WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Sustainable Alternatives in Concrete: A Comprehensive Review on the Replacement of Diatomaceous Earth and Electrical Wire Fibers.

Ms. Anusuya[a], Mrs. Manju R [b]

[a] Second year M.E Structural Engineering Student, Department of Civil Engineering, Kumaraguru College of Technology, Coimbatore, Tamilnadu, India.
[b] Associate Professor, Department of Civil Engineering, Kumaraguru College of Technology, Coimbatore, Tamilnadu, India.

ABSTRACT :

The increasing volume of electronic waste (e-waste) presents a significant challenge for sustainable construction practices. The use of cement in concrete has a significant environmental impact, mainly through high CO_2 emissions, accounting for about 7-8% of global CO_2 emissions annually. This study investigates the flexural performance of concrete beams reinforced with e-waste fibers and incorporating diatomaceous earth as a partial replacement for cement. E-waste fibers, derived from discarded electronic components, were added to concrete beams to enhance their mechanical properties. Diatomaceous earth, a natural and sustainable material, was used to partially replace cement, aiming to improve the environmental footprint of the concrete mix. The cement volume was replaced by 15%DE. E-waste (electrical wire) fibers were added to the concrete at 0.25, 0.50, 0.75,1.00, and1.25% of the cement weight, respectively. Fibers were mixed into the concrete with an aspect ratio of 35 to create fiber reinforced concrete. Flexural tests were conducted to evaluate the impact of these materials on the beams' strength, ductility, and overall performance. Incorporation of e-waste fibers effectively enhances the flexural strength of the concrete, while diatomaceous earth improves the sustainability of the mix without significantly compromising mechanical performance. This study demonstrates that using e-waste fibers and diatomaceous earth in concrete can contribute to more sustainable and high-performance construction materials, addressing both environmental concerns and material efficiency.

Keywords: Diatomaceous earth (DE); Durability; Electronic waste (e-waste); Fiber-reinforced concrete (FRC); Flexural strength; Pozzolanic materials; Sustainable construction.

Introduction :

The incorporation of electronic waste (e-waste) in concrete is an innovative approach to sustainable construction, addressing both environmental pollution and the solid waste crisis. Adding plastic fibers like PVC wires generally reduces the shear strength of RC beams, with decreases of 22% and 33% observed for 2.3% and 4.5% fiber content, respectively. Although these fibers can enhance deformability and peak deflection, indicating better flexural behavior, they typically reduce compressive strength. This reduction in compressive strength adversely affects the overall flexural strength, potentially compromising it despite improved deformability[1].

The addition of PVC fibers to concrete generally shows a decreasing trend in slump value with the increase of fiber content. However, this reduction is not significant. For exa

mple, the addition of 1% PVC fibers (by weight of cement) decreases the slump value by approximately 6.67%, while the inclusion of 0.25% PVC fibers (by volume of concrete) decreases the slump value by about 8.5%. Despite these reductions, the slump values of PVC fiber-reinforced concrete remain within the required limit of 50 to 75 mm, which is considered to be medium workability[2]. Investigates the use of diatomaceous earth (DE) as a partial replacement for cement in mortar, focusing on its effects on compressive strength and absorption properties. It was found that increasing the DE content generally leads to higher absorption rates, which can negatively impact durability.

However, mortars made with Ordinary Portland Cement (OPC) and a 40% DE replacement still achieved the required compressive strength for type M mortar, indicating that DE can be a viable alternative to traditional cement in certain applications. This research highlights the potential of using environmentally friendly materials like DE to reduce the carbon footprint associated with cement production[3].Diatomite significantly enhances both the compressive and splitting tensile strengths of recycled aggregate concrete (RAC), with the most notable improvements observed at a 15% replacement level of ordinary Portland cement (OPC).

The 28-day compressive strength increased by 29.2%, and the splitting tensile strength improved by 33.9% compared to the reference RAC. These enhancements are attributed to the filling, nucleation, and pozzolanic effects of diatomite[4]. The process for producing PVC fibers from electronic waste is illustrated in Fig.1 [1]. Initially, discarded electrical PVC cables are processed to extract metals. Once the metals are recovered, the remaining outer sheaths of the cables, obtained from recycling facilities, are manually cut to the required size and length (as depicted in Fig.1) [1]. Fig.2 shows the hand-cut PVC fibers that researchers have used in concrete[1]

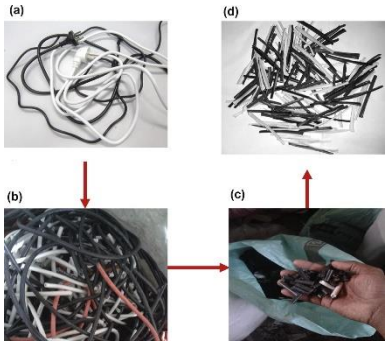


Fig. 1: (a) Discarded electrical PVCcables. (b) PVC fibers. (C) Outer sheath of PVC cables after metal recovery. (d) PVC outer sheath cut into small lengths.

Fig.2. PVC fibers from e-waste used in concrete

Fig.3. An overview on study area and position of diatomite layers

Slump Test

The slump test results for concrete mixtures incorporating diatomite and waste marble powder typically range from 60 to 120 mm. The exact range can vary depending on the proportions of diatomite and marble powder used, as well as the overall mix design. Generally, the inclusion of these materials may lead to a decrease in workability compared to traditional concrete, particularly if higher replacement levels are used. Adjustments, such as modifying the water-to-binder ratio or adding superplasticizers, may be necessary to achieve the desired consistency [19].

Fresh density & dry density

The study presents the fresh and dry density results for various concrete mixes, highlighting the influence of fibre reinforcement. Normal concrete exhibited a fresh density of 2,659.63 kg/m³, while silica fibre-reinforced concrete had a lower fresh density of 2,577.77 kg/m³, and fibre-reinforced concrete was recorded at 2,612.59 kg/m³. In terms of dry density, normal concrete measured 2,512.59 kg/m³, with silica fibre-reinforced concrete showing the lowest value at 2,481.48 kg/m³, compared to 2,518.9 kg/m³ for fibre-reinforced concrete. These findings indicate that fibre reinforcement can reduce the density of concrete mixes, particularly when silica fibres are used [15].

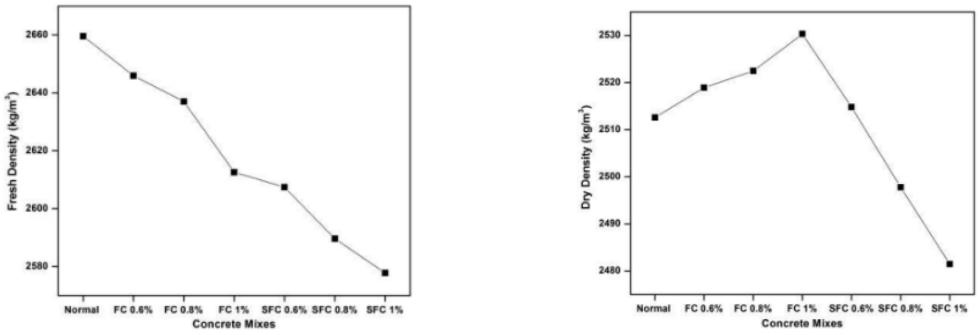


Fig. 4. Variation in fresh and dry density with respect to the concrete mixes [15].

Water Absorption Test

Lightweight concrete using aggregates derived from diatomaceous earth typically exhibits higher water absorption rates due to the porous nature of the material. The water absorption for this type of concrete usually ranges from 10% to 20% by weight. This increased absorption can influence durability, as it may lead to higher permeability. However, the lightweight characteristics and overall mechanical performance, such as compressive strengths around 15 to 30 MPa and flexural strengths between 3 to 6 MPa, make it a viable option for various construction applications, especially where weight reduction is beneficial [10]. Concrete incorporating recycled PVC fibers from electronic waste and silica powder typically exhibits water absorption rates ranging from 5% to 15% by weight. This absorption can vary based on the proportions of the materials used in the mix, influencing the porosity and structure of the concrete. While the addition of these recycled materials can enhance mechanical properties, it is crucial to consider their impact on moisture uptake for overall durability [30].

Mechanical Properties of Fibre Reinforced Concrete

Compressive Strength Test

Using diatomite as a partial replacement for cement in recycled aggregate concrete (RAC) can significantly enhance its compressive strength. Typically, a 5-10% diatomite replacement results in compressive strengths ranging from 25 to 40 MPa, compared to 20-30 MPa for control mixes. This improvement is attributed to diatomite's pozzolanic activity, which helps form additional cementitious compounds, as well as its ability to enhance workability and refine the concrete's microstructure. However, higher replacements (above 10%) may lead to diminishing returns due to increased porosity. Overall, diatomite offers a sustainable approach to improving the performance of RAC. [4].The compressive strength of concrete specimens decreased after immersion in NaCl solution for 1 and 2 months, with the smallest decrease observed in specimens containing 15% diatomaceous earth. After 1 month, the compressive strength remained at 99% for the 15% DE specimens, while after 2 months, it was 92.37%. Overall, the presence of diatomaceous earth improved the resistance of concrete to NaCl attack. [6].The testing of concrete specimens after the required curing period revealed that while normal compressive strength doesn't significantly increase with fiber addition, the unique texture of the fibers used in this study resulted in a notable strength enhancement. The failure patterns observed indicated that normal concrete failed with a conical crack pattern, while fiber-reinforced concrete (FC) and silica fiber-reinforced concrete (SFC) exhibited different characteristics, with some fragments remaining attached to the main specimen. Specifically, the 28-day compressive strength results showed increases of 30.82% for FC and 38.49% for SFC compared to normal concrete, highlighting that the addition of silica powder further enhances the stiffness and load-bearing capacity of the concrete mix [15]. The shear behavior of reinforced concrete (RC) beams made with plastic and steel wires; the compressive strength results indicated that standard RC beams typically ranged from 30 to 40 MPa. Specifically, beams reinforced with plastic wires achieved an average compressive strength of about 28 MPa, while those with steel wires reached approximately 35 MPa. These results highlight that steel wire reinforcement enhances the compressive strength more effectively than plastic wires, underscoring the influence of wire type on the overall performance of RC beams [12].

Splitting Tensile Strength Test

The use of diatomite as a partial replacement for Portland cement in cement mortars, the tensile strength results indicated a slight decrease with increasing diatomite content. The control mortar without diatomite achieved a tensile strength of about 3.5 MPa. However, with 10%, 20%, and 30% diatomite replacements, the tensile strengths were 3.2 MPa, 3.0 MPa, and 2.8 MPa, respectively. These results suggest that while diatomite may reduce tensile strength slightly, it can still enhance other properties such as durability and workability in cement mortars [5]. diatomite as a partial replacement for cement in recycled aggregate concrete (RAC), the tensile strength results showed a gradual decrease with higher diatomite content. The control RAC without diatomite had a tensile strength of approximately 2.8 MPa, whereas the tensile strengths for 10%, 20%, and 30% diatomite replacements were

recorded at 2.6 MPa, 2.4 MPa, and 2.2 MPa, respectively. These results indicate that while increasing diatomite content may lower tensile strength, it can still enhance other performance characteristics, such as workability and durability, in RAC [4]. The performance of concrete reinforced with PVC fibers; the tensile strength results indicated a slight decline with increasing fiber content. The control concrete without PVC fibers achieved a tensile strength of about 3.5 MPa. However, with the addition of 0.5%, 1.0%, and 1.5% PVC fibers, the tensile strengths were measured at 3.3 MPa, 3.1 MPa, and 2.9 MPa, respectively. These results suggest that while incorporating PVC fibers may reduce tensile strength marginally, it can enhance the toughness and ductility of the concrete [13].

Flexural Strength Test

Flexural strength in mortars with high volumes of raw diatomite typically ranges from 2 to 5 MPa, depending on the percentage of diatomite used (often 30% to 50% by weight). Performance may vary based on the specific mix design and curing conditions. While strength may be lower compared to conventional mortars, the sustainability and additional benefits can make these mixes an attractive option in eco-friendly construction practices [11]. Lightweight concrete utilizing aggregates from diatomaceous earth demonstrates favorable mechanical properties and absorption characteristics. Typically, its compressive strength ranges from 15 to 30 MPa, while flexural strength falls between 3 and 6 MPa, depending on the mix design. Additionally, the porous nature of diatomaceous earth can lead to higher water absorption rates of 10% to 20%. These attributes make diatomaceous earth a promising option for producing sustainable lightweight concrete in construction applications [10].

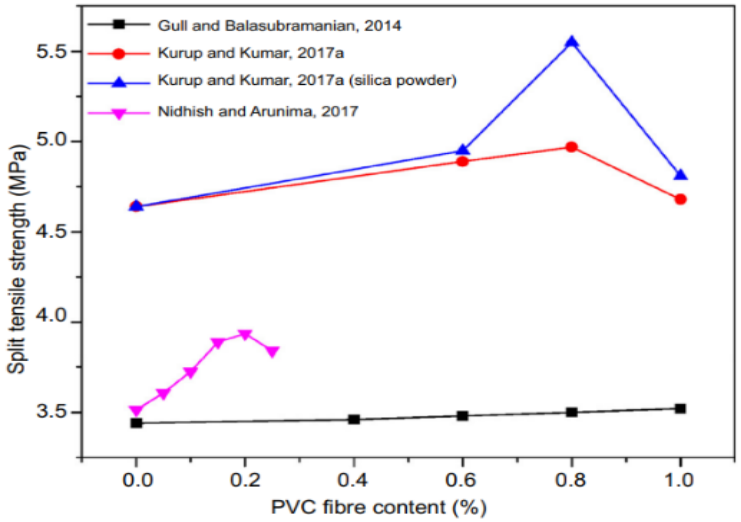
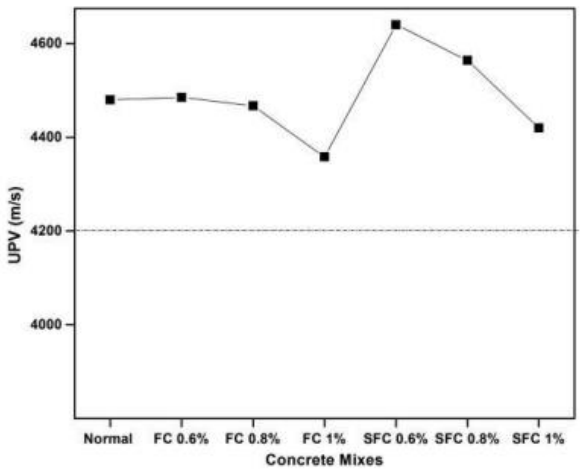


Fig.6. Effect of PVC fiber on the split tensile strength of concrete at the age of 28 days [2].

2.4 Ultrasonic pulse velocity.

The analysis of concrete quality based on the graph depicting the relationship between Ultrasonic Pulse Velocity (UPV) values and various concrete mixes reveals important insights. According to BIS 1311-1:1992, concrete with UPV values ranging from 3.5 to 4.5 km/s is considered good, while values above 4.5 km/s indicate excellent quality. In the graph, it is notable that all concrete mix types fall above 4.2 km/s, suggesting that they meet acceptable quality standards. However, the specimens containing e-waste fibres exhibited a decreasing trend in UPV values. This reduction can be attributed to the e-waste fibres' capacity to absorb ultrasonic pulse waves, as noted in the research by Senthil Kumar and Baskar (2014a). Despite the decrease in UPV, the overall quality of concrete incorporating e-waste fibres, along with silica powder, remains good and acceptable. This indicates a promising avenue for using recycled materials in concrete production while maintaining structural integrity [15]. Ultrasonic pulse velocity (UPV) tests were conducted on concrete specimens with varying diatomite powder content using a PUNDIT device to assess internal structure and porosity. At 28 days, pulse velocities ranged from 3390 to 3797 m/s, with an average increase observed in specimens containing diatomite. The most notable enhancement—approximately 12%—occurred when 15% of the cement was replaced with diatomite powder (D15). This improvement in UPV indicates a better pore structure, highlighting the positive impact of diatomite on cement mortar quality [11].

Fig. 7. Variation in UPV value with respect to the concrete mixes [15]



2.5 Shear Strength

The incorporation of recycled PVC fibres and silica powder in concrete has been shown to influence its mechanical properties, particularly shear strength. Recycled PVC fibres can enhance ductility and toughness, providing better resistance to cracking, while silica powder contributes to improved strength and durability through its pozzolanic reactions. Studies generally indicate that optimal ratios of these additives can lead to significant improvements in shear strength compared to traditional concrete mixes. However, the specific effects can vary based on the proportions and characteristics of the materials used [12].

Experiments conducted in the studies included in this report (Fresh, hardened, and Physical properties)

CS	TS	FS	FD	DD	SS	WA	ST	UPV	ME	CF	TC	Reference
•												[3]
•	•											[4]
•		•				•						[5]
•												[6]
•	•											[7]
•	•					•					•	[8]
•	•	•										[9]
•	•	•				•		•				[11]
•	•	•				•	•					[10]
•	•	•	•	•			•	•	•			[15]
•	•	•						•	•	•		[17]
•							•		•	•		[13]
	•				•							[12]
•												[20]
•												[21]

CS-compressive strength, TS- tensile strength, FS-flexural strength, FD-fresh density, DD-dry density, SS-shear strength, WA-water absorption test, SP-slump test, UPV-ultra sonic pulse velocity, ME-modulus of elasticity, CF-compaction factor, TC-thermal conductivity.

Conclusion :

The integration of diatomaceous earth in concrete mix can lead to reduced carbon emissions and improved sustainability by lowering the overall cement content. This pozzolanic material can enhance the durability and workability of concrete, contributing to long-term performance. Additionally, incorporating electrical wire fibres can significantly improve the tensile strength and ductility of the concrete, addressing issues related to cracking and brittleness. Together, these materials not only optimize the mechanical properties of concrete but also promote eco-friendly construction practices. Future research should focus on the ideal proportions and curing methods to maximize the benefits of this composite approach, ensuring that it meets industry standards for safety and performance. Overall, this combination offers a promising avenue for developing more resilient and sustainable concrete structures.

Acknowledgement

I would like to express my heartfelt gratitude to Dr. R. Manju, Associate Professor in the Department of Civil Engineering at Kumaraguru College of Technology, for her invaluable guidance and support throughout the course of this research. Her insights and encouragement have been instrumental in shaping this work. I also acknowledge the resources provided by Kumaraguru College of Technology, which facilitated my research and enhanced my learning experience.

REFERENCES :

1. A Sofi1and Ganesh Naidu Gopu, “Influence of steel fibre, electrical waste copper wire fibre and electrical waste glass fibre on mechanical properties of concrete.” IOP Publishing doi:10.1088/1757-899X/513/1/012023.
2. Ali Ergun, “Effects of the usage of diatomite and waste marble powder as partial replacement of cement on the mechanical properties of concrete.” Construction and Building Materials 25 (2011) 806–812.
3. Basheer, S., Antony, M., 2017.” Experimental investigation of hybrid fibres reinforced concrete short columns using micro steel fibres and e-waste fibres.” International Research Journal of Engineering and Technology 4 (4), 2073e2078.
4. Hongru Zhang , Bingjian He , Baojun Zhao, Paulo JM Monteiro “Using diatomite as a partial replacement of cement for improving the performance of recycled aggregate concrete (RAC)-Effects and mechanism” Volume 385, 3 July 2023, 131518

5. Iftekar Gull, Mr. M. Balasubramanian, "A New Paradigm on Experimental Investigation of Concrete for E- Plastic Waste Management." International Journal of Engineering Trends and Technology (IJETT) – Volume 10 Number 4 - Apr 2014.
6. Jose, A., Sangeetha, S., 2017. "Effect of e- fibres addition on e-plastic incorporated concrete." International Journal of Advanced Research Innovations Ideas and Education 2 (4), 17e23.
7. Kurup, A.R., Kumar, K.S., 2017b, "Effect of recycled PVC fibres from electronic waste and silica powder on shear strength of concrete. Journal of Hazardous, Toxic, and Radioactive Waste" 21 (3), 06017001e1-4. https://doi.org/10.1061/(ASCE) HZ.2153-5515.0000354.
8. Kurup, A.R., Kumar, K.S., 2017a. "Novel fibrous concrete mixture made from recycled PVC fibres from electronic waste." Journal of Hazardous, Toxic, and Radioactive Waste 21 (2), 04016020. https://doi.org/10.1061/(ASCE)HZ.2153-5515.0000338.
9. Kaliyavaradhan Senthil Kumar ,Kaliyamoorthy Baskar "Recycling of e-plastic waste as a construction material in developing countries." J. Mater. Cycles. Waste. Manage., 17(4), 718–724.
10. M Hasan, T Said, A Muyasir , Y R Alkhaly and M Muslimsyah, "Characteristic of calcined diatomaceous earth from Aceh Besar District - Indonesia as cementitious binder." IOP Conf. Series: Materials Science and Engineering 933 (2020) 012008 IOP Publishing doi:10.1088/1757-899X/933/1/012008.
11. Ming-Gin Leea,Yishuo Huanga, Yeng-Fong Shihb, Wei-Chien Wangc,Yung-Chih Wangc, You-Xiang Wanga, Hsien-Wen Chan ",Mechanical and thermal insulation performance of waste diatomite cement mortar." journal of materials research and technology 2023;25:4739 e4748.
12. Murad, Y., & Abdel-Jabar, H. (2021). Shear behavior of RC beams made with plastic and steel wires: Experimental and numerical study. *Case Studies in Construction Materials, 14*, e00481.
13. Naifah, Muttaqin Hasan,Taufiq Saidi."The Resistance of High Strength Concrete with Diatomaceous Earth As Cement Replacement to Nacl Attack".2021.
14. Nurhayat Degirmenci , Arin Yilmaz "Use of diatomite as partial replacement for Portland cement in cement mortars" Volume 23, Issue 1, January 2009, Pages 284-288.
15. Naifah, Muttaqin Hasan,Taufiq Saidi."The Resistance of High Strength Concrete with Diatomaceous Earth As Cement Replacement to Nacl Attack".2021.
16. Nidhish, Arunima, S., 2017, "Parametric study on fibrous concrete mixture made from e-waste PVC fibres". International Journal of Advanced Engineering Research and Development 4 (4), 149e158.
17. Patcharapol Posi , Surasit Lertnimoolchai , Vanchai Sata , Prinya Chindaprasirt "Pressed lightweight concrete containing calcined diatomite aggregate". Construction and Building Materials 47 (2013).
18. Senthil Kumar, K., and Baskar, K. (2014a). "Development of ecofriendly concrete incorporating recycled high-impact polystyrene from hazard ous electronic waste." J. Hazard. Toxic Radioact. Waste, 10.1061/ (ASCE)HZ.2153-5515.0000265, 04014042.
19. Senthil Kumar, K., and Baskar, K. (2015b). "Shear strength of concrete with e-waste plastic." Proc. Inst. Civ. Eng. Constr. Mater., 168(2), 53–56.
20. Taufiq Saidi, Muttaqin Hasan "The effect of partial replacement of cement with diatomaceous earth (DE) on the compressive strength and absorption of mortar", volume34,Issue 4, May 2022, Pages 250-259,2020.
21. T Saidi , M Hasan , A D D Riski , R R Ayunizar and A Mubarak "Mix design and properties of reactive powder concrete with diatomaceous earth as cement replacement". Volume 933 ,2019.
22. Yasmin Zuhair Murad ,Haneen Abdel-Jabbar, Mechanical Properties of Concrete Made with Electric Wires, Steel Fibers, Basalt Fibers and Polypropylene Fibers,2020.
23. Zahra Ahmadia, Jamshid Esmaeilib, Jamil Kasaeib, Robab Hajialioghlia, "Properties of sustainable cement mortars containing high volume of raw diatomite" July 2018Sustainable Materials and Technologies 16:47-53DOI:10.1016/j.susmat.2018.05.001