# ASSESSMENT OF THE RECYCLING POTENTIAL OF WASTE TIRES FOR THE CONSTRUCTION SECTOR IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT IN VIETNAM

**Ung Thi Thuy Ha, Pham Tuan Hung*, Nguyen Viet Phuong, Chu Thi Hong Nhung, Le Hoang Son**

*Hanoi University of Civil Engineering, Vietnam*

*Corresponding author: hungpt@huce.edu.vn

(Received: March 26, 2026; Revised: May 12, 2026; Accepted: June 01, 2026)

DOI: 10.31130/ud-jst.2026.24(7B).572E

**Abstract -** The rapid growth of vehicle ownership in Vietnam has generated approximately 400,000 metric tons of waste tires annually, most of which are still disposed of through landfilling or incineration, exerting substantial environmental pressure. Within the sustainable development context, recycling waste tires into construction materials represents a promising resource recovery pathway. This study assesses the feasibility of incorporating recycled rubber into construction materials through a systematic literature review and field surveys at 20 tire facilities in Hanoi. Results indicate that replacing 5%-20% of concrete aggregate with recycled rubber improves impact absorption, acoustic insulation, and flexibility, though compressive strength tends to decline. The current collection and processing system remains fragmented, dominated by small-scale operators, with no established value chain linking waste tire flows to the construction sector. Technical standards and targeted policy instruments are needed to enable large-scale adoption and advance circular economy practices in Vietnam's waste management and construction sectors.

**Key words -** Waste tires; recycled rubber; building materials; circular economy; sustainable development.

## 1. Introduction

The rapid growth of transportation has significantly increased the volume of end-of-life tires (ELT), with more than 1.5 billion tires discarded annually [1], accounting for about 2% of total solid waste worldwide [2]. Approximately 4 billion tires are currently stockpiled in uncontrolled landfills globally [3], posing serious challenges for waste management and environmental protection.

In the context of promoting a circular economy, policies such as Extended Producer Responsibility (EPR) have helped raise tire collection and recycling rates above 90% in Europe, Japan, and the United States. In Vietnam, Decree No. 08/2022/NĐ-CP stipulates that producers and importers must recycle at least 5% of the tires placed on the market during 2024–2026, with gradual increases in subsequent phases. Compared to developed countries, this rate remains modest. Traditional disposal methods in Vietnam mainly include landfilling and incineration, with collection systems fragmented and largely dependent on informal sectors, leading to high environmental risks.

Previous studies have demonstrated that recycled rubber can be applied in construction materials, improving properties such as impact absorption, damping, and sound insulation.

Within the framework of circular economy, waste tires are considered valuable secondary resources, particularly in construction, which consumes large volumes of materials. Recycling rubber from waste tires not only reduces environmental pressure but also contributes to resource conservation and greenhouse gas reduction.

However, despite increasing interest in recycled rubber applications, existing studies in Vietnam remain fragmented and are largely limited to laboratory-scale investigations. Most research has focused on evaluating material properties, while relatively little attention has been paid to waste tire availability, collection systems, and the practical conditions required for large-scale implementation in the construction sector. Furthermore, integrated assessments linking waste tire management, recycling supply chains, and construction-material applications remain limited in the Vietnamese context.

As Vietnam begins implementing EPR regulations and promoting circular economy strategies, understanding both the technical potential and resource availability of waste tires has become increasingly important. A comprehensive assessment combining literature evidence with field-based information is therefore needed to support decision-making and policy development.

Accordingly, this study aims to: (i) review and synthesize existing knowledge on recycled rubber applications in construction materials; (ii) evaluate their technical and environmental characteristics; (iii) assess waste tire generation, collection, and recycling practices through field surveys conducted in Hanoi; and (iv) discuss opportunities and challenges for integrating waste tire recycling into the construction sector in Vietnam.

## 2. Literature review

### *2.1. Overview of waste tires and treatment methods*

Tires are complex composite materials consisting of natural and synthetic rubber, carbon black, vulcanizing agents [1], and reinforced with steel and textile fibers, making them nearly non-biodegradable [5]. They also contain pollutants such as polycyclic aromatic hydrocarbons (PAHs) and heavy metals, which may be released if improperly managed [4].

Currently, methods for managing discarded tires can be categorized into three main groups: landfilling, energy recovery, and material recycling.

*(1) Landfilling*

Landfilling is a simple but unsustainable method for managing waste tires. This is because vulcanized rubber has very low biodegradability. Low-density tires tend to remain in landfills for extended periods. Additionally, tires occupy a large volume and contain significant empty spaces, leading to gas trapping (especially methane), causing them to float to the surface and impacting the stability of landfill liners and sealing systems. To mitigate these issues, many regulations require tires to be shredded or crushed before landfilling, or transported to specialized landfills to limit environmental and operational impacts [6].

*(2) Burning for energy recovery*

Tires have a high calorific value (approximately 30–35 MJ/kg) [7], and can therefore be used as an alternative fuel in cement kilns or furnace systems. However, pollutants such as NOx, SOx, and fine particulate matter (PM) may be generated, depending on operating conditions and emission control.

*(3) Recycling materials*

Recycling materials is considered the most sustainable approach today. Mechanical grinding to produce rubber granules (crumb rubber) is widely used in practice. In addition, advanced technologies such as pyrolysis and devulcanization allow for the recovery of valuable products such as pyrolysis oil, syngas, and recycled carbon black, while improving the reusability of rubber materials. These approaches align with the circular economy model and the trend towards sustainable development.

According to recent international reports, the trend in ELT management is shifting in the waste hierarchy, where material recycling and reuse are given the highest priority, followed by energy recovery and finally landfilling. In Europe, the rate of tire landfilling has been almost completely eliminated, while more than 60% of waste tires are recycled into materials and about 30-40 % are used as alternative fuels [8]. Conversely, in many developing countries, landfilling and incineration still account for a large proportion due to technological limitations and management systems. This difference shows the decisive role of recycling policies and infrastructure in guiding the flow of waste tire materials.

### 2.2. Applications and technical characteristics of recycled rubber in construction materials

The application of recycled rubber in construction materials is considered a potential solution due to its ability to utilize large volumes of waste materials and diversify its applications.

*(1) Rubberized concrete*

Recycled rubber is used to partially replace aggregate in concrete, typically accounting for 5–20% by volume. Rubber particles act as flexible inclusions within the cement matrix, leading to reduced mechanical strength due to weak interfacial bonding, particularly at the interfacial transition zone (ITZ) [9]. However, their presence improves energy absorption, impact resistance, and damping capacity, making rubberized concrete suitable for applications requiring enhanced deformation behavior and vibration control.

*(2) Asphalt rubber*

Recycled rubber is widely used in rubberized asphalt. The blending of rubber changes the rheological properties of asphalt and improves the performance of the asphalt mixture under traffic load. Studies show that rubber-modified asphalt has the ability to enhance the deformation resistance of the material, improve crack resistance and increase the durability of the pavement [10], [11], [21].

*(3) Tire-derived aggregate (TDA)*

TDA is a material created from shredding discarded tires and used in a number of civil engineering applications. According to the U.S. Environmental Protection Agency (EPA), TDA is used in roadbeds, retaining walls, and other infrastructure projects due to the mechanical properties of recycled tire materials [12].

The addition of recycled rubber to building materials leads to significant changes in the mechanical properties and functionality of the materials, clearly demonstrating a trade-off between mechanical strength and energy absorption capacity. Studies on rubber concrete materials show that the addition of rubber particles increases the plasticity and deformation resistance of the material compared to traditional concrete [13]. In addition, many studies have shown that the use of rubber often reduces the compressive strength of the material due to poor compatibility between rubber particles and cement binder [10], [13].

Overall, rubberized concrete is more suitable for non-structural or low-load-bearing applications due to its reduced compressive strength, while rubberized asphalt is primarily used to enhance pavement performance. In contrast, tire-derived aggregate is mainly applied in geotechnical and infrastructure backfill applications.

### 2.3. Research gap and study contribution

Current research on recycled rubber in construction materials is mainly conducted in two directions: experimental studies and literature reviews. Experimental studies focus on evaluating the influence of factors such as rubber content, particle size, and processing methods on material performance; however, the results are often difficult to compare due to differences in experimental conditions. Meanwhile, literature reviews provide a systematic overview of development trends and engineering applications but remain largely focused on technical aspects.

Despite numerous studies, significant gaps remain. Much of the existing research is limited to laboratory-scale investigations and evaluates material properties individually, while integrated environmental and economic assessments, particularly life cycle assessments (LCAs), are relatively scarce. Furthermore, the relationship between recycled rubber applications and waste tire management systems has not been adequately examined, especially in the Vietnamese context, where information on waste tire generation, collection, and recycling practices remains limited.

Based on these gaps, the present study adopts an integrated approach that combines literature synthesis with field survey data collected from waste tire generators and traders in Hanoi. Unlike previous studies that primarily focused on material performance, this study additionally examines waste tire availability, collection practices, and recycling pathways that may support construction-sector applications. By linking technical evidence with practical resource and market conditions, the study provides a more comprehensive assessment of the potential for waste tire recycling in Vietnam and contributes to discussions on circular economy implementation and EPR-related resource management.

### 2.4. Research methodology

This study employed a mixed approach combining literature review and field surveys to assess the potential of waste tire recycling for construction applications in Vietnam. The research framework consisted of four main steps: (i) reviewing and synthesizing published studies on recycled rubber applications in construction materials; (ii) identifying research gaps and implementation challenges; (iii) conducting field surveys to investigate waste tire generation, collection, and trading practices; and (iv) integrating the findings to evaluate the applicability of recycled rubber in the Vietnamese context.

*The literature review*: the focus is on peer-reviewed journal articles, technical reports, and policy documents related to waste tire management, recycled rubber applications, circular economy, and EPR. The collected information was analyzed to identify major application areas, technical performance characteristics, environmental implications, and existing research gaps.

*The field surveys*: to complement the literature review, field surveys were conducted. The survey was designed as an exploratory assessment rather than a statistical census and aimed at obtaining information on waste tire generation and management practice including collection and disposal methods, and market conditions. The survey methodology included stratified sampling combined with systematic sampling of establishments generating waste tires. The establishments were classified by type (motorcycle repair shops, car repair shops, and tire dealerships), then selected based on route and distance to improve the diversity of sources and types of waste tire generators. The total number of surveyed establishments was 20, including 10 motorcycle repair shops, 5 car repair shops, and 5 car tire dealerships. The selected establishments represent key actors involved in the waste tire supply chain within the study area.

The collected information was analyzed using descriptive statistical methods, including frequency distributions, average values, and comparative assessments among surveyed groups. Survey findings were then synthesized with evidence from the literature to evaluate the opportunities and challenges of developing waste tire recycling pathways for construction applications in Vietnam.

## 3. Research and survey results

### 3.1. Current status of waste tire generation in Vietnam

Waste tires in Vietnam are primarily generated from two major vehicle groups: motorcycles and automobiles. By the end of 2025, the total number of registered automobiles nationwide had reached nearly 7.5 million, while the number of motorcycles exceeded 79 million [14]. In major cities such as Hanoi and Ho Chi Minh City, where the combined vehicle fleet is estimated at 17–18 million vehicles, the generation of waste tires is substantial.

***Table 1.*** *Lifespan, weight and sale price of waste tires*

| Vehicle type | Tire life span (km) | Average weight (kg) | Price (VND/kg) |
|---|---|---|---|
| **Car** | | | |
| Sedan/Hatchback | 50,000 - 100,000 | 8 - 10 | 1,500 - 3,000 |
| Crossover/ SUV | 50,000 - 80,000 | 11 - 14 | 1,500 - 3,000 |
| Pickup trucks | 60,000 - 100,000 | 15 - 19 | 1,500 - 3,000 |
| Light trucks | 60,000 - 120,000 | 20 - 25 | 1,500 - 3,000 |
| Heavy trucks/ Containers | 80,000 - 150,000 | 70 - 105 | 1,500 - 3,000 |
| **Motorbike** | | | |
| Honda SH | 15,000 - 20,000 | 3.5 - 5 | 500 - 1,000 |
| Honda Wave RSX | 15,000 - 18,000 | 2 - 3 | 500 - 1,000 |
| Piaggio Vespa | 15,000 - 20,000 | 3 - 5 | 500 - 1,000 |
| Yamaha Exciter 135 | 18,000 - 22,000 | 2 - 3 | 500 - 1,000 |
| Yamaha Janus | 15,000 - 20,000 | 2.5 - 4 | 500 - 1,000 |
| Honda Lead | 15,000 - 20,000 | 2.8 - 3.8 | 500 - 1,000 |

*Source: Data synthesis by the authors, 2025*

According to the General Statistics Office, the number of businesses operating in automobile and motorcycle retail, repair, and maintenance services exceeded 32,100 establishments in 2023 [15]. This reflects the large scale of the service sector associated with vehicle maintenance and tire replacement activities. Given the average tire replacement cycle of approximately 50,000–150,000 km for automobiles and 15,000–22,000 km for motorcycles, a continuous stream of waste tires is generated each year. According to Environmental Magazine, Vietnam produces an estimated 400,000 tons of waste tires annually (approximately 30,000 tons per month), equivalent to 20–30 million waste tires of various types [16].

The above findings indicate that waste tire generation in Vietnam is not only substantial in scale but is also expected to increase steadily with continued urbanization, economic growth, and vehicle ownership. In addition, the extensive network of vehicle repair and maintenance establishments provides favorable conditions for the collection and recovery of end-of-life tires. These factors suggest that waste tires constitute a relatively stable secondary resource that could support the production of recycled-rubber construction materials and contribute to circular economy objectives in Vietnam.

### *3.2. Current status of waste tire collection and treatment*

Based on the survey results obtained from 20 tire repair, replacement, and trading establishments in Hanoi, the current waste tire collection and management system is characterized by a largely informal and small-scale operating model. The system mainly involves automobile and motorcycle repair shops, tire dealers, and scrap-material collectors, which serve as important points of waste tire generation and accumulation within the urban waste management chain.

Regarding disposal methods, according to research [17], about 50% of tires can be directly disposed of into the environment, 40% are disposed of by incineration, and about 10% are reused or recycled.

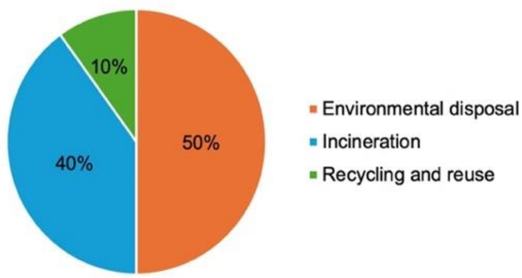


***Figure 1.*** *Fate of waste tires*

*Source: Compiled by the authors based on data from [17]*

Figure 1 indicates that disposal practices continue to dominate waste tire management in Vietnam, whereas recycling and reuse account for only a small proportion of the total waste tire stream. This suggests that a significant amount of potentially recoverable material remains underutilized.

The current state of waste tire disposal reveals limited management effectiveness, leading to resource waste and increased environmental pressure. Landfilling of tires occupies large areas, is difficult to biodegrade, and can become a breeding ground for disease-carrying insects.

Meanwhile, the method of burning tires to recover energy in the form of tire-derived fuel (TDF) has been applied in some industries such as cement. However, if not strictly controlled, this process can generate toxic compounds such as dioxins and furans.

The current trend in sustainable management is to enhance tire recycling through technologies such as rubber grinding and pyrolysis. Grinding allows for the reuse of rubber in the production of construction materials, sports fields, or asphalt, while pyrolysis can recover oil, steel, and carbon black, contributing to a circular economy and towards sustainable development [18].

Although these technologies have demonstrated technical feasibility, their large-scale implementation in Vietnam remains constrained by collection efficiency, investment costs, and market demand for recycled products.

In the context of Vietnam's ongoing EPR implementation, the waste tire management system is still in its formative stage, not yet developed into a complete value chain from collection to recycling and end-use. This indicates that the potential for connecting the supply of waste tires with various uses has not been fully exploited.

Figure 2 illustrates the current waste tire management chain in Vietnam, from waste tire generation and collection to treatment pathways and potential construction-sector applications. Waste tires are mainly generated by motorcycle and auto repair shops as well as tire dealers. They are collected through a fragmented network of small-scale collectors, recycling enterprises, and environmental companies, and are subsequently directed to landfilling, incineration, or recycling.

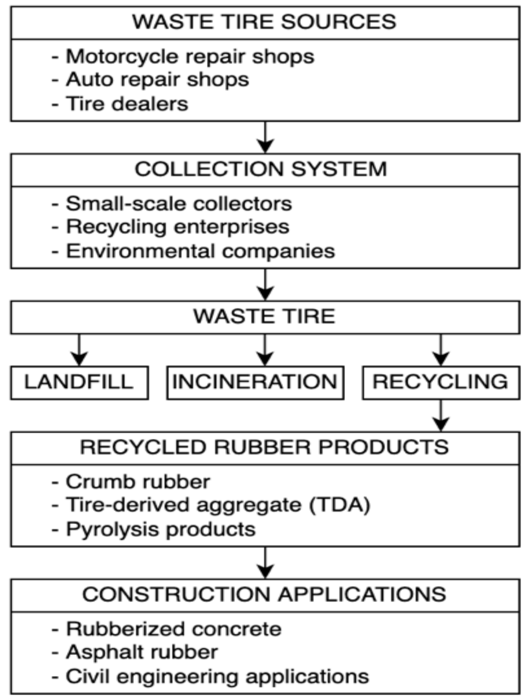


***Figure 2.*** *Current waste tire collection and management chain in Vietnam*

*Source: Authors' compilation based on survey data and literature review*

Although recycling pathways enable the production of crumb rubber, tire-derived aggregate (TDA), and pyrolysis products for construction applications, these activities remain limited compared with conventional disposal methods. This highlights the need to strengthen the linkage between waste tire collection systems and value-added recycling applications in the construction sector.

Overall, the findings suggest that considerable opportunities exist to strengthen waste tire collection and recycling systems in Vietnam. Improving linkages between waste tire suppliers, recyclers, and end-use sectors such as construction could increase resource recovery efficiency, reduce environmental impacts, and support the transition toward a circular economy.

### *3.3. Results of the field survey*

The survey results indicate that waste tire generation is concentrated in vehicle repair shops and tire dealerships, which serve as the primary collection points within the urban waste tire management chain. However, collection and distribution activities remain largely informal, with limited coordination among stakeholders and a lack of systematic management practices.

***Table 2.*** *Survey results on the collection and consumption of discarded tires at tire shops and vehicle repair shops*

| Facility | Tires per month | Collection method | Buyer | Price (VND/tire) |
|---|---|---|---|---|
| **Auto repair shop** | | | | |
| 1 | 80 - 100 | Self-collection | Small-scale collectors | 20,000 - 30,000 |
| 2 | 65 | Self-collection | Recycling enterprises | 15,000 - 50,000 |
| 3 | 40 - 50 | Self-collection | Small-scale collectors | 20,000 - 40,000 |
| 4 | 30 | Self-collection | Small-scale collectors | 15,000 - 40,000 |
| 5 | 10 - 20 | Self-collection | Recycling enterprises | 25,000 - 45,000 |
| **Car tire dealer** | | | | |
| 1 | 250 - 300 | Self-collection | Recycling enterprises | 45,000 - 120,000 |
| 2 | 300 - 500 | Self-collection | Recycling enterprises | 25,000 - 75,000 |
| 3 | 400 - 430 | Self-collection | Recycling enterprises | 30,000 - 125,000 |
| 4 | 350 - 700 | Self-collection | Recycling enterprises | 20,000 - 40,000 |
| 5 | 280 - 400 | Self-collection | Recycling enterprises | 15,000 - 60,000 |
| **Motorcycle repair shop** | | | | |
| 1 | 90 - 110 | Self-collection | Small-scale collectors | No sale |
| 2 | 80 - 95 | Self-collection | Environmental companies | 2,000 - 5,000 |
| 3 | 40 - 50 | Self-collection | Recycling unit | 2,000 - 5,000 |
| 4 | 15 - 17 | Self-collection | Small-scale collectors | 2,000 - 5,000 |
| 5 | 22 | Self-collection | Recycling enterprises | 2,000 - 5,000 |
| 6 | 65 - 80 | Self-collection | Small business | 2,000 - 5,000 |
| 7 | 120 - 125 | Self-collection | Recycling enterprises | 2,000 - 5,000 |
| 8 | 70 - 100 | Self-collection | Recycling enterprises | 2,000 - 5,000 |
| 9 | 25 - 40 | Self-collection | Small-scale collectors | 2,000 - 5,000 |
| 10 | 80 - 100 | Self-collection | Environmental companies | 2,000 - 5,000 |

*Source: Survey by the authors, 2025*

For motorcycle repair shops, the amount of discarded tires generated ranges from approximately 15 to 100 tires per month. The selling price of waste tires is relatively low, commonly between 2,000 and 5,000 VND per tire. Some shops do not sell directly but instead transfer them to collection units on a regular basis.

For auto repair shops, the amount of discarded tires generated varies greatly, ranging from 10 to 100 tires per month depending on the scale of operation. The purchase price for car tires is higher than that of motorcycle tires, approximately 15,000 - 50,000 VND per tire. Discarded tires are consumed through various channels, including small-scale collectors and some recycling businesses.

Car tire dealers generate the largest amount of discarded tires, ranging from 250 to 700 tires per month. The purchase price for these tires ranges from 15,000 to 120,000 VND per tire, depending on the type and condition. Most of the discarded tires from this group are sent to recycling facilities.

The survey results reveal substantial differences in waste tire generation among the surveyed groups. Tire dealers generate significantly larger quantities of waste tires than repair shops and therefore have greater potential to function as collection hubs within future recycling networks. In contrast, repair shops generate smaller but more geographically dispersed waste tire streams, highlighting the need for efficient collection and aggregation mechanisms.

Collection activities at these facilities are primarily carried out on-site and sold once sufficient quantities are accumulated. The buyers are relatively diverse, including small-scale businesses, environmental companies, and some recycling enterprises. However, these transactions are generally unstable and lack binding long-term contracts.

The survey results show that the source of waste tires in urban areas is relatively stable; however current waste tire collection chain is fragmented, with limited linkages between stages and ineffective connections with industries that have high consumption potential, such as construction. This indicates the need to build a more professional collection and distribution system to improve recycling efficiency and resource utilization.

### *3.4. Overall Assessment*

Globally, the waste tire recycling market has expanded rapidly due to increasing environmental regulations and circular economy policies. The Asia–Pacific market was estimated at approximately USD 2.16 billion in 2023 and is projected to reach USD 3.05 billion by 2033. Europe has achieved high waste tire recovery rates through strict regulatory frameworks, while North America has focused on developing advanced recycling technologies and value-added products [19].

In Vietnam, the EPR framework established under Decree No. 08/2022/NĐ-CP provides an important institutional driver for improving waste tire collection and recycling systems, and may create favorable conditions for expanding recycled-rubber applications in construction materials.

Field survey results indicate that waste tire generation in urban areas is relatively stable and concentrated at repair shops and tire dealerships. In particular, tire dealers generate substantially larger quantities of waste tires and may serve as potential collection hubs within future recycling networks. However, the current collection chain remains fragmented, relying largely on informal intermediaries and lacking strong linkages with recycling facilities and end-use industries such as construction materials.

Compared with many developed countries, waste tire management and recycling activities in Vietnam remain at an early stage of development. While several European countries have established comprehensive collection and recycling systems supported by technical standards and market incentives, waste tire management in Vietnam is still characterized by limited recycling capacity, fragmented collection practices, and a lack of specific standards for recycled-rubber construction materials. These differences help explain the relatively low recycling rate and limited practical application of recycled rubber in the construction sector.

Nevertheless, Vietnam possesses several favorable conditions for developing recycled-rubber construction materials, including abundant waste tire resources, relatively low processing costs, and increasing demand for infrastructure development. Strengthening cooperation among waste generators, collectors, recyclers, policymakers, and end-use industries could improve resource recovery, reduce environmental impacts, and support the transition toward a circular economy. If accompanied by appropriate technical standards and supportive policies, recycled rubber could become an important secondary resource for sustainable construction development in Vietnam.

### *3.5. Challenges and constraints*

Despite its significant potential, the application of recycled tire materials in the construction sector in Vietnam faces several challenges and constraints.

From a technical perspective, Vietnam currently lacks comprehensive standards and specifications for construction materials incorporating recycled rubber, particularly rubberized concrete and asphalt mixtures. This creates difficulties in quality control, performance evaluation, and large-scale implementation.

Regarding technology, rubber recycling activities remain limited and are generally conducted on a small scale with relatively low levels of mechanization. Although numerous studies have demonstrated the feasibility of using recycled rubber in construction materials, practical applications remain limited.

From a policy perspective, Decree No. 08/2022/ND-CP introduced the EPR framework for waste tire management. However, implementation is still at an early stage, and specific mechanisms encouraging the use of recycled materials in construction have not yet been fully developed.

In terms of management, field survey results indicate that waste tire collection is primarily carried out by small-scale operators, with limited sorting, coordination, and integration with formal recycling facilities. As a result, collection efficiency remains low, while transportation and handling costs may increase.

Furthermore, stakeholder awareness remains insufficient. Many construction companies and investors remain cautious about adopting recycled materials because of concerns regarding product quality, long-term performance, and the limited availability of technical guidance. At the same time, some waste tire generators have not fully recognized the economic value and recycling potential of discarded tires.

Overall, these challenges indicate that promoting tire recycling in the Vietnamese construction sector will require coordinated efforts involving policy support, technological advancement, technical standard development, market incentives, and greater stakeholder awareness. Addressing these constraints could improve resource recovery, facilitate the wider adoption of recycled-rubber materials, and enhance the contribution of recycling activities to circular economy and greenhouse gas reduction objectives.

### *3.6. Environmental impacts and potential for reducing greenhouse gas emissions*

In addition to technical and economic benefits, waste tire recycling can provide significant environmental benefits, particularly in reducing greenhouse gas (GHG) emissions. In the context of Vietnam's commitment to achieving net-zero emissions, evaluating the emission reduction potential of alternative waste tire management strategies is increasingly important.

According to several life-cycle assessment (LCA) studies, recycling one ton of waste tires can reduce greenhouse gas emissions by approximately 1.4–1.6 tons of $CO_2$ equivalent ($CO_2e$) compared with incineration [20]. These reductions are mainly achieved through two mechanisms: (i) avoiding direct emissions associated with tire combustion and (ii) reducing indirect emissions by partially replacing virgin materials such as aggregates and cement in construction applications.

Based on the estimated annual generation of approximately 400,000 tons of waste tires in Vietnam [16], and assuming that 40–50% of this volume is diverted from disposal to recycling, the quantity of recycled tires would range from 160,000 to 200,000 tons per year. Applying the emission reduction factors reported in previous LCA studies results in a potential reduction of approximately 220,000–320,000 tons $CO_2e$ annually.

This estimate is intended to provide an indicative assessment of the environmental benefits of waste tire recycling. Actual emission reductions may vary depending on collection efficiency, recycling technologies, transportation distances, energy sources, and end-use applications.

These findings suggest that waste tire recycling could contribute meaningfully to Vietnam's greenhouse gas mitigation objectives while supporting circular economy principles. However, realizing this potential will require coordinated efforts in policy implementation, technological development, and market expansion. Strengthening the EPR mechanism, establishing technical standards for recycled materials, and promoting practical applications in the construction sector are important steps toward achieving these environmental benefits. Further quantitative studies under Vietnamese conditions are also needed to improve the accuracy of future emission reduction assessments.

## 4. Conclusion

This study reviewed and synthesized domestic and international research on the application of recycled rubber from waste tires in construction materials and complemented the analysis with field survey data collected from tire repair shops and dealers in Hanoi. By integrating technical evidence from the literature with information on waste tire generation, collection, and recycling practices, the study provides a broader assessment of the feasibility of recycled-rubber applications in the Vietnamese context.

The results indicate that recycled rubber can be used in various construction materials, particularly at appropriate replacement rates, where improvements in functional properties such as sound insulation and energy absorption may be achieved, although some reductions in mechanical strength can occur. Field survey findings further demonstrate that waste tire generation in urban areas is relatively stable; however, collection and recycling activities remain fragmented and are not yet effectively connected to high-value applications such as construction materials.

The study highlights considerable opportunities for promoting waste tire recycling in Vietnam, particularly under the implementation of the EPR framework. Nevertheless, several challenges remain, including the lack of technical standards, limited recycling infrastructure, fragmented collection systems, and insufficient market acceptance of recycled materials.

Future research should focus on experimental validation under local conditions, comprehensive life-cycle assessment (LCA), and techno-economic analyses to better quantify the environmental and economic benefits of recycled-rubber applications. Strengthening cooperation among waste generators, collectors, recyclers, policymakers, and end-use industries will be essential for improving resource recovery and supporting the transition toward a circular economy in Vietnam.

**Acknowledgments:** This research is funded by the Ministry of Science and Technology under the Project NCUD.02-2024.17.

## REFERENCES

[1] W.A. Laftah and W. A. Wan Abdul Rahman, "A comprehensive review of tire recycling technologies and applications," *Materials Advances,* vol. 6, pp. 4992–5010, 2025. doi: 10.1039/D5MA00463B.

[2] K. Donnelly, "The current state of global tire recycling: facts and figures," *Gradeall,* 2026. [Online]. Available: https://gradeall.com/the-current-state-of-global-tyre-recycling-facts-and-figures/. [Accessed March 20, 2026]

[3] World Business Council for Sustainable Development (WBCSD), *End-of-Life Tire (ELT) Management: Toolkit,* Geneva, Switzerland, 2019.

[4] M. Hashamfirooz et al., "A systematic review of the environmental and health effects of waste tires recycling," *Heliyon,* vol. 11, no. 2, e41909, 2025.

[5] B. Adhikari, D. De, and S. Maiti, "Reclamation and recycling of waste rubber," *Progress in Polymer Science,* vol. 25, no. 7, pp. 909–948, 2000. doi: 10.1016/S0079-6700(00)00020-4.

[6] U.S. EPA, "Waste tires – Basic Information," *EPA Archive,* 2003. [Online]. Available: https://archive.epa.gov/epawaste/conserve/materials/tires/web/html/basic.html. [Accessed March 20, 2026]

[7] J. D. Martínez *et al*., "Waste-based value-added feedstocks from tire pyrolysis oil distillation: defossilization of the petrochemical industry," *Green Chemistry,* vol. 27, pp. 670–683, 2025. doi: 10.1039/D4GC05185H.

[8] Tires Europe, End-of-life tires in a circular economy: for a competitive recycling sector, *tyreseurope.org* Jun. 2025. [Online]. Available: https://tyreseurope.org/end-of-life-tyres-in-a-circular-economy-etrmas-perspective-on-a-competitive-recycling-sector/ [Accessed March 20, 2026]

[9] R. B. Ataria and Y. C. Wang, "Mechanical Properties and Durability Performance of Recycled Aggregate Concrete Containing Crumb Rubber," *Materials,* vol. 15, no. 5, Art. no. 1776, 2022. doi: 10.3390/ma15051776.

[10] N. S. Mashaan, A. Ali, M. Rehan, and M. R. Karim, "A review on using crumb rubber in reinforcement of asphalt pavement," *The Scientific World Journal,* vol. 2014, Art. no. 214612, 2014, doi: 10.1155/2014/214612.

[11] S. Huang, Y. Wang, J. Li, and X. Zhang, "Effects of crumb rubber-modified asphalt on pavement performance: A review," *Coatings*, vol. 14, no. 4, 2025.

[12] U.S. EPA, "Waste tires: Civil Engineering Applications," *archive.epa.gov* [Online]. Available: https://archive.epa.gov/epawaste/conserve/materials/tires/web/html/civil_eng.html. [Accessed March 20, 2026]

[13] E. Ganjian, M. Khorami, and A. A. Maghsoudi, "Scrap-tyre-rubber replacement for aggregate and filler in concrete," *Construction and Building Materials*, vol. 23, no. 5, pp. 1828–1836, 2009. doi: 10.1016/j.conbuildmat.2009.02.020.

[14] V. Hue, "Many solutions to ensure traffic safety and order in 2026," *Construction Magazine,* Jan. 2026. [Online]. Available: https://tapchixaydung.vn/nhieu-giai-phap-dam-bao-trat-tu-atgt-trong-nam-2026-20201224000035734.html. [Accessed March 20, 2026]

[15] General Statistics Office, *Vietnam Statistical Yearbook 2023,* Hanoi, 2024.

[16] A. Khue, "The challenge of transforming transportation into green in Ho Chi Minh City," *VnEconomy,* Jul. 2025. [Online]. Available: https://vneconomy.vn/bai-toan-chuyen-doi-giao-thong-xanh-o-tp-hcm.htm. [Accessed March 20, 2026]

[17] Q. V. Tran, G. H. Nguyen, and T. N. Nguyen, "Assessment of factors affecting the compressive strength and elastic modulus of rubber aggregate concrete using machine learning modeling," *Journal of Construction Science and Technology,* vol. 17, no. 2V, pp. 95–107, 2023.

[18] P. T. Williams, "Pyrolysis of waste tires: A review," *Waste Management,* vol. 33, no. 8, pp. 1714–1728, Aug. 2013. doi: 10.1016/j.wasman.2013.05.003.

[19] Climate Change Department, "Tire Recycling: A Solution to Reduce Emissions and Promote a Circular Economy," *dcc.mae.gov.vn,* Dec. 2025. [Online]. Available: https://dcc.mae.gov.vn/tai-che-lop-xe-giai-phap-gop-phan-giam-phat-thai-va-thuc-day-kinh-te-tuan-hoan-3715.htm [Accessed March 20, 2026]

[20] G. Kolendo, V. Voronova, G. Bumanis, A. Korjakins, and D. Bajare, "Life Cycle Assessment of End-of-Life Tire Disposal Methods and Potential Integration of Recycled Crumb Rubber in Cement Composites," *Applied Sciences,* vol. 14, no. 24, Art. no. 11667, Dec. 2024, doi: 10.3390/app142411667.

[21] L. T. N. Y. Le, "Investigating the blending of scrap tire rubber into asphalts mixtures for simultaneously increasing the road surface quality and decreasing price and environmental pollution," *The University of Danang – Journal of Science and Technology,* vol. 9, no. 106, pp. 58–63, 2016.