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An Analysis on Recycled Aggregate Concrete Mixture Properties Through the Incorporation of Fava Bean Husk Fiber

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Abstract: Concrete recycling has been an important research topic considering minimizing energy consumption and its negative effects on the environment. After the February 6, 2023, earthquakes in Türkiye, construction and demolition waste (CDW), which is a huge amount, has been a major concern in order to eliminate environmental problems but also benefit from its possibilities as recycle concrete aggregate (RCA). Fly ash (FA) and blast furnace slugs (BFS) are one of the most used additives in RCA. This paper aims to examine both material properties and environmental performance of RC with a new bio-based fiber additive, fava bean husk fibers (FBHF). The study has two phases: (1) concrete mixture with FA and BFS are analyzed to have optimum performed sample and (2) C50S50 cod-ed sample is selected to create concrete mixture; FBHF are applied as secondary additives to the selected concrete mixture with different ratios, 3%, 6%, 9%, and their properties and environmental performance are evaluated. The findings point out that C50S50 coded sample is selected to create concrete mixture with FBHF. According to the analysis, S50FB3 is a good alternative to design non-loadbearing building materials. The use of concrete mixtures that contribute to the recycling of waste such as BFS and natural fiber, FBHF, used as admixtures contributes to reducing the environmental damage of these wastes.

Keywords: Recycled aggregate concrete mixture, Fava bean husk fiber, Mechanical analysis, Environmental analysis

Introduction

Cement production in concrete industry makes a huge contribution to CO₂ emissions and environmental damage. Cement factories responsible for more than 5% carbon dioxide emissions all around the world (Oh, 2014). Through concrete production, minimizing cement and natural aggregates decreases the negative effects of the concrete industry on the environment. Supplementary cementing materials (SCMs), like fly ash (FA) and blast furnace slugs (BFS) as additives roles for cement replacement may have been critical issue to contribute to reducing the CO₂ footprint of concrete production. Fly ash, waste marble, rubber, foundry sand slag are used as additives of concrete mixture (Bakharev et al., 2006; Imbabi et al., 2012; Rondi et al., 2016; De Domenico et al., 2018; Mwititi et al., 2018; Smirnova & Potyomkin, 2018; Smirnova et al., 2021). Recently, FA and BFS as additives have been commonly applied to concrete mix both for environmental concerns and improving material properties (Dinakar et al., 2013; Junak, 2015; Abbass et al., 2021; Ahmad et al., 2022; Tran et al., 2023).

It is pointed out that using ground-granulated blast slag (GGBS) in concrete mixture may reduce CO₂ emissions per ton of cementitious based materials (Thomas et al., 2012). Test results of a study present that compressive

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strength and strength of RAC mixtures, even though the cement replacement amount with BFS, reduced strength compared to NAC mixtures, however the strength gains for the BFS-based concrete are higher than the reference mixtures without BFS in long term (Lin & Wu, 2021). A study on RCA indicates that incorporation of 15% GGBS and 15% FA, 90 days compressive strength, frost resistance and chloride penetration resistance of RAC incorporating 50% RCA were performed better than an original concrete mixture (Chen et al., 2023). It is clear that using recycled aggregate is the most environmentally positive role in lower strength concrete compared to mechanical properties with natural aggregate concrete (NAC) (Bennett et al., 2022).

Besides additives, aggregates are the fundamental input that can directly affect engineering and economical properties of concrete mix. It is indicated that more than 165 million tons of natural aggregates are used in various constructions every year (Limbachiya et al., 2012). Considering the amount of aggregates used in concrete mix, it has been significant issue to preserve natural sources and find a beneficial way to have aggregate in concrete mix. Therefore, recycled concrete aggregates are a good alternative to minimizing natural source consumption and reuse of construction demolition waste.

In developing countries as Türkiye, based on fast growth and urbanization, a growing need for infra-structure and housing have been occurred. As a most demanded construction material, concrete has is required to develop sustainable solutions regarding global concerns. Concrete consists of approximately 50-70% natural coarse aggregate (NCA). Therefore, NCA plays a significant role in carbon footprint of concrete mix. Using recycled concrete aggregate instead of NCA in concrete mix is being prioritized to conserve natural resources. Construction and demolition waste (CDW) is the major source of RCA. After the February 6, 2023, earthquakes in Türkiye, CDW has been a critical issue. Doğdu and Alkan (2023) indicated that after Kahramanmaraş earthquakes approximately 38 million tons of concrete waste was generated. It is observed that using recycling concrete (RC) can be a good alternative of natural sources considering environmental sustainability (Alkan et al., 2025).

This study presents a novel approach to design a concrete mixture of recycled aggregate concrete, RAC through the effect of fly ash (FA), blast furnace slugs (BFS) and sustainable natural fibers, particularly fava bean husk fibers (FBHF). In the context of rapidly developing countries as Türkiye, where there is a critical concern considering sustainable construction materials due to the increasing infrastructure demands, this paper addresses a gap by examining alternative concrete mixture design with sustainable additives to optimize concrete performance of RAC for non-structural elements such as brick. While prior research has examined FA and BFS as additives, this study focuses on the comparative effectiveness of mechanical performance of FA and BFS in high-RCA mixes. This research is distinctive in its incorporation of FBHF in terms of economical and environmentally sustainable reinforcement while supporting ecological objectives using agricultural waste. Additionally, this study also evaluates the combined effects of activated BFS and natural fiber reinforcement, FBHF, aiming to design a concrete mixture for non-structural elements that balance strength, sustainability, and economic feasibility.

Method

The paper is structured into three phases in order to optimize and test samples for concrete mixtures' performance enhancement. The first phase presents laboratory test on concrete mixtures with RCA and different additives. EN 196-2 standard is applied for laboratory tests. In the second phase, environmental analysis of the samples is evaluated. Laboratory tests were done in two steps.

In the first step, mechanical tests results of FA and BFS as additives are analyzed. This phase identifies the most effective concrete mixture using FA and BFS additives. Various proportions of FA and BFS are tested to evaluate mechanical properties of the samples. The coded system is based on the ingredients and the proportion of the concrete mixtures. Letters and their codes are presented in the following: C: concrete, F: BFS, S: BFS, FB: FBHF. The second phase presents concrete mixture design with FBHF and mechanical tests of the samples. Based on the results of the first phase laboratory tests, C50S50 coded sample is selected to create concrete mixture with FBHF. %50 BFS with different percentages of FBHF reinforcements are tested in the second phase to determine an optimal concrete mixture design. The study concentrates on the relationships between BFS and FBHF in mechanical properties of concrete and the results obtained at two periods: 7 and 28 days. The concrete mixtures are grouped into three sets, each associated with the variation in FBHF content (3%, 6%, 9%). In this phase, the samples were examined to find out the best possible combination of BFS and FBHF. The third phase covers the environmental analysis of the samples applying a simplified life cycle assessment (LCA) approach. This analysis concerned: (i) carbon footprint (kg CO₂-equivalent per batch), (ii) natural resource

conservation, and (iii) waste utilization efficiency. For the first step of the laboratory tests, RCA with FA and BFS additives are designed. In Table 1, presented the samples and proportions.

Table 1. The concrete mixture with FA and BFS additives

Sample name	Cement (gr)	Fine aggregate (gr)	Recycled aggregate (gr)	Water (gr)	Fly ash (gr)	Blast furnace slugs (gr)
NA	250	1400	-	200	-	-
RA	250	-	1400	250	-	-
C50F50	125	-	1400	250	125	-
C25F75	62.5	-	1400	250	187.5	-
C50S50	125	-	1400	250	-	125
C25S75	62.5	-	1400	250	-	187.5

Laboratory Tests, Results and Discussions

Firstly, wet and dry weight of the samples are determined. The wet weight of the mixture, volume and unit volume weight of the samples is presented in Table 2. It is observed that when the additives ratio is increased, the unit volume weight of the concrete mixtures is reduced. However, there is not a specific difference between FA and BFS additives affecting unit volume weight of the concrete mixtures.

Table 2. The wet weight, volume, unit volume weight of the mixtures

Sample name	Wet weight of mixture (gr)	Volume of mixture (cm ³)	Unit volume weight of mixture (gr/cm ³)
NA	794.30	390	2.04
RA	736.4	390	1.89
C50F50	756.4	390	1.94
C25F75	736	390	1.89
C50S50	760.5	390	1.95
C25S75	744.9	390	1.91

The slump flow tests were studied (Figure 1). Based on the results, C50F50 and C50S50 have close value to NA concrete mixture. However, RA, C25F75 and C25S75 concrete mixtures' slump flow values are as close to 16 cm.

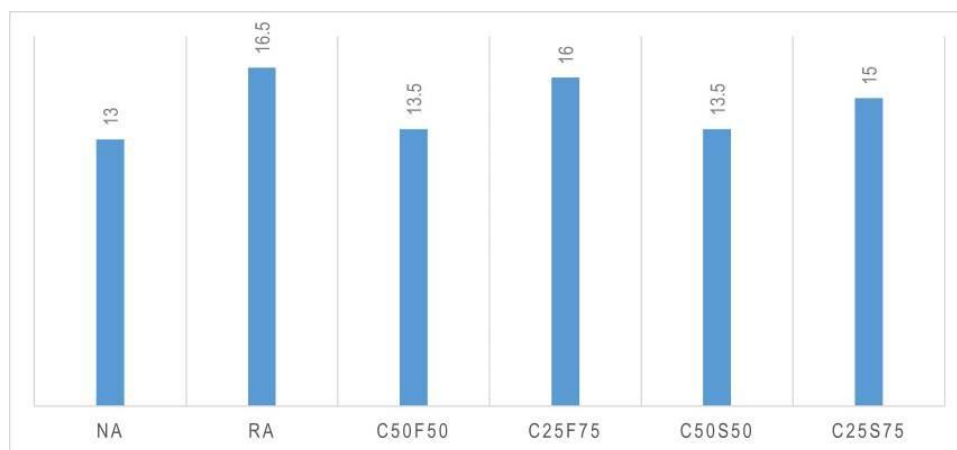


Figure 1. Slump flow test results

Figure 2 presents water absorption values of the samples after 7 and 28 days. It is clear that FA and BFS additives are directly related to water absorption values of the samples. C50F50 and C25F75 water absorption values both 7 and 28 days are indicated as approximately 100% higher than NA concrete mixture. Similarly, C50S50 and C25S75 water absorption values of 7 days are close to 100% higher than NA concrete mixture. Conversely, there is not a big difference between NA concrete mixture and C50S50, C25S75 water absorption values of 28 days.

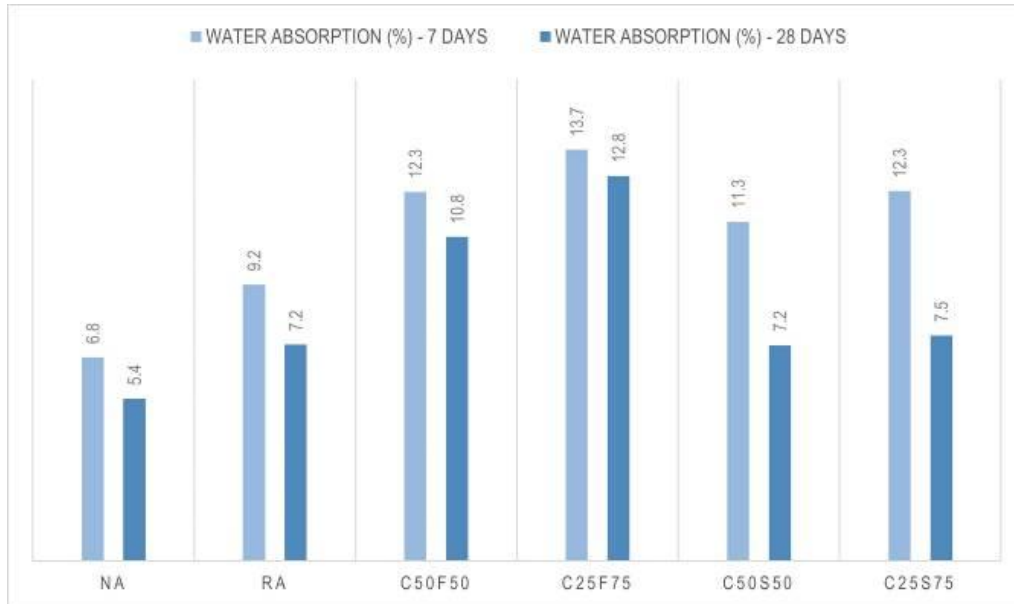


Figure 2. The water absorption values of the samples after 7 and 28 days

The compressive strength findings are illustrated in Figure 3. The results point out that there is not a specific difference in compressive strength values of both 7 and 28 days between NA concrete mixture and RA concrete mixture. The compressive strength value of NA concrete mixture is 15.61 N/mm² in 7 days and 23.15 N/mm² in 28 days. The compressive strength value of RA concrete mixture is 15.54 N/mm² in 7 days and 22.35 N/mm² in 28 days. Considering FA and BFS as additives, it is clear that samples with BFS performed better than FA especially after 28 days. To compare different ratios for BFS, compressive strength findings of C50S50 is better than C25S75 particularly in 28 days as 18.25 N/mm². On the other hand, compressive strength values of C25F75 are very low (2.01 N/mm² in 7 days, 5.20 N/mm² in 28 days).

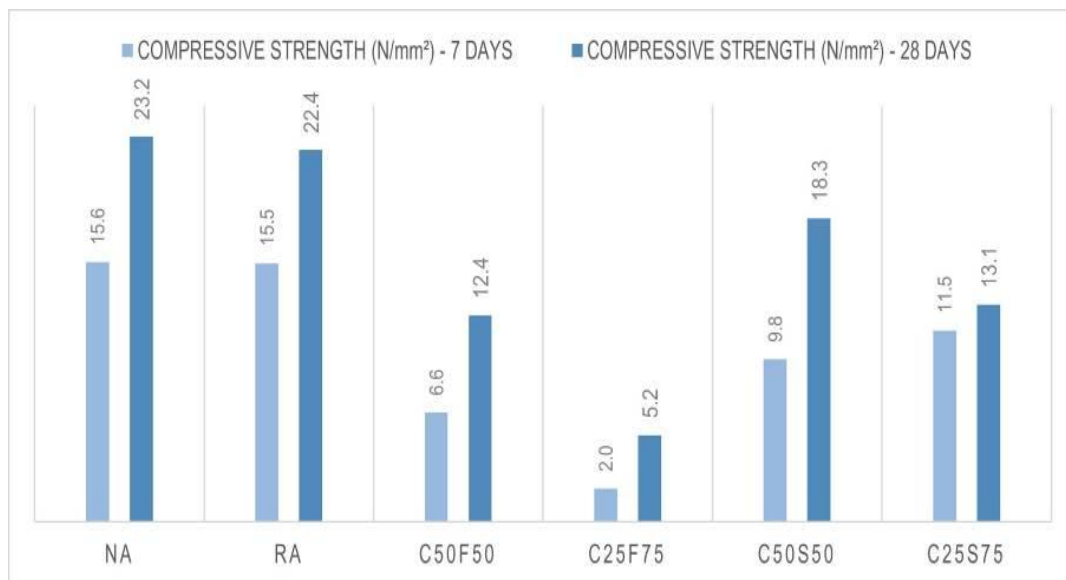


Figure 3. The compressive strength findings of the samples after 7 and 28 days

Figure 4 shows flexural strength findings. The results demonstrate that there is not a specific difference in flexural strength values of 28 days between NA concrete mixture and RA concrete mixture except 7 days values: 4.65 N/mm² for NA concrete mixture and 3.69 N/mm² for RA concrete mixture. The flexural strength value of NA concrete mixture is 4.11 N/mm² and the flexural strength value of RA concrete mixture is 4.48 N/mm² in 28 days. Regarding FA and BFS as additives, it is observed that samples with BFS performed better than FA especially after 28 days. To compare different ratios for BFS, flexural strength findings of C50S50 is better than C25S75 particularly in 28 days as 2.14 N/mm². Conversely, flexural strength values of C25F75 are very low (0.64 N/mm² in 7 days, 1.31 N/mm² in 28 days).

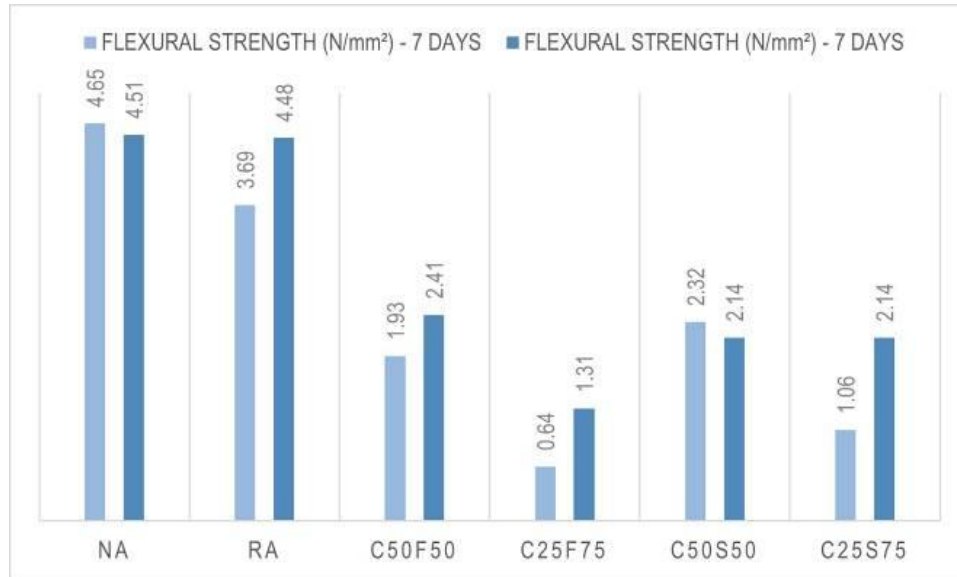


Figure 4. The flexural strength findings of the samples after 7 and 28 days

Depending on the results of mechanical analysis, C50S50 is selected as a concrete mixture for fiber concrete mixture design. In the first stage of the fiber mixture design process, fava bean husks were dried at room temperature. The dried fava bean husks were cut into 4-10 cm long fibers and 1-2 mm thick (Figure 5).



Figure 5. FBHF samples

Three different ratios have been determined for fiber mixtures. Table 3 shows the fiber mixtures and ratios.

Table 3. The fiber mixtures

Sample name	Cement (gr)	Recycled aggregate (gr)	Water (gr)	Blast furnace slug (gr)	Fava bean husk fibers (gr)
S50FB3	125	1400	250	125	3.45
S50FB6	125	1400	250	125	6.90
S50FB9	125	1400	250	125	10.35

Table 4 shows unit weight values of the samples. In order to make comparative analysis under the same situation the selected concrete mixture design, C50S50, is also re-evaluated throughout the test phases and named as C50S50-1.

Table 4. Wet weight, volume, unit volume weight and spread of the mixtures

Sample name	Wet weight of mixture (gr)	Unit weight (gr/cm³)
C50S50-1	701.7	1.80
S50FB3	699.7	1.79
S50FB6	722.4	1.85
S50FB9	713.7	1.83

The slump flow test results are represented in Figure 6. Based on the results, C50S50-1 and S50FB3 have same value as 16 cm. However, S50FB6 and S50FB9 concrete mixtures' slump flow values are same as 13.5 cm. It is observed that fiber addition may direct relation with slump flow of concrete mixtures.

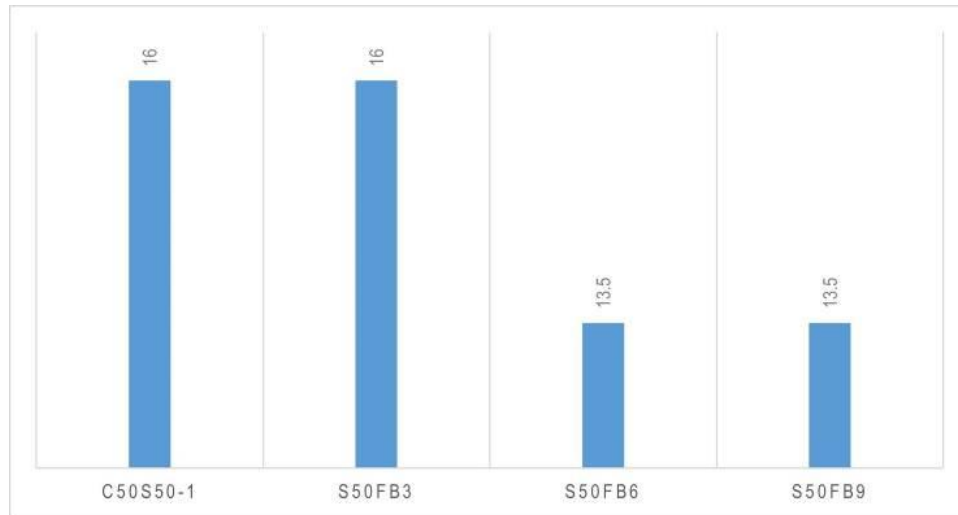


Figure 6. Slump flow test results

The water absorption values of the samples after 7 and 28 days are reported in Figure 7. It is seen that FBHF additive is directly affected by water absorption values of the samples. Especially in 28 days, water absorption values of the samples increased depending on the amount of FBHF in concrete mixtures. The water absorption value of C50S50-1 is 12.47% after 7 days and 9.01% after 28 days. The water absorption value of S50FB3 is 16.65%, S50FB6 is 16.03%, S50FB9 is 14.60% after 7 days. After 28 days, the water absorption value of S50FB3 is 11.30%, S50FB6 is 14.22%, S50FB9 is 17.53%. The differences in water absorption between S50FB3 and S50FB9 are approximately 6% after 28 days.

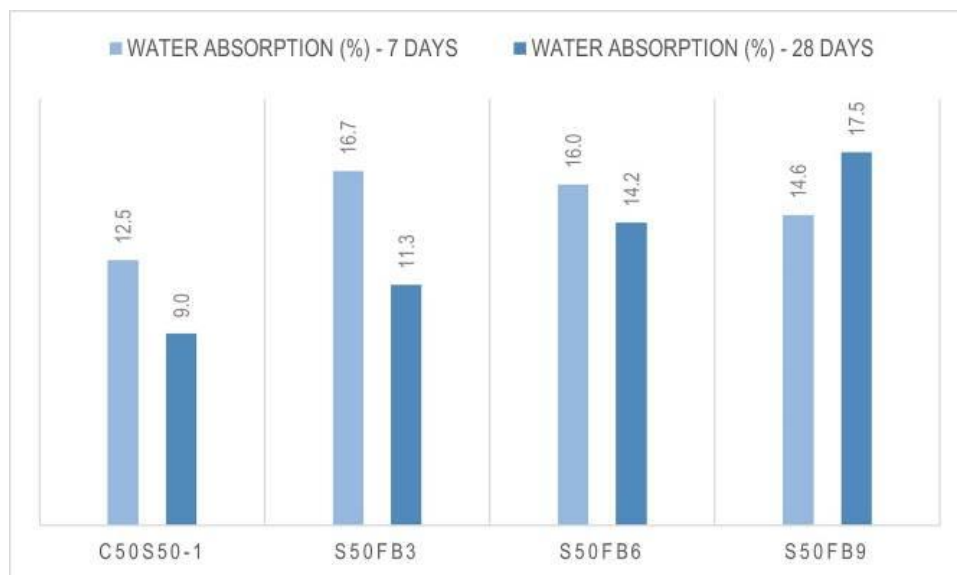


Figure 7. The water absorption values of the samples after 7 and 28 days

Figure 8 shows compressive strength findings (left) and flexural strength findings (right). The results indicate that there is a remarkable difference in compressive strength values between the samples and also 7 and 28 days. The compressive strength value of C50S50-1 is 6.57 N/mm² in 7 days and 11.77 N/mm² in 28 days. By FBHF additives, the compressive strength value decreased. The compressive strength value of S50FB3 is 3.74 N/mm² in 7 days and 9.66 N/mm² in 28 days. The compressive strength value of S50FB6 is 1.32 N/mm² in 7 days and 5.51 N/mm² in 28 days. The compressive strength value of S50FB9 is 0.64 N/mm² in 7 days and 2.67 N/mm² in 28 days. It is observed that FBHF additives affect the compressive strength of the sample negatively. Moreover, S50FB9 is not suitable for even non-load bearing building materials such as brick.

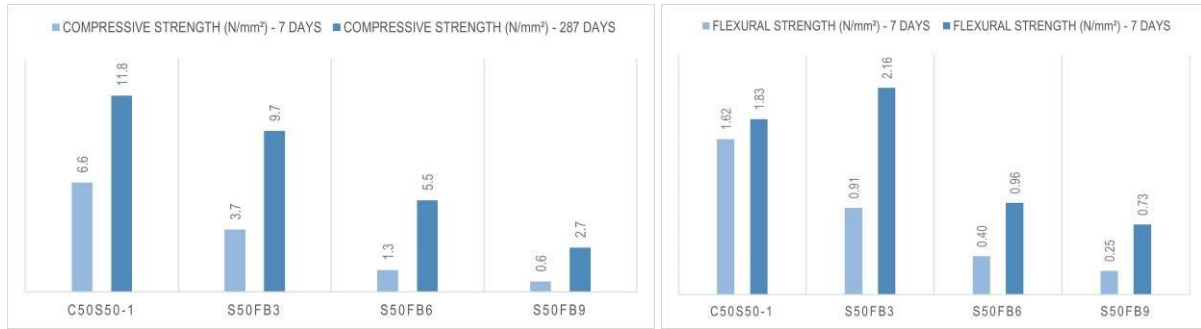


Figure 8. The compressive strength findings (left) and flexural strength findings (right) of the samples after 7 and 28 days

The samples remained intact without splitting after flexural strength tests. The flexural strength value of S50FB3 after 28 days is 2.16 N/mm² and the flexural strength value of C50S50-1 after 28 days is 1.83 N/mm². It is observed that with 3% FBHF perform better than C50S50-1 after 28 days considering flexural strength. However, 6% and 9% FBHF additives affect the flexural strength negatively. The flexural strength value of S50FB6 after 28 days is 0.96 N/mm² and the flexural strength value of S50FB9 after 28 days is 0.73 N/mm². Furthermore, it is clear that by time flexural strength of the samples with FBHF is rapidly increasing compared to C50S50-1. Figure 9 shows the load deflection curve of the samples after 7 days (above) and 28 days (below). The effects of fiber may not be observed in test results after 7 days. However, it is seen that fracture energy changes with the effects of fiber after 28 days. The results point out that 3% FBHF performed better than C50S50-1 after 28 days considering fracture energy. Therefore, it is possible to indicate that the increasing amount of fiber has not directly improved the flexural strength of the samples and fracture energy.

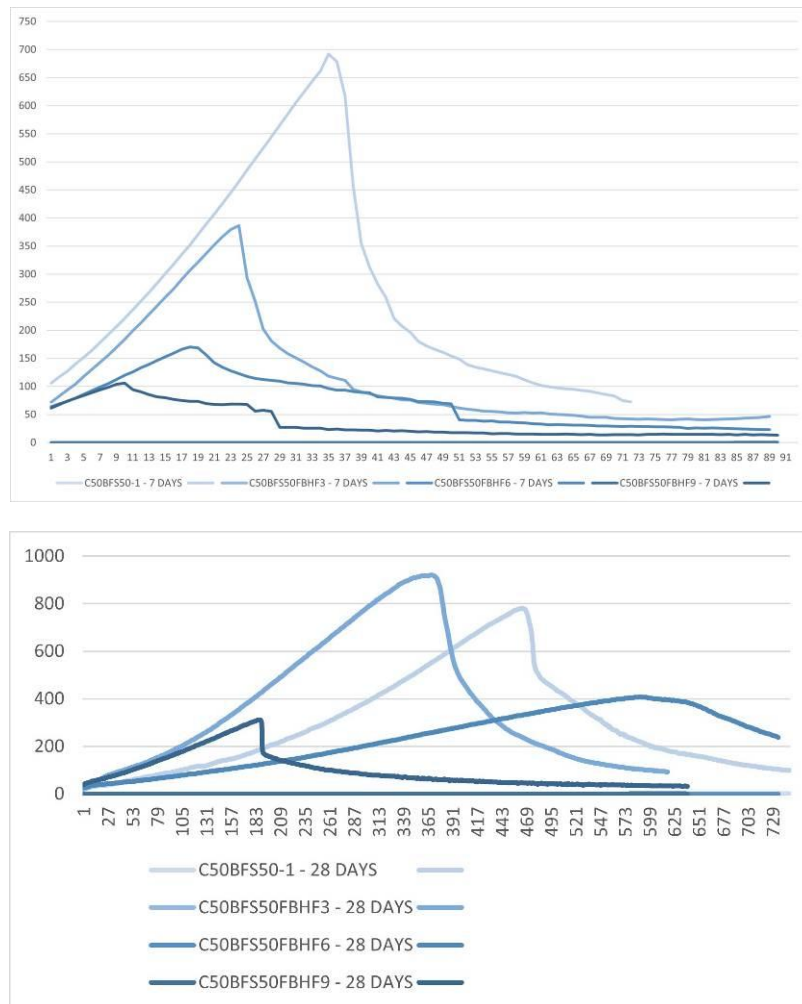


Figure 9. The load deflection curve of the samples after 7 days (above) and 28 days (below)

According to the laboratory tests results, S50FB3 may be an alternative for non-loadbearing building materials such as brick. Especially, compressive and flexural strength values of S50FB3 are close to C50S50-1.

Environmental Analysis

This study evaluates both mechanical and environmental performance of recycled aggregate concrete (RAC) mixtures incorporating fly ash (FA), blast furnace slag (BFS), and fava bean husk fibers (FBHF) using a simplified life cycle assessment (LCA) approach. The analysis adopts a cradle-to-gate system boundary, focusing on the material production and processing stages, which are known to dominate concrete's environmental impacts (Chen et al., 2010; Habert et al., 2011). The functional unit is defined as one laboratory-scale batch as specified in Tables 1 and 2, enabling direct comparison across all mix proportions. Three complementary indicators were quantified: (i) carbon footprint (kg CO₂-equivalent per batch), (ii) natural resource conservation, and (iii) waste utilization efficiency.

Emission Factors and System Boundary

Emission factors (EFs) for each constituent material were drawn from established LCA databases and peer-reviewed literature (Table 5). Portland cement was assigned an EF of 0.870 kg CO₂-eq/kg, consistent with IPCC (2006) and Habert (2011). Fly ash (FA) and ground granulated blast furnace slag (BFS) were treated as industrial by-products with markedly lower EFs of 0.027 and 0.060 kg CO₂-eq/kg, respectively, reflecting only the processing and transport burden rather than the full upstream production impact (Marceau et al., 2007). Recycled concrete aggregate (RCA) was assigned an EF of 0.015 kg CO₂-eq/kg, accounting for crushing and screening operations (Haber, 2011). Fava bean husk fibers (FBHF), being an agricultural residual, were assigned a negligible EF of approximately zero.

Table 5. Emission factors adopted for the cradle-to-gate LCA

Material	EF (kg CO ₂ -eq/kg)	References
Portland cement	0.870	IPCC, 2006; Habert (2011)
Natural fine aggregate	0.010	Marceau et al., 2007
Recycled concrete aggregate (RCA)	0.015	Serres et al., 2016
Fly ash (FA)	0.027	Chen et al., 2023
Ground granulated BFS	0.060	Habert, 2011
Water (tap)	0.000344	Wernet et al., 2016
Fava bean husk fiber (FBHF)	≈ 0.000	Agricultural waste – negligible

Carbon Footprint

The carbon footprint of each mixture was computed by summing the product of the mass of each constituent (kg) and its corresponding EF (kg CO₂-eq/kg), as expressed in formula (1):

$$CF = \sum (m_i \times EF_i)$$

where CF denotes the total carbon footprint (kg CO₂-eq), m_i is the mass of material i in the batch (kg), and EF_i is the corresponding emission factor. Results are presented in Table 6.

Table 6. Carbon footprint results for all mix designs

Sample	CO ₂ (kg/batch)	Cement CO ₂	Aggr. CO ₂	vs NA (%)
NA	0.2316	0.21750	0.01400	Baseline
RA	0.2386	0.21750	0.02100	+3.0%
C50F50	0.1332	0.10875	0.02100	-42.5%
C25F75	0.0805	0.05437	0.02100	-65.2%
C50S50	0.1373	0.10875	0.02100	-40.7%
C25S75	0.0867	0.05437	0.02100	-62.6%
S50FB3	0.1373	0.10875	0.02100	-40.7%
S50FB6	0.1373	0.10875	0.02100	-40.7%
S50FB9	0.1373	0.10875	0.02100	-40.7%

The reference mixture NA, composed entirely of Portland cement and natural fine aggregate, recorded a carbon footprint of 0.232 kg CO₂-eq per batch, with cement alone accounting for 93.9% of total emissions. Replacing natural aggregates with RCA (mixture RA) marginally increased the footprint to 0.239 kg CO₂-eq due to the energy required for RCA processing, while cement remained unchanged. Progressive substitution of cement with FA yielded substantial reductions. The C50F50 and C25F75 mixtures achieved footprint reductions of 42.5% and 65.2%, respectively, relative to NA. A comparable trend was observed for BFS-based mixtures: C50S50 and C25S75 attained reductions of 40.7% and 62.6%, respectively. The marginal difference between FA and BFS at equivalent replacement ratios (e.g., -42.5% vs. -40.7% at 50% replacement) reflects the slightly higher EF of BFS compared with FA.

The Phase 2 fiber-reinforced mixtures (S50FB3, S50FB6, S50FB9) maintained an identical carbon footprint of 0.137 kg CO₂-eq because the FBHF additive has a negligible EF. This confirms that incorporating agricultural fiber waste into the optimal BFS-substituted mixture introduces no additional carbon burden while potentially improving mechanical performance.

Natural Resource Conservation

Two dimensions of natural resource conservation were assessed. First, the substitution of natural fine aggregate with RCA was quantified in terms of avoided CO₂ emissions using the differential emission factor approach ($\Delta EF = EF_{\text{natural}} - EF_{\text{RCA}} = 0.010 - 0.015 = -0.005$ kg CO₂-eq/kg). It is noteworthy that RCA carries a slightly higher processing EF than natural aggregate in this study; consequently, the environmental benefit of RCA is realized primarily through conservation of primary mineral resources and landfill diversion rather than through direct carbon savings.

Second, cement replacement by SCMs was the primary lever for resource conservation. The C25F75 and C25S75 mixtures replaced 0.188 kg of cement per batch, yielding avoided cement-production emissions of 0.163 kg CO₂-eq per batch, equivalent to a 70.4% reduction relative to the cement-only carbon contribution in NA. At 50% replacement (C50F50, C50S50), avoided emissions amounted to 0.109 kg CO₂-eq per batch (50.0% reduction). Collectively, these results demonstrate that SCM-based cement substitution is the most impactful environmental lever available in the studied mix designs.

Waste Utilization Efficiency

Waste utilization efficiency (WUE) was defined as the mass fraction of industrial and agricultural byproducts, comprising RCA, FA, BFS, and FBHF, relative to the total batch mass in formula (2):

$$WUE (\%) = (m_{\text{waste}} / m_{\text{total}}) \times 100$$

Results are summarized in Table 7.

Table 7. Waste utilization efficiency and SCM replacement rates for all mixtures

Sample	Waste content (kg)	Total batch (kg)	WUE (%)	Cement replaced (kg)
NA	0.000	1.850	0.0%	0.000
RA	1.400	1.900	73.7%	0.000
C50F50	1.525	1.900	80.3%	0.125
C25F75	1.588	1.900	83.6%	0.188
C50BFS50	1.525	1.900	80.3%	0.125
C25BFS75	1.588	1.900	83.6%	0.188
C50BFS50FBHF3	1.529	1.904	80.3%	0.125
C50BFS50FBHF6	1.532	1.907	80.3%	0.125
C50BFS50FBHF9	1.535	1.910	80.4%	0.125

The reference mixture NA recorded a WUE of 0.0%, as no by-products were incorporated. The use of RCA alone (mixture RA) increased WUE to 73.7%, reflecting the dominant mass contribution of the aggregate fraction. Partial replacement of cement with FA or BFS at 50% (C50F50, C50S50) further increased WUE to 80.3%, while 75% replacement (C25F75, C25S75) raised it to 83.6%. The fiber-reinforced series maintained WUE values of approximately 80.3–80.4%, with a slight increase as FBHF dosage rose from 3.45 g to 10.35 g.

The convergence of high WUE values (>80%) with substantial reductions in carbon footprint (>40%) in BFS- and FA-substituted mixtures highlights their dual environmental benefit. These formulations both maximize the utilization of industrial by-products and reduce greenhouse gas emissions. The addition of FBHF extends this benefit to agricultural waste streams without incurring a measurable carbon penalty, offering a promising pathway for developing circular concrete composites suitable for non-structural applications.

This study investigated the incorporation of a bio-based additive, fava bean husk fibers (FBHF), to RCA-based concrete mixtures. The research is conducted in two phases: the first evaluated FA and BFS combinations to identify the optimum-performing concrete mixture, while the second introduced FBHF at proportions of 3%, 6%, and 9% into the selected mixture, assessing mechanical properties and environmental performance.

The experimental findings demonstrated that the C50S50 mixture exhibited the most favorable performance characteristics, making it the foundation for subsequent FBHF incorporation. Among the tested combinations, S50FB3 emerged as the most promising formulation, proving to be a viable and sustainable alternative for non-load-bearing building materials, such as brick. This outcome underscores the potential of combining industrial by-products like BFS with bio-based fiber additive to produce construction materials that are both functionally adequate and environmentally responsible.

From an environmental perspective, the integration of waste-derived materials such as BFS and naturally sourced FBHF into concrete mixtures significantly contributes to reducing the ecological burden associated with their disposal. These findings highlight a meaningful step toward circular economy principles within the construction sector, encouraging the repurpose of industrial and agricultural by-products as valuable construction resources.

Conclusion

Natural resources have become a critical global issue due to the escalating demands of uncontrolled energy consumption. Concrete, as one of the most widely utilized construction materials worldwide, exerts a remarkable impact on energy use throughout its production phases. In order to response to environmental challenges, concrete recycling has emerged as a pivotal area of research, offering pathways to reduce both energy consumption and ecological concerns. The catastrophic earthquakes of February 6, 2023, in Türkiye generated an unprecedented volume of construction and demolition waste (CDW), intensifying the urgency to develop sustainable strategies that not only address environmental risks but also harness the potential of recycled concrete aggregate (RCA).

The findings revealed that the C50S50 mixture demonstrated the most favorable performance, serving as the basis for FBHF incorporation. Among all tested formulations, S50FB3 proved to be the most promising, offering a viable and sustainable alternative for non-load-bearing building applications such as brick production.

Recommendations

The integration of industrial by-products like BFS alongside naturally sourced FBHF contributed meaningfully to reducing the ecological burden of waste disposal, reinforcing circular economy principles in the construction sector. Future research should further explore the long-term durability and scalability of these mixtures under diverse structural and climatic conditions.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest.

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References

- Abbass, M., Singh, D., & Singh, G. (2021). Properties of hybrid geopolymer concrete prepared using rice husk ash, fly ash and GGBS with coconut fiber. *Materials Today: Proceedings*, 45, 4964–4970.
- Ahmad, J., Kontoleon, K. J., Majdi, A., Naqash, M. T., Deifalla, A. F., ... & Ben Kahla, N. (2022). A comprehensive review on the ground granulated blast furnace slag (GGBS) in concrete production. *Sustainability*, 14(14), Article 8783.
- Alkan, S. N., Doğdu Yüçetürk, G., & Şengül, Ö. (2025). Lifecycle assessment analysis of recycled concrete aggregate incorporating fly ash and hemp fiber. *Environmental Research and Technology*, 8(3), 523–534.
- Bakharev, T. (2006). Thermal behaviour of geopolymers prepared using class F fly ash and elevated temperature curing. *Cement and Concrete Research*, 36, 1134–1147.
- Bennett, B., Visintin, P., & Xie, T. (2022). Global warming potential of recycled aggregate concrete with supplementary cementitious materials. *Journal of Building Engineering*, 52, Article 104394.
- Chen, C., Habert, G., Bouzidi, Y., Jullien, A., & Ventura, A. (2010). LCA allocation procedure used as an incentive method for waste recycling: An application to mineral additions in concrete. *Resources, Conservation and Recycling*, 54(12), 1231–1240.
- Chen, C., Lu, C., Lu, C., Wei, S., Guo, Z., ... & Zhou, Q. (2023). Synergetic effect of fly ash and ground-granulated blast slag on improving the chloride permeability and freeze–thaw resistance of recycled aggregate concrete. *Construction and Building Materials*, 365, Article 130015.
- De Domenico, D., Faleschini, F., Pellegrino, C., & Ricciardi, G. (2018). Structural behavior of RC beams containing EAF slag as recycled aggregate: Numerical versus experimental results. *Construction and Building Materials*, 171, 321–337.
- Dinakar, P., Sethy, K. P., & Sahoo, U. C. (2013). Design of self-compacting concrete with ground granulated blast furnace slag. *Materials & Design*, 43, 161–169.
- Doğdu, G., & Alkan, S. N. (2023). Deprem sonrası oluşan inşaat ve yıkıntı atıklarının değerlendirilmesi: 6 subat 2023 Kahramanmaraş depremleri. *Artvin Çoruh Üniversitesi Mühendislik ve Fen Bilimleri Dergisi*, 1(1), 38–50.
- Habert, G., d'Espinose de Lacaillerie, J. B., & Roussel, N. (2011). An environmental evaluation of geopolymer based concrete production: Reviewing current research trends. *Journal of Cleaner Production*, 19(11), 1229–1238.
- Imbabi, M. S., Carrigan, C., & McKenna, S. (2012). Trends and developments in green cement and concrete technology. *International Journal of Sustainable Built Environment*, 1, 194–216.
- Intergovernmental Panel on Climate Change. (2006). *2006 IPCC guidelines for national greenhouse gas inventories: Vol. 3. Industrial processes and product use*. IPCC/IGES.
- Junak, J., & Številová, N. (2015). The study of washed recycled concrete aggregates and blast furnace slag utilization in concrete production. *Advanced Materials Research*, 1100, 197–201.
- Limbachiya, M., Meddah, M. S., & Ouchagour, Y. (2012). Use of recycled concrete aggregate in fly-ash concrete. *Construction and Building Materials*, 27(1), 439–449.
- Lin, S. K., & Wu, C. H. (2021). Improvement of bond strength and durability of recycled aggregate concrete incorporating high volume blast furnace slag. *Materials*, 14(13), Article 3708.
- Marceau, M. L., Nisbet, M. A., & VanGeem, M. G. (2007). *Life cycle inventory of Portland cement concrete* (Report No. SN3011). Portland Cement Association.
- Mwiti, M. J., Karanja, T. J., & Muthengia, W. J. (2018). Thermal resistivity of chemically activated calcined clays-based cements. In *RILEM Bookseries* (pp. 327–333). Springer.
- Oh, D. Y., Noguchi, T., Kitagaki, R., & Park, W. J. (2014). CO₂ emission reduction by reuse of building material waste in the Japanese cement industry. *Renewable and Sustainable Energy Reviews*, 38, 796–810.

- Rondi, L., Bregoli, G., Sorlini, S., Cominoli, L., Collivignarelli, C., & Plizzari, G. (2016). Concrete with EAF steel slag as aggregate: A comprehensive technical and environmental characterisation. *Composites Part B: Engineering*, 90, 195–202.
- Serres, N., Braymand, S., & Feugeas, F. (2016). Environmental evaluation of concrete made from recycled concrete aggregate implementing life cycle assessment. *Journal of Building Engineering*, 5, 24–33.
- Smirnova, O. M., & Potyomkin, D. A. (2018). Influence of ground granulated blast furnace slag properties on the super-plasticizers effect. *International Journal of Civil Engineering and Technology*, 9, 874–880.
- Smirnova, O. M., Menéndez Pidal de Navascués, I., Mikhailevskii, V. R., Kolosov, O. I., & Skolota, N. S. (2021). Sound-absorbing composites with rubber crumb from used tires. *Applied Sciences*, 11, Article 7347.
- Thomas, M. D. A., Hooton, R. D., Scott, A., & Zibara, H. (2012). The effect of supplementary cementitious materials on chloride binding in hardened cement paste. *Cement and Concrete Research*, 42, 1–7.
- Tran, M. T., Babalola, O. E., & Le, D. H. (2023). Experimental investigation of the performance of ground granulated blast furnace slag blended recycled aggregate concrete exposed to elevated temperatures. *Clean Waste Systems*, 4, Article 100069.
- Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., & Weidema, B. (2016). The ecoinvent database version 3 (part I): Overview and methodology. *The International Journal of Life Cycle Assessment*, 21(9), 1218–1230.

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