Journal of Materials and Construction
ISSN 2734-9438
Website: www. jomc.vn

# Preliminary assessment of the economic efficiency of using recycled fine aggregate in self-compacting concrete with high fly ash content

**Nguyen Hung Cuong[1], Nguyen Anh Duc[1*], Chu Thi Hai Ninh[2], Doan Hieu[1], Luong Tuan Dung[1], Nguyen Dang Nhat Minh[3], Do Xuan Cuong[1], Dang Tan Tai[1]**

[1]Faculty of Building and Industrial Construction, Hanoi University of Civil Engineering

[2]Military Academy of Logistics

[3]College of Civil and Transportation Engineering, Hohai University

KEYWORDS

self-compacting concrete
Workability
High fly ash content
Concrete compressive strength
Recycled fine aggregate
Economic efficiency

ABSTRACT

This paper presents a preliminary study on the economic efficiency of using recycled fine aggregate (RFA) from concrete waste, combined with a high fly ash content to produce self-compacting concrete (SCC) in Vietnam. Evaluation results indicate that using 100 % RFA can reduce the material cost of SCC production to approximately 905,149 VND/m$^3$, representing a decrease of 10.74 % compared to SCC using natural sand and 31.64 % compared to conventional concrete of equivalent grade (M400). The integration of RFA with high fly ash content emerges as a feasible solution, reducing construction costs while also contributing to environmental protection and natural resource conservation.

## 1. Introduction

Concrete is the most widely used construction material globally [1]. Its annual consumption is estimated at approximately 35 billion tons, including about 4.2 billion tons of cement, 28 billion tons of aggregate, 2.8 billion tons of water, and various admixtures [2]. In Vietnam, natural sand is the primary fine aggregate in concrete production; however, the rapid pace of infrastructure development has rendered the supply insufficient to meet growing demand [3].

Construction activities generate a significant amount of non-biodegradable solid waste. In Hanoi, for instance, solid waste from construction activities reached 4.186 tons per day in 2021 and is projected to rise to 9.431 tons per day by 2025, while only 1.350 tons are processed daily [4]. Unprocessed waste, such as concrete debris or broken bricks, negatively impacts the environment and urban landscapes. These wastes can be recycled into coarse and fine aggregates for concrete production, and several studies have demonstrated the efficient utilization of such waste materials [5].

Self-compacting concrete (SCC) is designed for high flowability, resistance to segregation, and the ability to fill formwork even in areas with dense reinforcement without external vibration. SCC offers benefits such as faster construction, reduced reliance on labor and equipment, improved working conditions, noise reduction, and environmental protection. However, the high powder content and chemical admixtures required for SCC result in higher material costs and stricter quality control compared to traditional concrete [6]. Therefore, using alternative materials, such as recycled aggregates and high fly ash content, is essential for minimizing SCC production costs.

Vietnam has established standards for the use of recycled coarse aggregates in concrete [7]. However, standards for recycled fine aggregates (RFA) are currently lacking. Domestic research has primarily focused on recycled coarse aggregates from concrete waste, leaving studies on RFA limited [1, 8]. This research gap challenges the wider application of recycled fine aggregates in concrete production. Some studies on RFA usage in concrete are summarized as follows:

- Kou SC [9] demonstrated that SCC could be produced using 100 %RFA while meeting acceptable workability and compressive strength requirements.

- Evangelista and de Brito [10] found that replacing up to 30 % of natural sand with RFA did not significantly affect the compressive strength properties of concrete but did reduce workability due to RFA's high water absorption.

- Diego Carro-López [11] examined the rheological properties of SCC mixes with 0 %, 20 %, 50 %, and 100 % RFA replacement, reporting that mixes with 50 % and 100 % RFA lost workability after 90 minutes, whereas those with 20 % maintained workability.

- Zhang [12] noted that concrete made with RFA has a more complex interfacial transition zone (ITZ) compared to that with natural fine aggregates due to the residual cement mortar on RFA.

- Bu [13] observed that using 100% RFA increases drying shrinkage compared to natural fine aggregates.

- Acker [14] highlighted that the high water absorption capacity of RFA reduces workability, especially in hot and dry climates.

To promote the widespread adoption of RFA in SCC production in Vietnam, evaluating its economic efficiency is crucial. This study offers a preliminary evaluation of the economic feasibility of producing SCC using RFA from concrete waste and high fly ash content. The mix proportions and compressive strength parameters of concrete were

*Corresponding author: ducna@huce.edu.vn
Received 23/01/2025, explanation 04/04/2025, accepted 07/04/2025
Link DOI: https://doi.org/10.54772/jomc.v15i01.836

referenced from previous research [3]. The materials used in the calculations were sourced from Ha Nam Province, with an estimated transportation distance of 26 kilometers.

## 2. Materials and Mix Proportions Used for Evaluation

The materials and mix proportions from the previous study [3] were utilized to evaluate economic efficiency. The SCC mix designs consisted of 0 % recycled fine aggregate (RFA0) and 100 % recycled fine aggregate (RFA100), with a fly ash-to-powder ratio (FA/P) of 0.5 and a water-to-powder ratio (W/P) of 0.4. The detailed mix compositions for 1 $m^3$ of SCC and the compressive strength of the concrete are shown in Table 1. The workability test results of the SCC mixes are presented in Table 2.

**Table 1.** Mix Composition for 1 $m^3$ of SCC [3].

| Mixture | PC40 Cement (kg) | Fly Ash (kg) | Sand (kg) | RFA (kg) | Stone (kg) | Water (kg) | SP (kg) | VMA (kg) | Compressive Strength (MPa) |
|---|---|---|---|---|---|---|---|---|---|
| RFA 0 | 264.1 | 264,1 | 748.8 | 0 | 770 | 211.3 | 2.11 | 0.37 | 40.3 |
| RFA 100 | 264.1 | 264.1 | 0 | 748.8 | 770 | 211.3 | 3.84 | 0.37 | 39.7 |

**Table 2.** Workability Properties of SCC According to [3].

| Mixture | SF (mm) | T500 (s) | Vfunnel (s) | Lbox | Jring (mm) | Sr (%) |
|---|---|---|---|---|---|---|
| RFA0 | 700 | 2.56 | 7.90 | 0.93 | 8.5 | 7.8 |
| RFA100 | 685 | 3.54 | 9.60 | 0.85 | 9.1 | 6.9 |

The materials used in the experiment, based on the findings of [3], included the following: Vicem But Son PC40 cement; Song Hong river sand with a specific gravity of 2.65 g/$cm^3$ and water absorption of 1.22 %; RFA (recycled fine aggregate) crushed from concrete waste with a specific gravity of 2.31 g/$cm^3$ and water absorption of 4.28 %; Crushed stone ($D_{max}$ = 20 mm) with a density of 2.75 g/$cm^3$; fly ash sourced from Pha Lai thermal power plant fly ash and classified as type F according to ASTM C618; superplasticizer (SD): a new-generation superplasticizer type BiFi-HV298, based on modified polymer with a density of 1.05, meeting ASTM C-494 type G standards; viscosity modifying agent (VMA): Culminal type MHPC400.

The RFA used in the study was produced from concrete waste sourced from demolished structures in Hanoi. The waste was processed and crushed at a grinding station located in Dong Anh District, Hanoi.

(a) Crushing process of concrete waste to produce sand

(b) RFA

**Figure 1.** RFA obtained from crushed concrete waste.

## 3. Economic Evaluation of Using Recycled Sand in High Fly Ash SCC

The economic efficiency of using recycled sand was evaluated by calculating the material costs for producing SCC with different mix designs (RFA0, RFA100) and traditional concrete with compressive strength M400 (BT400). Material consumption for BT400 was determined according to construction norms (Code 11.11317) as per Norm 12/2021 [15], issued by the Ministry of Construction, Vietnam (Table 3). Material prices were sourced from the official price list for August 2024 in Ha Nam province (transport distance 20 km) and market prices at the time of calculation: Cement PC40: 1,470,000 VND/ton; River Sand: 592,000 VND/$m^3$; Stone (1x2): 305,000 VND/$m^3$; Fly Ash: 250,000 VND/ton; SP: 25,000 VND/liter; VMA: 100,000 VND/kg. The production cost of RFA covers the expenses for handling, transportation, sorting of waste materials, and crushing. As per the guidance in [16], the estimated production cost for RFA is approximately 318,438 VND/$m^3$. Table 4 presents the material costs before

tax for the production of SCC and traditional concrete whiletable 5 shows the pre-tax production costs for RFA.

**Table 3.** Material Consumption for Traditional Concrete BT400 [15].

| Code | Cement (kg) | Stone ($m^3$) | Sand ($m^3$) | Water (l) | SP (kg) |
|---|---|---|---|---|---|
| 11.11317 | 518 | 0.745 | 0.456 | 185 | 2.59 |

The calculation results indicate that the material costs for producing concrete for the mix designs RFA0, RFA100, and BT400 are 1,014,088 VND/$m^3$, 905,149 VND/$m^3$, and 1,324,220 VND/$m^3$, respectively. Using RFA significantly reduces the material costs for producing SCC. Specifically, the RFA100 mix reduces cost by 10.74 % compared to RFA0. Additionally, compared to traditional concrete with similar compressive strength (BT400), the material cost for the RFA100 mix is reduced by 31.64 %. This reduction is primarily due to the high cost of natural sand, which is approximate 592,000 VND/$m^3$. In contrast, the production cost of RFA is merely 318,438 VND/$m^3$. Furthermore, the use of high-content fly ash, which is significantly cheaper than cement, contributes to reducing the production costs of SCC compared to traditional concrete with similar compressive strength.

**Table 4.** Material Costs for SCC and Traditional Concrete (VND/$m^3$).

| Mixture | Cement | Fly Ash | Stone | Sand or RFA | SP | VMA | Water | Total Cost (VND/$m^3$) |
|---|---|---|---|---|---|---|---|---|
| RFA0 | 388,227 | 66,025 | 152,500 | 316,635 | 52,750 | 37,000 | 951 | 1,014,088 |
| RFA100 | 388,227 | 66,025 | 152,500 | 164,446 | 96,000 | 37,000 | 951 | 905,149 |
| BT400 | 761,460 | 0 | 227,225 | 269,952 | 64,750 | 0 | 833 | 1,324,220 |

**Table 5.** Pre-tax Production Costs for RFA.

| No. | Expense Component | Unit | Quantity | Unit Price (VND) | Total Amount (VND) |
|---|---|---|---|---|---|
| 1 | 125 Crusher Machine $m^3$/h | work shift | 0.0019 | 8,356,914 | 15,878 |
| 2 | Loading onto transport vehicles | $m^3$ | 1 | 33,810 | 33,810 |
| 3 | Transportation cost (estimated for 26km) | $m^3$ | 1 | 251,993 | 251,993 |
| 4 | Labor cost 3/7 | labor unit | 0.01196 | 267,026 | 3,194 |
| 5 | Excavator 1.25 $m^3$ | work shift | 0.00328 | 3,802,802 | 12,473 |
| 6 | Bulldozer 110CV | work shift | 0.00057 | 1,912,099 | 1,090 |
| | Total | VND/$m^3$ | | | 318,438 |

## 4. Conclusion

In Vietnam, research and application of recycled fine aggregates in concrete production remain limited. Preliminary studies indicate that recycled fine aggregates from concrete waste, when combined with high fly ash content, can yield self-compacting concrete (SCC) with significant economic benefits. The material cost of producing SCC is approximately 905,149 VND/$m^3$, which is about 10.74 % lower than SCC produced with natural sand, and 31.64 % lower than that of traditional concrete with the same grade (M400).

Utilizing recycled fine aggregates with high fly ash content in SCC production not only reduces construction costs but also significantly contributes to environmental protection and natural resource conservation.

## Acknowledgments

This study was funded by the Hanoi University of Civil Engineering (HUCE) under the project code 27-2024/KHCN. The authors would like to express their sincere thanks for the support provided by the university.

## References

[1]. Le Vinh An & Nguyen Xuan Tung. "Research on the application of concrete using recycled aggregates in Vietnam and experiences from Japan." *Transport Journal*, 06/2023.

[2]. Vietnam Construction Association. "6th Congress of the Vietnam Concrete Association for the 2022-2025 Term." 2022.

[3]. Cuong, Nguyen Hung. "WORKABILITY, MECHANICAL AND DURABILITY INVESTIGATIONS ON SELF-COMPACTING CONCRETE WITH HIGH FLY ASH CONTENT AND RECYCLED FINE AGGREGATE." *GEOMATE Journal* 26.118 (2024): 96-104.

[4]. Hanh, V. T. & Hien, N. K. "Study on the management of construction solid waste in Hanoi towards a circular economy." *Environmental Journal*, 1 (2022): 3-7.

[5]. Joyklad, P., Yooprasertchai, E., Rahim, A., Ali, N., Chaiyasarn, K., & Hussain, Q. "Sustainable and low-cost hemp FRP composite confinement of B-waste concrete." *Sustainability* 14.13 (2022): 7673.

[6]. Cuong, Nguyen Hung. "Study on water evaporation, shrinkage, and water absorption of self-compacting concrete with high fly ash content using recycled coarse aggregates." *Journal of Materials and Construction - Ministry of Construction* 13.06 (2023): 33.

[7]. TCVN 11969:2018. Recycled Coarse Aggregates for Concrete, *Ministry of Science and Technology*, Vietnam.

[8]. Sang N. T. & Tinh N. V. "Overview of recycled aggregates and recycled aggregate concrete in construction." *Construction Journal*, 3 (2024).

[9]. Kou, S. C. & Chi Sun Poon. "Properties of self-compacting concrete prepared with coarse and fine recycled concrete aggregates." *Cement and Concrete composites* 31.9 (2009): 622-627.

[10]. Evangelista, Luis, & Jorge De Brito. "Mechanical behaviour of concrete made with fine recycled concrete aggregates." *Cement and concrete composites* 29.5 (2007): 397-401.

[11]. Carro-López, D., González-Fonteboa, B., Martínez-Abella, F., González-Taboada, I., de Brito, J., & Varela-Puga, F. "Proportioning, microstructure and fresh properties of self-compacting concrete with recycled sand." *Procedia engineering* 171 (2017): 645-657.

[12]. Zhang, H., Ji, T., Zeng, X., Yang, Z., Lin, X., & Liang, Y. "Mechanical behavior of ultra-high-performance concrete (UHPC) using recycled fine aggregate cured under different conditions and the mechanism based on integrated microstructural parameters." *Construction and Building Materials* 192 (2018): 489-507.

[13]. Bu C., Liu L., Lu X., Zhu D., Sun Y., Yu L., OuYang Y., Cao X. & Wei Q. "The Durability of recycled fine aggregate Concrete: A Review." *Materials* 15.3 (2022): 1110 1-18.

[14]. Van Acker, Arnold. "Recycling of concrete at a precast concrete plant." *Sustainable Construction: Use of Recycled Concrete Aggregate: Proceedings of the International Symposium organised by the Concrete Technology Unit, University of Dundee and held at the Department of Trade and Industry Conference Centre, London, UK on 11–12 November 1998*. Thomas Telford Publishing (1998): 321-332.

[15]. Circular 12/2021/TT-BXD. Issuing construction norms. *Ministry of Construction of Vietnam* (2021).

[16]. Specific cost estimation norms for the extraction and processing of various types of stone, sand, and gravel. No. 196/CB-SXD. *Department of Construction of Dien Bien Province* (2016).