce environmental pollution and save natural sand resources. Experimental samples were designed with the replacement ratio of natural sand with waste mixture (50% broken bricks + 50% colored glass) of 25%, 50% and 75%, respectively. The results showed that the 25% replacement sample achieved a compressive strength of 9.18 MPa and a flexural strength of 1.92 MPa after 28 days of curing, meeting the TCVN 3121-11:2022. Replacement ratios above 50% significantly reduce mechanical properties due to high porosity and poor bonding performance. These ventilation brick products have the potential for practical application in civil works, contributing to reducing 25% of raw material costs and 30% of construction waste landfilled. The study demonstrates the feasibility of using recycled materials in the production of environmentally friendly building materials.

Keywords: *Compressive strength, flexural strength, ventilation bricks, wall waste, recycled glass, sustainable materials, recycled materials.*

1. INTRODUCTION

The global construction industry generates more than 10 billion tons of waste annually, of which masonry debris and glass account for 30–40% of the total volume [1]. In Vietnam, an estimated 23 million tons of construction waste are produced each year, yet only 10–15% is recycled [2]. This results in severe overloading of landfills and significant environmental pollution. In particular, in the Mekong Delta (MKD), excessive extraction of natural sand has caused riverbank erosion, soil degradation, and saltwater intrusion [3]. Ventilation blocks (breeze blocks) are widely used decorative materials in tropical architecture, enhancing natural air circulation and reducing energy consumption. However, traditional production still relies on natural sand and clay, without utilizing abundant waste resources. This study addresses two urgent issues: (1) reducing pressure on landfills through recycling construction waste, and (2) conserving natural sand resources by developing sustainable alternative materials.

Recent studies have demonstrated the potential of construction waste in producing new materials. Le Quoc Tien used recycled masonry aggregate sourced from demolished 100-mm brick walls of grade-4 houses to produce non-fired bricks with a compressive strength of 75, indicating broad practical applicability [4]. Meanwhile, Ngo Kim Tuan investigated the use of recycled aggregates from construction and industrial waste to produce permeable concrete blocks capable of draining rainwater, preventing flooding, and mitigating urban heat island effects [5].

According to Jaman M. Khatib, recycled aggregates—crushed concrete (CC) or crushed brick (CB) with particle sizes smaller than 5 mm—were evaluated while keeping the free water-to-cement ratio constant across mixtures. Fine aggregate in concrete was replaced with 0%, 25%, 50%, and 100% CC or CB. Overall, strength decreased by 15–30% in concrete containing CC. However, concrete with up to 50% CB exhibited long-term strength similar to the control mix, and even with 100% CB replacing fine aggregate, the strength decreased by only 10% [1].

Waste glass has also been explored for potential reuse. Ho Viet Thang concluded that waste glass can meet the required criteria for use in concrete, demonstrating its feasibility as a sand replacement [3]. Research by Le Duc Hien, Vo Van Thao, and Nguyen Ngoc Chien evaluated the workability, compressive strength, elastic modulus, and sulfate resistance of concrete using recycled glass aggregate as a substitute for natural fine aggregate (sand) [6].

Several domestic studies have proposed substituting waste glass in construction materials. According to Truong Hoai Chinh and Huynh Thi My Dung, partially or fully replacing coarse aggregate with glass aggregate is feasible in terms of compressive strength, while also contributing to the treatment of local medical solid waste and yielding a construction material with practical applicability. Their findings also showed that the compressive strength of glass concrete strongly depends on the mechanical properties of the glass material [7].

Research by Le Thi Thu Hang, Le Quoc Tien, and Nguyen Van Ket revealed that samples containing 25% and 50% glass replacement exhibited variations in compressive strength within ±20%. The 75% glass mixture showed an approximately 30% increase in strength compared with the 100% sand mixture, indicating that finely ground glass can fully replace sand in construction to help reduce excessive sand exploitation [8].

Furthermore, Batayneh Malek, Marie Iqbal, and Asi Ibrahim conducted tests on workability, unit weight, compressive strength, flexural strength, and splitting tensile strength. Their key findings showed that glass is one of three waste materials that can be successfully reused as a partial replacement for sand or coarse aggregate in concrete mixtures [9].

However, no study to date has simultaneously combined masonry waste and glass waste to produce ventilation blocks—a research gap that this study aims to address. This combination not only leverages the complementary characteristics of the two waste types (coarse particles from crushed brick and fine particles from glass) but also creates aesthetically appealing products thanks to the color effects of glass.

2. RESEARCH CONTENT

2.1. Materials

2.1.1. Brick masonry waste

Brick masonry waste was collected from buildings undergoing demolition, specifically from the Project for Upgrading the Administration Building and the Teaching Facilities in Area A of the Mien Tay Construction University. This approach aimed to utilize available local waste sources and contribute to the management of construction solid waste.

Figure 1. Brick masonry waste from demolition works in Area A – Mien Tay Construction University

2.1.2. Glass Waste

Glass waste was collected from daily household products (bottles, jars, glass containers, etc.) and reclaimed glass from used construction materials.

2.1.3. Cement

The cement used in this study was Vicem Ha Tien PCB40 multipurpose cement, a commonly used blended Portland cement meeting all technical requirements specified in TCVN 6260:2020 [10]. This product exhibits stable quality and is widely applied in civil and industrial construction. According to the manufacturer, its compressive strength reaches 24.50 MPa after 3 days and 44.70 MPa after 28 days, exceeding the minimum requirement (≥40 MPa) for PCB40, ensuring good early-age and long-term strength development.

Figure 2. Vicem Ha Tien PCB40 cement

2.1.4. Water

The water used in this study was domestic water supplied by the Construction and Environmental Laboratory Center of Mien Tay Construction University, meeting all standards for domestic use.

2.1.5. Sand

Sand was sourced from Vinh Long City with a bulk density of approximately 1450.40 kg/m³, a fineness modulus (FM) of around 1.70, and physical–mechanical properties meeting the requirements of TCVN 7570:2006 [11].

2.2. Research Methods

The research team reviewed previous studies related to the use of masonry and glass waste as sand replacement materials in brick production, followed by experimental fabrication and strength evaluation of ventilation bricks.

Based on available scientific literature, four mix designs were developed, including one control mix and three mixes replacing 25%, 50%, and 75% of natural sand with a waste mixture consisting of 50% crushed brick and 50% crushed colored glass. This replacement ratio was selected primarily because the fineness modulus (FM) of masonry waste and glass waste differs significantly from that of natural sand (FM = 1.7). Therefore, combining the two waste materials (per TCVN 10796:2015 [12]) yields an FM closer to that of natural sand, meeting the design objectives.

The samples were produced using a layered compaction method, consisting of two outer layers of wet mortar for product surfaces and a core layer of adequately moist mortar to ensure high compaction and minimal voids. For each mix, three specimens were cast; flexural strength was taken as the average of three tests, while compressive strength was the average of six tests. Finally, the potential of replacing sand with waste materials in ventilation brick production was assessed through mechanical indicators. It is noted that masonry waste shares a similar mineral composition with natural sand and can be crushed to appropriate sizes, while glass waste contains SiO_2 as its main component, making partial replacement feasible.

2.3. Mix Proportions

Based on Circular No. 12/2021/TT-BXD dated August 31, 2021, issued by the Ministry of Construction [13], the material consumption for 1 m³ of mortar using PCB40 cement and fine sand for 75-grade mortar is presented below.

Table 1: Material consumption for 1 m³ of mortar

Cement (kg)	Sand (kg)	Water (kg)
301	1599,42	281

Using these values, four mix proportions (M1–M4) were developed, where 50% masonry waste and 50% crushed glass replaced 25%, 50%, and 75% of the sand content.

Table 2: Description of mix samples

Sample	Sand Replacement (%)	In the Replacement Mixture	
		Brick Masonry Waste (%)	Glass Waste (%)
M1	0	0	0
M2	25	50	50
M3	50	50	50
M4	75	50	50

Table 3: Mix proportions for M1 (Control)

M1 (Control)	Sand	Cement	Water	Total
Content (%)	73,30	13,80	12,90	100,00
Mass (kg)	6,40	1,20	1,10	8,70

Table 4: Mix proportions for M2

M2	Sand	Cement	Brick Masonry Waste	Glass Waste
Content (%)	55,17	13,80	9,20	9,20
Mass (kg)	4,80	1,20	0,80	0,80

Table 5: Mix proportions for M3

M3	Sand	Cement	Brick Masonry Waste	Glass Waste
Content (%)	36,80	13,80	18,40	18,40
Mass (kg)	3,20	1,20	1,60	1,60

Table 6: Mix proportions for M4

M4	Sand	Cement	Brick Masonry Waste	Glass Waste
Content (%)	18,40	13,80	27,60	27,60
Mass (kg)	1,60	1,20	2,40	2,40

2.4. Experimental Procedure

- Step 1: Collect raw materials, followed by cleaning, breaking, and grinding.

Figure 3. Breaking and coarse grinding of materials

Figure 4. Fine grinding of brick masonry waste

Figure 5. Fine grinding of glass waste

- Step 2: Determine particle size distribution and fineness modulus. To analyze particle size distribution and material coarseness, sieve analysis and fineness modulus determination were conducted following TCVN 7572-2:2006. A 100 g sample was dry-sieved through sieves of 5 mm, 2.5 mm, 1.25 mm, 0.63 mm, 0.315 mm, 0.14 mm, and <0.14 mm. Based on the results, fineness modulus (FM) and bulk density were calculated.

Table 7: Fineness modulus and bulk density

Material	FM	Bulk Density (kg/m^3)
Brick masonry waste	2,08	1075,90
Glass waste	1,23	1345,30
Sand	1,70	1450,40

- Step 3: Weighing and mixing materials according to the mix designs. Dry mixing was performed first to ensure uniform distribution, followed by wet mixing to achieve homogeneity.

Figure 6. Weighing raw materials

Figure 7. Mixing component materials

- Step 4: Casting ventilation bricks with dimensions 20 × 20 × 10 cm and test specimens with dimensions 40 × 40 × 160 mm. The mix included two outer layers of wet mortar to form the product faces and an inner layer of adequately moist mortar. Layered compaction was applied to ensure high density and minimize voids.

Figure 8. Molding using the compaction method

2.5. Strength Testing

After curing, specimens with dimensions 40 × 40 × 160 mm were tested for mechanical properties, including compressive and flexural strength, in accordance with TCVN 3121-11:2022 [14], to evaluate their applicability in construction.

For each mix, three specimens were cast. Flexural strength was determined as the average of three tests, while compressive strength was calculated as the average of six tests to ensure reliability.

Figure 9. Flexural testing process

Figure 10. Compressive testing process

3. RESULTS AND DISCUSSION

3.1. Research Results

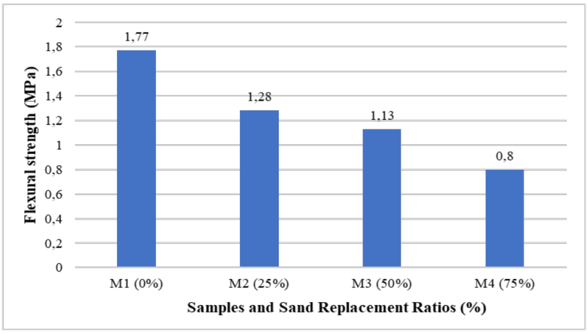

Figure 11. Variation of flexural strength according to sand replacement ratios at 7 days.

The average flexural strength results show a clear decreasing trend as natural sand is increasingly replaced by the mixture of brick masonry waste and colored glass. Among the samples, M4 exhibits the lowest strength at 1.21 MPa, representing a reduction of 55% relative to M1. Sample M2 shows an average flexural strength of 1.92 MPa, which remains mechanically sufficient for decorative ventilation blocks, confirming the feasibility of replacing natural sand with the waste mixture at a 25% ratio.

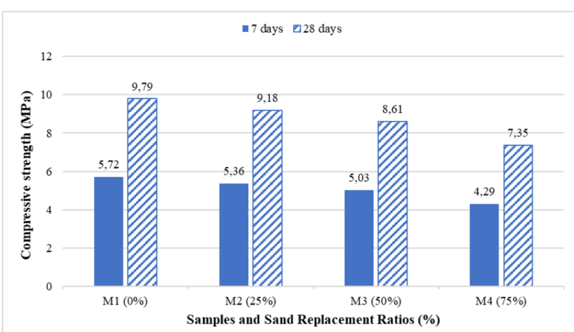

Figure 12. Variation of compressive strength according to sand replacement ratios at 7 and 28 days.

The test results indicate that sample M1 achieves the highest compressive strength, with 5.72 MPa at 7 days and 9.79 MPa at 28 days. These values reflect effective hydration, strong particle bonding, and a dense matrix when using fully natural sand. Sample M4 shows the lowest compressive strength, with 4.29 MPa at 7 days and 7.35 MPa at 28 days. Sample M2 reaches 5.36 MPa at 7 days and 9.18 MPa at 28 days. Maintaining high strength at both stages demonstrates the mechanical stability and practical applicability of M2 for producing ventilation blocks—products that do not require high compressive strength but demand uniformity and durability.

3.2. Discussion

Experimental results demonstrate that replacing natural sand with brick masonry waste and colored glass in the production of ventilation blocks is entirely feasible. At a 25% replacement ratio (sample M2), the product still meets compressive and flexural strength requirements, approaching the control sample. This confirms the practical applicability of recycled materials in decorative construction.

However, one notable physical property of brick masonry waste is its high water absorption. Therefore, careful control of the water content in the mix design is essential. Insufficient water during mixing may lead to “water-starved” cement paste, creating porous zones, weakening interfacial bonding, and significantly reducing the final strength.

Furthermore, long-term physical and chemical behaviors should also be investigated, including moisture resistance, salt resistance, and mold resistance. Optimization of the mortar mix using mineral additives, superplasticizers, or additional binders may further enhance strength. Large-scale production processes and industrial design considerations should also be explored to facilitate product commercialization.

4. CONCLUSION

Based on the experimental investigation using brick masonry waste and colored glass as partial replacements for natural sand in decorative ventilation block production, the research team draws the following conclusions and recommendations:

** Conclusions:*

- At a 25% replacement level of natural sand with brick masonry waste and colored glass, ventilation blocks still satisfy compressive and flexural strength requirements and closely match the control sample;

- Experimental results show that replacing sand at levels of 50–75% leads to significant reductions in both compressive and flexural strength; specifically, sample M4 (75%) fails to meet the requirements of Circular No. 12/2021/TT-BXD. Therefore, a recommended replacement ratio should not exceed 25%;

- These findings contribute to construction waste management, reducing natural sand consumption, and the promotion of green material production, thereby supporting sustainable development and urban environmental protection;

**Recommendations:*

- Practical application: Ventilation blocks containing ≤ 25% brick masonry waste and colored glass are suitable for partition walls, ventilation structures, and exterior non-load-bearing applications. The material also aligns with green architecture and sustainable ecological design.

- For future studies**:** In addition to strength evaluation, further analysis should focus on water absorption, aggregate size and shape, and block porosity to clarify their influence on mechanical behavior and product quality.

ACKNOWLEDGMENT

The authors would like to thank the Mien Tay Construction University for funding the student research project "Research on using brick and colored glass wall waste to make decorative ventilation bricks," Project Code: SV.25.03.

REFERENCES

[1] J.M. Khatib, "*Properties of concrete incorporating fine recycled aggregate*," Cement and Concrete Research, 35(4), 763–769, 2005.

[2] Ministry of Construction, *Report on the Environmental Status of Vietnam's Construction Sector 2023*, Hanoi, 2023.

[3] H.V. Thang, "*Study on reusing waste glass as a replacement for natural sand in M300 concrete production*," Journal of Science and Technology – University of Danang, 21(8.2), 75–79, 2023.

[4] L.Q. Tien, "*Designing mortar mix using brick masonry waste for non-fired brick production*," Journal of Construction, 8, 90–94, 2023.

[5] Ngo Kim Tuan, "*Study on the use of construction waste and industrial by-products for producing hollow concrete blocks*," Journal of Science and Technology in Construction, 14, 106–117.

[6] Le Duc Hien, Vo Van Thao, and Nguyen Ngoc Chien, "*Reusing waste glass as aggregate in concrete mixtures*," Journal of Construction, 05, 63–67, 2022.

[7] Truong Hoai Chinh and Huynh Thi My Dung, "*Study on mix design of medical glass aggregate for concrete production*," Journal of Science and Technology – University of Danang, 5(126), 6–8, 2018.

[8] Le Thi Thu Hang, Le Quoc Tien, and Nguyen Van Ket, "*Evaluation of compressive strength of cement mortar using glass as sand replacement*," *JSTE-MTU*, 11, 82–89, 2024.

[9] Batayneh Malek, Marie Iqbal, and Asi Ibrahim, "*Use of selected waste materials in concrete mixe*s," Waste Management, 27(12), 1870–1876, 2007.

[10] Ministry of Science and Technology, TCVN 6260:2020, *Blended Portland Cement – Specifications*, 2020.

[11] Ministry of Science and Technology, TCVN 7570:2006, *Aggregates for Concrete and Mortar – Specifications*, 2006.

[12] Ministry of Construction, TCVN 10796:2015, *Fine Aggregates for Concrete and Mortar*, 2015.

[13] Ministry of Construction, *Circular No. 12/2021/TT-BXD on Promulgation of Construction Norms*, 2021.

[14] Ministry of Science and Technology, TCVN 3121-11:2022, *Building Mortar – Test Methods – Part 11: Determination of Flexural and Compressive Strength of Hardened Mortar*, 2022