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EVALUATION OF SUSTAINABLE GREEN CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY WASTE SUPPLEMENTARY CEMENTITIOUS MATERIAL: A DETAILED REVIEW

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ABSTRACT
The concrete industry forms an integral part of construction activity worldwide. It is increasingly coming under pressure in terms of its effect on the environment, especially concerning energy use and raw material consumption. Different waste materials as partial replacements for cement have been investigated by researchers to improve this aspect of concrete production, making it more environment-friendly. A review of the possibility that can be achieved if building demolition waste is used as an alternative binder to ordinary cement in green concrete mix. The synthesis of recent studies in the review focuses on the physical, mechanical, and environmental behavior of concrete that incorporates demolition waste as a replacement for cement. Prior research has shown that waste building materials such as concrete rubble aggregate (CRA), ceramic, and glass can be partially utilized in the production of concrete with reduced environmental impact compared to their traditional counterparts without compromising on fresh or hardened properties. In general, the results of this review suggest that using building demolition waste as cement replacement provides a promising approach to generating more sustainable green concrete options, leading toward a circular economy in the construction industry.
Keywords: Green Concrete, Building Demolition Waste, Cement Replacement, Sustainability, Environmental Impact, physical properties, mechanical properties.

I. Introduction
The construction industry plays a crucial role in global resource consumption and greenhouse gas emissions, particularly due to the significant contribution of cement and concrete production to these environmental impacts. Cement production alone accounts for around 8% of worldwide CO2 emissions, while the concrete industry as a whole consumes substantial amounts of natural resources like aggregates, water, and energy.
In response to these challenges, scholars have investigated various methods to enhance the sustainability of concrete manufacturing. These include utilizing alternative cementitious materials and incorporating waste materials as partial substitutes for cement and aggregates. One promising strategy involves the reutilization of building demolition waste, which is a notable waste stream in the construction and demolition fields.

II. Literature
The extent of research that has been undertaken on this topic thus far is relatively constrained. This section gives an outline of the key findings from previous studies, encapsulating their importance in the field.
Hedayat Ullah Safi, Mohammad Mukhlis Behsoodi, and Mohammad Naseer Sharifi [2024] This study reveals that partial cement replacement with building demolition waste can enhance concrete strength up to a certain threshold. The optimal replacement level of 17.5% demonstrated significant improvements in both compressive and flexural strength at 28 days, outperforming even the 15% and 10% replacements. However, the 20% replacement showed decreased strength, indicating a potential

upper limit for effective use. These findings suggest that incorporating building demolition waste as a partial cement substitute can be beneficial for concrete performance, but careful consideration must be given to the replacement percentage to ensure optimal results and avoid compromising structural integrity.

Silvina V. Zito, Edgardo F. Irassar, and Viviana F. Rahhal [2023] The results indicate that the ground ceramic-based waste from construction and demolition waste (C&DW) promotes hydration throughout all stages. At first, this enhancement is mainly due to physical factors (filler effect), but as time progresses, it transitions to chemical mechanisms (pozzolanic reaction). The findings of this research suggest that it is feasible to manufacture concrete with mechanical characteristics similar to traditional concrete after 28 days.

Herbert Sinduja Joseph, Thamilselvi Pachiappan, Siva Avudaiappan, Nelson Maureira-Carsalade, Angel Roco-Videla, Pablo Guindos, and Pablo F. Parra [2023] This paper looks at the possibilities and problems of using recycled aggregate (RA) in the making of concrete. Even though RA is not the same as natural aggregate, pozzolanic materials and preparation can help it function better. The study suggests using adjusted mixing methods, appropriate ratios, and a maximum replacement of 30% RA. It is recommended to use pozzolanic and precoated materials to improve workability, strength, and durability. These results provide a road map for integrating RA into concrete in a way that balances structural performance and sustainability. Sufficient execution can result in the effective utilization of RA, encouraging ecologically sustainable building methods.

Maria V. Borrachero, Jordi Paya, Santiago Brito, Yasna Pamela Segura, Lourdes Soriano, Mauro M. Tashima, and Jose Maria Monzo [2022] This study demonstrates the successful development of sustainable alkali-activated binders using construction and demolition waste (C&DW) from Valencia, Spain, combined with blast furnace slag (BFS). The C&DW, rich in CaO, SiO2, and Al2O3, was alkali-activated with BFS using sodium hydroxide and sodium silicate. The resulting pastes showed promising characteristics through thermogravimetry and SEM analysis. Notably, mortars produced from these binders achieved high compressive strengths, with the 50% C&DW-50% BFS mixture reaching 58 MPa. This research proves that new, sustainable binders can be created through the alkali activation of C&DW-BFS mixtures without using Portland cement. These findings represent a significant advancement in eco-friendly construction practices, offering a viable method for repurposing construction waste while substantially reducing the carbon footprint associated with traditional cement production.

Imane Raini, Laila Mesrar, Abdelhamid Touache, Imad Raini, and Raouf Jabrane [2022] The results show that, as per the required standards, using up to 15 waste powders (WPs) doesn't change the mechanical properties of cement mortar. Interestingly, when it comes to waste brick powder (WBP), using 5% or 10% improves strength. A maximum strength of 52.9 MPa was recorded with this combination. Moreover, the microstructure analyses suggest that both WBP and mixed waste powder (MWP) create a denser mortar structure in comparison to the standard reference. The mineralogy analysis backs this up, showing that WBP and MWP strongly influence the hydration products found in the developed mortars.

Manuel Contreras Llanes, Maximina Romero Perez, Manuel Jesus Gazquez Gonzalez, and Juan Pedro Bolivar Raya [2021] The findings showed that incorporating recycled aggregate (RA) at levels of up to 50 wt.% is possible. Furthermore, RA was effectively utilized to create paving blocks that meet industrial standards. Consequently, water absorption rates under 6.0% and tensile strength exceeding 3.6 MPa were achieved. These figures align closely with those of a reference sample, staying within the limits set by regulations. Achieving these outcomes involved decreasing the amount of cement used, which not only lowers production costs but also reduces environmental impact.

Blas Cantero, Miguel Bravo, Jorge de Brito, Isabel Fuencisla Saez del Bosque, and Cesar Medina [2020] This study demonstrates the effectiveness of combining ground-recycled concrete (GRC) and mixed recycled aggregate (MRA) in concrete production. Using 10–25% GRC with 50% MRA significantly improves thermal properties by reducing conductivity and increasing heat capacity. These improvements, linked to lower density and higher porosity, result in superior energy efficiency compared to conventional concrete. This research provides valuable insights into using GRC as a cement replacement alongside MRA, addressing a gap in the existing literature and promoting more sustainable construction practices. The findings present a promising alternative for the construction industry, balancing environmental concerns with improved material performance.

Deepak Patel, Raj Singh, and Peeyush Gond [2019] The present study showcases the advantages of using fly ash in recycled aggregate concrete (RAC) instead of partial cement. The study reveals that 15% fly ash (RAC15) is the ideal amount for testing M45-grade mixes with 0–20% fly ash, demonstrating greater strength over the control mix. By using less cement and increasing recycling, fly ash is an environmentally friendly substitute that improves RAC strength and fosters sustainability. These results may promote a broader use of fly ash in buildings, which would result in the creation of more environmentally friendly infrastructure.

Jianzhuang Xiao, Zhiming Ma, Tongbo Sui, Ali Akbarnezhad, and Zhenhua Duan [2018] The outcomes show that blends with recycled powder (RP) have a higher hydration rate than concrete blends without RP. Up to a 30% substitution of RP is found to have a positive or insignificant adverse consequence on the mechanical properties of recycled powder concrete (RPC). Then again, substitution rates above 45% lead to an extensive diminishment in all mechanical properties researched. Accordingly, because of the outcomes, an RP substitution rate in the range of 15%–30% is suggested. The substantial functionality and early-age breaking are found to be adversely affected by the expansion of RP, and breaking control measures should be implemented.

Serkan Subasi, Hakan Ozturk, and Mehmet Emiroglu [2017] Granulated waste ceramic powder (WCP) was explored as a potential filler material for self-consolidating concrete. Incorporating up to 15% WCP enhanced the concrete's viscosity, indicating positive effects on workability. However, a slight reduction in strength was observed at this replacement level. Considering both flowability and strength properties, the study suggests that finely ground WCP can be effectively used as a cement replacement in self-consolidating concrete up to a 15% substitution rate.

M.S. Rosman, N.F. Abas, and M.A. Othuman Mydin [2014] This study examined the mechanical and thermal qualities of using leftover concrete to make concrete blocks. Testing was done on three combinations, including 0%, 5%, and 15% concrete waste. The 15% waste combination had the highest thermal performance, with the lowest temperature relative to the surrounding air. The combination under control, which had no waste, had the maximum density and compressive strength. When it came to pulse velocity, the 5% waste combination showed mediocre quality. According to their results, adding leftover concrete may enhance thermal qualities while marginally reducing mechanical strength. This might provide a building material that strikes a balance between performance and sustainability.

Vikas Srivastava, Mohd Monish, V. C. Agarwal, and P. K. Mehta [2013] In this study, an experimental study was conducted to evaluate the effect of partial replacement of conventional cement in concrete with different percentages of demolition waste. In this study, concrete cubes were cast with part of the cement replaced with recycled powder. The cubes were tested after 7 and 28 days. The compressive strength of these cubes was compared with that of a reference concrete (design mix concrete, M25). The test results show that recycled waste concrete with part of the cement (20%) replaced with recycled waste powder behaves almost the same as the reference concrete.

III. Conclusion

Incorporating building demolition waste as a partial replacement for cement is a feasible and effective approach. Optimal replacement levels range from 15–30%, with some studies showing improvements in strength, thermal properties, and sustainability. Key findings include enhanced hydration rates, comparable or improved mechanical properties, and reduced environmental impact.

Based on the past research of the experts outlined above, many conclusions can be drawn:

- The optimal waste glass powder replacement for cement is 17.5%, consistently providing peak strength improvements across all testing periods. This level demonstrates significant enhancements in both compressive and flexural strengths, making it ideal for structures subject to various loading conditions.
- Ground ceramic-based waste from construction and demolition waste (C&DW) enhances cement hydration through both physical and chemical mechanisms. Initially, it acts as a filler, but over time, it contributes to the pozzolanic reaction, promoting continuous strength development in concrete.
- Concrete incorporating C&DW can achieve mechanical properties comparable to traditional concrete after 28 days, indicating its potential as a viable and sustainable alternative in construction applications.
- Recycled aggregate (RA) concrete showed encouraging outcomes. It is possible to improve RA performance by utilizing pre-treatment procedures and pozzolanic materials. Experts advise replacing no more than 30% RA, which needs exact proportioning and the use of specialist mixing techniques.
- The study confirmed the successful development of sustainable and strong alkali-activated binders using construction and demolition waste and blast furnace slag. These binders, achieving compressive strengths up to 58 MPa without Portland cement, offer a promising alternative for eco-friendly construction.
- Adding up to 15% waste powder to cement mortar does not negatively impact its mechanical properties. Using 5–10% waste brick powder as a replacement can increase the mortar's strength, reaching a maximum of 52.9 MPa.
- Up to 50% of the materials in paving blocks can be effectively replaced with recycled aggregate without compromising industry standards. These blocks exhibit water absorption rates below 6.0% and tensile strength exceeding 3.6 MPa. By reducing cement consumption, this substitution contributes to lower production costs and a diminished environmental impact.
- Combining 10–25% ground recycled concrete with 50% mixed recycled aggregate significantly improves the thermal properties of concrete, making it more energy-efficient than conventional concrete.
- Using 15% fly ash as a cement replacement in recycled aggregate concrete results in optimal performance. This mixture demonstrates improved strength compared to the control mix while promoting sustainability.
- Fly ash reduces the need for cement and supports recycling efforts, making it an eco-friendly solution for the construction industry.
- Recycled powder enhances concrete hydration. A substitution rate of 15–30% is recommended for optimal mechanical properties in recycled powder concrete.
- Adopting waste utilization strategies in construction promotes a circular economy by minimizing waste and CO2 emissions. This approach is particularly beneficial in regions with abundant industrial byproducts.
- Waste ceramic powder (WCP) improved the workability of self-consolidating concrete, but it led to a slight decrease in strength.
- Finely ground WCP can be effectively used as a filler material up to 15% in self-consolidating concrete while maintaining overall performance.
- Incorporating concrete waste into concrete blocks can enhance thermal insulation properties.

- The compressive strengths of concrete cubes containing up to 20% recycled waste powder were similar to those of control mixtures.
- The findings of the experiments point to the possibility of using recycled waste powder in place of cement to make concrete that performs comparably to regular concrete.

Statements and Declarations:

Data Availability Statement:

Data supporting the study's conclusions are accessible from ResearchGate (https://www.researchgate.net) and DOI.org (https://doi.org) upon reasonable request.

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References

[1] Hedayat Ullah Safi, Mohammad Mukhlis Behsoodi, and Mohammad Naseer Sharifi 2024, “A Comparative Analysis of Compressive and Flexural Strength in Concrete with Partial Cement Replacement Using Waste Glass Powder.” Indonesian Journal of Material Research, e-ISSN: 2987-1654, Vol. 2, No. 1, March 2024. DOI: https://doi.org/10.26554/ijmr.20242120.

[2] Silvina V. Zito, Edgardo F. Irassar, and Viviana F. Rahhal 2023, “Recycled Construction and Demolition Waste as Supplementary Cementing Materials in Eco-Friendly Concrete.” Recycling 2023, 8, 54. https://doi.org/10.3390/ recycling8040054.

[3] Herbert Sinduja Joseph, Thamilselvi Pachiappan, Siva Avudaiappan, Nelson Maureira-Carsalade, Angel Roco-Videla, Pablo Guindos, and Pablo F. Parra 2023, “A Comprehensive Review on Recycling of Construction Demolition Waste in Concrete.” Sustainability 2023, 15, 4932. https://doi.org/10.3390/su15064932.

[4] Maria V. Borrachero, Jordi Paya, Santiago Brito, Yasna Pamela Segura, Lourdes Soriano, Mauro M. Tashima, and Jose Maria Monzo 2022, “Reusing Construction and Demolition Waste to Prepare Alkali-Activated Cement.” Materials 2022, 15, 3437. https://doi.org/10.3390/ma15103437.

[5] Imane Raini, Laila Mesrar, Abdelhamid Touache, Imad Raini, and Raouf Jabrane 2022, “Performance Evaluation of Cement Mortar Containing Construction and Demolition Waste as Supplementary Cement Materials.” Ceramics-Silikaty 66 (4), 407–418 (2022), www.ceramics-silikaty.cz, doi: 10.13168/cs.2022.0036.

[6] Manuel Contreras Llanes, Maximina Romero Perez, Manuel Jesus Gazquez Gonzalez, and Juan Pedro Bolivar Raya 2021, “Construction and demolition waste as recycled aggregate for

environmentally friendly concrete paving." Environmental Science and Pollution Research (2022) 29:9826–9840. https://doi.org/10.1007/s11356-021-15849-4.
[7] Blas Cantero, Miguel Bravo, Jorge de Brito, Isabel Fuencisla Saez del Bosque, and Cesar Medina 2020, "Thermal Performance of Concrete with Recycled Concrete Powder as Partial Cement Replacement and Recycled CDW Aggregate." Appl. Sci. 2020, 10, 4540; doi:10.3390/app10134540; www.mdpi.com/journal/applsci.
[8] Deepak Patel, Raj Singh, and Peeyush Gond 2019. "Green Concrete: Recycled Aggregate and Partial Replacement of Cement with Fly Ash." International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol. 8, Issue 4, April-2019 www.ijert.org.
[9] Jianzhuang Xiao, Zhiming Ma, Tongbo Sui, Ali Akbarnezhad, and Zhenhua Duan 2018. "Mechanical properties of concrete mixed with recycled powder produced from construction and demolition waste." Journal of Cleaner Production, Volume 188, 1 July 2018, Pages 720–731.https://doi.org/10.1016/j.jclepro.2018.03.277.
[10] Serkan Subasi, Hakan Ozturk, and Mehmet Emiroglu 2017. "Utilizing of waste ceramic powders as filler material in self-consolidating concrete." Construction and Building Materials, Volume 149, 15 September 2017, Pages 567–574. https://doi.org/10.1016/j.conbuildmat.2017.05.180.
[11] M.S. Rosman, N.F. Abas, and M.A. Othuman Mydin 2014. "Concrete Waste as a Cement Replacement Material in Concrete Blocks for Optimization of Thermal and Mechanical Properties." SHS Web of Conferences 11, 01013 (2014).
https://doi.org/10.1051/shsconf/20141101013.
[12] Vikas Srivastava, Mohd Monish, V. C. Agarwal, and P. K. Mehta 2013. "Demolition Waste as Cement Replacement in Concrete." J. Environ. Nanotechnol. Volume 2, No. 3, pp. 17–20. ISSN (Print): 2279–0748. ISSN (online): 2319–5541. doi: 10.13074/jent 2013.09.132026.