

UTILISING PET PLASTIC AND GLASS WASTE IN MANUFACTURING OF MASONRY BRICKS

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Received:	02/4/2024	Nowadays, the manufacturing process of burnt clay masonry bricks causes serious environmental pollution such as loss of agricultural land, climate change. Besides, PET plastic and glass waste also cause serious problems for the environment. Therefore, we reuse PET plastic and glass waste to produce masonry bricks aiming to minimize the environmental harm caused by burnt clay bricks and these wastes. Different PET plastic/glass mass ratios are performed to produce masonry bricks. The brick samples are evaluated for bulk density, compressive strength, bending strength, water absorption and compared with burnt clay brick samples. The results show that the bulk density, compressive strength, and bending strength of brick samples made from PET plastic and glass waste are higher than those of burnt clay brick samples, while water absorption is much smaller than that of burnt clay brick samples. The best brick sample in this study is the M37 sample with a compressive strength of 33.9 MPa which is 3 times higher than the burnt clay brick samples.
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NGHIÊN CỨU SẢN XUẤT GẠCH XÂY DỰNG SỬ DỤNG NHỰA PET VÀ THỦY TINH PHÉ THẢI

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THÔNG TIN BÀI BÁO		TÓM TẮT
Ngày nhận bài:	02/4/2024	Ngày nay, quá trình sản xuất gạch xây dựng bằng đất sét nung gây ô nhiễm môi trường nghiêm trọng như mất đất nông nghiệp, biến đổi khí hậu. Bên cạnh đó, chất thải nhựa PET và thủy tinh cũng gây ra những vấn đề nghiêm trọng cho môi trường. Vì vậy, chúng tôi tái sử dụng nhựa PET và thủy tinh phế thải để sản xuất gạch xây dựng nhằm giảm thiểu tác hại đến môi trường do gạch đất sét nung và các chất thải này gây ra. Các tỷ lệ nhựa/thủy tinh khác nhau được khảo sát để sản xuất gạch xây dựng. Các mẫu gạch này được đánh giá về khối lượng thể tích, cường độ nén, cường độ uốn, độ hút nước và so sánh với các mẫu gạch đất sét nung. Kết quả cho thấy khối lượng thể tích, cường độ nén, cường độ uốn của các mẫu gạch làm từ nhựa PET và thủy tinh phế thải cao hơn mẫu gạch đất sét nung, trong khi đó độ hút nước nhỏ hơn nhiều so với mẫu gạch đất sét nung. Mẫu gạch tốt nhất trong nghiên cứu này là mẫu gạch M37 có cường độ chịu nén 33,9 MPa cao gấp 3 lần so với mẫu gạch đất sét nung.
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1. Introduction

In order to promptly meet the strong socioeconomic development and increase in population, the construction of infrastructure is increasing accordingly. This is also the reason that motivates the rapid development of the construction materials industry in general and masonry bricks in particular. However, masonry bricks have been mainly produced by burnt clay. This manufacturing process causes serious problems with environmental pollution from the loss of agricultural land to the pollution of the gaseous environment because the bricks are burnt by using mainly coal. It is estimated that to produce one billion burnt clay bricks, it consumes about 1.5 million m³ of clay, 150 thousand tons of coal and emits about 0.57 million tons of CO₂ and SO₂ [1]. Therefore, in recent years, the State has promoted the production of unburnt masonry bricks in order to reduce environmental pollution caused by burnt clay brick manufacturing process. Although unburnt masonry bricks have reduced environmental harm due to the reduction in the use of clay and coal, the production of unburnt bricks still causes environmental pollution because the main raw materials used in this current process are cement and natural sand. According to calculations, for each ton of cement production, 0.8-0.9 tons of CO₂ are emitted into the environment [2]. Sand or crushed stone used in the production of unburnt bricks also has harmful impacts on the environment because sand mining generates deep holes, changes the direction of riverbed flow and results in massive whirlpools. This causes a significant effect on the river bank.

In addition to the fact that the earth is increasingly warming due to CO₂ emissions from human activities, the unsustainable production of building materials is a depletion of natural resources without additional sources. Also, the rapid proliferation of solid waste and inappropriate disposal of solid waste are increasingly causing problems for the environment. Among solid wastes, PET plastic and glass wastes have been causing great harm to the environment. According to a report by the Organization for Economic Co-operation and Development, the world used 460 million tons of plastic in 2021, almost double that recorded in 2000. Along with that, the amount of plastic waste released more than doubled during that time to 353 million tons. However, only 9% of plastic waste was recycled, 19% was destroyed and nearly 50% was buried in qualified garbage pits. Still 22% of plastic waste was disposed of in improper landfills, burned in open landfills or leaked into the environment [3].

Besides plastic waste, glass waste is also increasing rapidly and this waste is difficult to decompose. The natural decomposition of glass wastes can take millions of years because they are non-biodegradable. Therefore, glass waste is now mostly landfilled. This will give rise to a lot of risks to the environment as well as human safety.

Therefore, recycling glass and plastic waste is an urgent task. This is not only a work that saves resources and energy but also minimizes environmental harm aiming to preserve our earth's environment secure. One of the effective approaches is to reuse PET plastic and glass waste in manufacturing construction materials. For example, PET plastic and glass wastes were reused to replace aggregate in the production of concrete and to produce building bricks [4] - [9].

Due to the posed practical challenges and requirements, we conduct research on manufacturing construction materials reusing PET plastic and glass waste in this study. The technical characteristics of the brick samples are evaluated for bulk density, bending strength, compressive strength and water absorption in order to ensure the requirements of technical standards for masonry bricks. On the basis of these results, we propose an appropriate approach to produce building bricks from PET plastic and glass waste. This study also contributes to reducing environmental pollution caused by plastic and glass waste as well as current construction brick production methods.

2. Materials and Methods

2.1. Materials

2.1.1. PET plastic waste

PET plastic waste is collected from different sources such as mineral water bottles, soft drink bottles, coffee cups.... then washed and dried. Next, the PET plastic waste is shredded to a small size to facilitate the experimental process when melting plastic, the plastic samples after this treatment are shown in Figure 1.



Figure 1. PET plastic waste after shredding

2.1.2. Glass waste

The glass waste used in this study was collected from waste glass bottles or at residential glass processing factories, and then the glass was washed and dried. These glass bottles are then crushed with a wheel mill, the particle size selected for this study is in the range of $0.14 \text{ mm} \div 5 \text{ mm}$ according to TCVN 7570:2006 [10], as shown in Figure 2 and Figure 3.

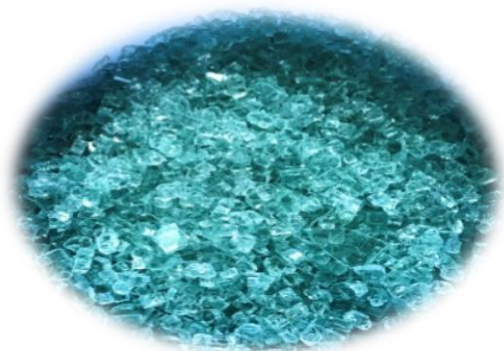


Figure 2. Glass waste after sanitizing and grinding



Figure 3. Glass waste after sieving

2.2. Methods

2.2.1. Mould casting

In this study, we moulded brick samples in a mould with dimension of length $\times$ width $\times$ height = $(190 \times 90 \times 45) \text{ mm}$ [11]. The brick moulding process is shown in Figure 4. In particular, the dried PET waste plastic was put into the pan and heated until the PET waste plastic melted. Continuous stirring was required to keep the plastic melted homogeneously during this process. The dried glass particles were immediately added to the pan when all the plastics were melted. To ensure the mixture was homogeneous, we stirred continuously. After the waste glass and melted plastic were mixed homogeneously, these mixed materials were placed in the prepared brick mould.

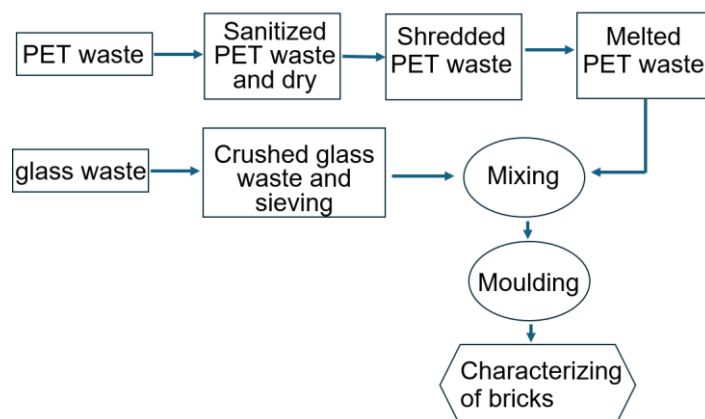


Figure 4. The process flow chart of producing masonry bricks from PET plastic and glass waste

Brick samples are cast with different PET plastic:glass mass ratios of 20:80; 30:70; 40:60 and 50:50. In order to compare the technical characteristics of bricks produced from PET plastic and glass waste, we also investigated these technical characteristics with burnt clay bricks. The investigated brick samples in this study are denoted as shown in Table 1.

Table 1. Notation of investigated brick samples

No	PET plastic:glass ratio	Notation
1	20:80	M28
2	30:70	M37
3	40:60	M46
4	50:50	M55
5	Burnt clay bricks	M _{dc}

2.2.2. Determination of bulk density

The bulk density of brick samples was evaluated according to TCVN 6355-5:2009 [12] procedures. The bulk density of bricks sample, ρ_v (g/cm³) was evaluated according to the formula (1):

$$\rho_v = \frac{m}{l.b.h} \quad (1)$$

where m is the mass of brick samples after drying, (g);

l, b, h is the length, width, and height of the brick sample, respectively, (cm).

Bulk density results are the average value of 5 test samples with an accuracy of 0.01 (g/cm³).

2.2.3. Determination of water absorption

Water absorption was conducted under TCVN 6355-4:2009 [13] protocols. Water absorption of brick samples, H (%) is calculated by formula (2):

$$H = \frac{m_1}{m_0} \cdot 100 \quad (2)$$

where m_0 is the mass of the dried samples to constant mass, (g);

m_1 is the mass of the samples in a water-saturated state, (g).

The water absorption results are the average value of 5 test samples with an accuracy of up to 0.1%.

2.2.4. Determination of compressive strength

The compressive strength of brick samples was evaluated according to TCVN 6355-2:2009 [14] procedures. The compressive strength of brick samples, R_n (MPa) is calculated by the formula (3):

$$R_n = K \cdot \frac{P}{S} \quad (3)$$

Where P is the load up to failure sample, (N).

S is the average area of the two compressive surfaces of the sample, (mm²).

K is the conversion factor. The compressive strength results are the average value of 5 test samples with an accuracy of 0.1%.

2.2.5. Bending strength

Bending strength of brick samples was carried out according to TCVN 6355-3:2009 [15] procedures. The bending strength of brick samples, R_u (MPa) is calculated by the formula (4):

$$R_u = \frac{3 \cdot P \cdot l}{2 \cdot b \cdot h^2} \quad (4)$$

where P is the load at the fracture point, (N);

l is the length of the support span, (mm);

b, h is the width, height of samples, respectively, (mm);

The bending strength results are the average value of 5 test samples with an accuracy of 0.1%.

3. Results and Discussions

3.1. Dimensions and visible defects

Brick samples made from PET plastic and glass waste are checked for dimensions and visible defects. Measurements show that the bricks had no serious visible defects. The deviation in dimensions (length × width × height) is smaller than 2 mm. The representative brick samples are shown in Figure 5. This result demonstrates that in terms of dimension and visible defects, the appearance of brick samples meets the requirement of construction bricks according to Vietnam standards TCVN 6477: 2016 [16].



Figure 5. Brick samples are manufactured from PET plastic and glass waste

3.2. Particle size distribution of crushed glass waste

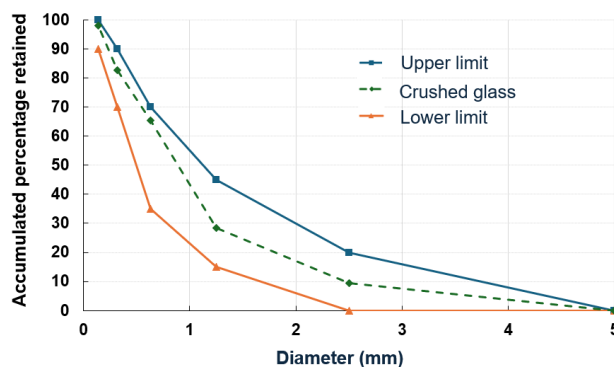


Figure 6. Particle size distribution curve of glass waste after grinding and sieving

Crushed glass waste is used as fine aggregate in brick production. To ensure the technical requirement, we evaluated the particle size distribution of glass waste after grinding and sieving. The particle size distribution of glass waste is presented in Figure 6. The results from Figure 6 show that the particle size of crushed glass is within the limit and suitable for fine aggregates in the production of building materials according to Vietnam standards, TCVN 7570:2006 [10].

3.3. Bulk density

According to Vietnam standards TCVN 1451:1998 [11], The bulk density of masonry bricks is required from 1.6 to 1.9 g/cm³. The results of the bulk density of investigated brick samples are within the permissible limits of TCVN 1451:1998 except for sample M55 and the results (Figure 7) show that the bulk density gradually decreases with increasing PET plastic content and reducing glass waste content. Particularly, the bulk density gradually decreased from 1.98 g/cm³ in the M28 sample to 1.380 g/cm³ in the M55 sample. Among these brick samples, the bulk density of M46 (1.653 g/cm³) and M55 (1.421 g/cm³) samples is smaller than in the burnt clay brick sample (M_{dc}) with a bulk density of 1.670 g/cm³. This indicates that the brick could be made with PET plastic/glass waste ratio less than 50:50 by mass.

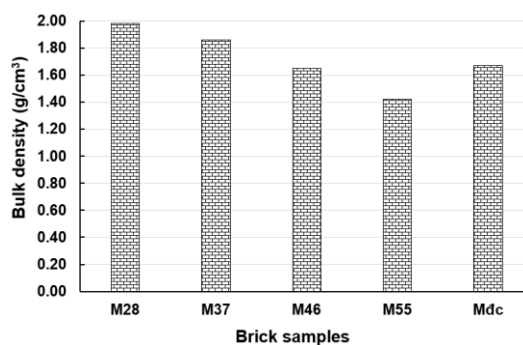


Figure 7. Bulk density of brick samples

3.4. Compressive strength

The results of measuring the compressive strength of brick samples are shown in Figure 8. The results from Figure 8 show that the compressive strength of brick samples manufactured from PET plastic and glass waste is higher than that of burnt clay brick samples. In particular, the compressive strength of brick samples of M28, M37, M46, M55 and M_{dc} has values of 26.9; 33.93; 19.94; 11.32 and 10.50 MPa, respectively. We found that the compressive strength of bricks made from PET plastic and glass waste is 2 to 3 times higher than that of the burnt clay brick samples. Our finding is in good agreement with previous study using PET plastic waste and natural sand [4]. This indicates that these brick samples can be applied in constructions which need higher compressive strength compared to burnt clay bricks.

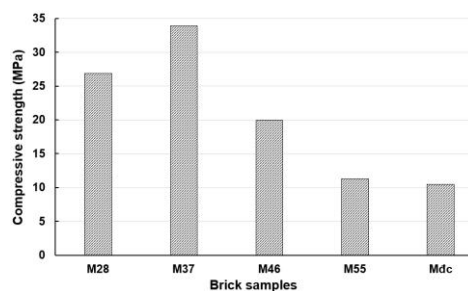


Figure 8. Compressive strength of brick samples

3.5. Bending strength

Similar to the compressive strength, the bending strength of brick samples made from PET plastic and glass waste is also higher than that of burnt clay bricks as shown in Figure 9. The bending strength of brick samples M28, M37, M46 and M55 has values of 5.56; 7.66; 4.36; 5.12 MPa, respectively while the burnt clay brick sample is 2.21 MPa. The bending strength of brick samples is proportional to compressive strength, as shown in Figure 8. This result is also higher than previous studies on masonry bricks manufacturing from plastic waste and natural sand [4].

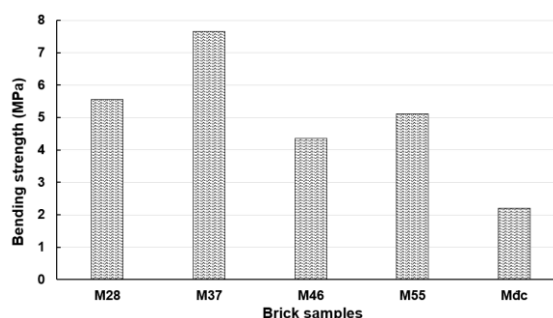


Figure 9. Bending strength of brick samples

3.6. Water absorption

The measured results of water absorption of brick samples made from PET plastic and glass waste are much smaller than those of burnt clay bricks (Figure 10). The water absorption of these bricks is less than 1.5%, while burnt clay brick samples are 14.26%. These values satisfy the technical requirement according to the Vietnam standards TCVN 1451:1998 that water absorption must not exceed 16%. The water absorption of these brick samples is quite similar to brick models manufactured from PET plastic and natural sand in the previous research [4].

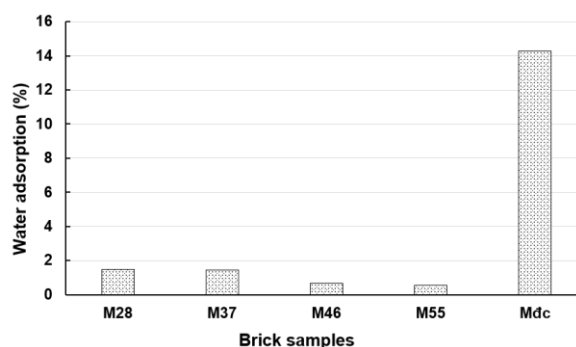


Figure 10. Water absorption of brick samples

4. Conclusions

This study reuses PET plastic and glass waste to produce masonry bricks. To ensure the specifications, we evaluated the technical characteristics of brick samples including bulk density, compressive strength, bending strength, and water absorption. From the results, the following conclusions are drawn:

- Bricks manufactured from PET plastic and glass waste meet the technical requirements for masonry bricks according to TCVN 1451:1998. In particular, bulk density and water absorption are within the limit; compressive strength and bending strength are 2 to 3 times higher than that of burnt clay bricks.

- Among the brick samples in this study, the best brick sample is M37 with the best technical characteristics in terms of compressive strength, bending strength, and water absorption. This brick can be used for constructions that require higher durability.

- The bricks made from PET plastic and glass waste can partly replace burnt clay bricks aimed at reducing environmental pollution and promoting sustainable development in the building material industry.

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REFERENCES

- [1] X. Hoang and L. Cu, "Lesson 3: Environmental protection is not taken seriously," 2022. [Online]. Available: <https://kinhtenongthon.vn/Bai-3-Cong-tac-bao-ve-moi-truong-chua-duoc-coi-trong-post53534.html>. [Accessed March 05, 2024].
- [2] G. U. Fayomi, S. E. Mini, O. S. I. Fayomi, and A. A. Ayoola, "Perspectives on environmental CO₂ emission and energy factor in Cement Industry," *IOP Conference Series: Earth and Environmental Science*, vol. 331, no. 1, p. 012035, 2019.
- [3] C. Bremer, "Plastic pollution is growing relentlessly as waste management and recycling fall short, says OECD," 2022. [Online]. Available: <https://www.oecd.org/environment/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.htm>. [Accessed March 05, 2024].
- [4] E. E. Ali and S. H. Al-Tersawy, "Recycled glass as a partial replacement for fine aggregate in self compacting concrete," *Construction and Building Materials*, vol. 35, pp. 785–791, 2012.
- [5] L. Yan and J.-F. Liang, "Use of waste glass as coarse aggregate in concrete: mechanical properties," *Advances in Concrete Construction*, vol. 8, no. 1, pp. 1–7, 2019.
- [6] J. O. Akinyele, U. T. Igba, and B. G. Adigun, "Effect of waste PET on the structural properties of burnt bricks," *Scientific African*, vol. 7, 2020, Art. no. e00301.
- [7] V. T. Ho, "Investigating into utilization of waste plastic in producing unburnt bricks with compressive strength of 7.5 MPa," *UD-JST*, vol.18, no 5.1, pp. 52–55, 2020.
- [8] S. S. Chauhan, B. Kumar, P. S. Singh, A. Khan, H. Goyal, and S. Goyal, "Fabrication and Testing of Plastic Sand Bricks," *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 691, no. 1, p. 012083, Nov. 2019.
- [9] P. D. T. Van, T. V. Nguyen, and H. P. A. Truong, "Recycling polyethylene terephthalate (PET) and its applications," *CTU JS*, vol. 39, pp. 57-65, 2015.
- [10] National Standards of Vietnam, "TCVN 7570:2006 – Aggregates for concrete and mortar – Specifications," Ministry of Science and Technology, 2006.
- [11] National Standards of Vietnam, "TCVN 1451:1998 – Solid clay bricks," Ministry of Science and Technology, 1998.
- [12] National Standards of Vietnam, "TCVN 6355-5:2009 –Bricks – Test Methods – Part 5: Determination of bulk density," Ministry of Science and Technology, 2009.
- [13] National Standards of Vietnam, "TCVN 6355-4:2009 – Bricks – Test Methods – Part 4: Determination of water absorption," Ministry of Science and Technology, 2009.
- [14] National Standards of Vietnam, "TCVN 6355-2:2009 – Bricks – Test Methods – Part 2: Determination of compressive strength," Ministry of Science and Technology, 2009.
- [15] National Standards of Vietnam, "TCVN 6355-3:2009 – Bricks – Test Methods – Part 3: Determination of bending strength," Ministry of Science and Technology, 2009.
- [16] National Standards of Vietnam, "TCVN 6477:2016 –Concrete bricks," Ministry of Science and Technology, 2016.