

Enhancing Concrete Performance with Marble Dust Powder and Rice Husk Ash for Sustainable Construction

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Abstract - This experimental study evaluates the performance of concrete that uses marble dust powder and Rice Husk Ash as sustainable substitutes to cement and fine aggregate. Five concrete mixes were developed, comprising a control mix and four experimental blends with 15% RHA (by weight of cement) and various MDP concentrations (5%, 10%, 15%, and 20% by weight of sand). When 15% of RHA and 10-15% MDP were added, the mechanical properties improved by up to 10% in compressive strength and 15% in flexural strength when compared to the control mix. Durability tests showed that the material absorbed less water, with the lowest amount being 3.05% when 20% MDP was used, which suggests the material has a tighter structure. From a cost perspective, using a mix of MDP and RHA saved 9.42% when 15% RHA and 20% MDP were used, and 3.18% when 15% MDP was used, showing that these materials can be a good and affordable choice. In terms of the environment, using MDP and RHA helps make construction more sustainable by cutting down CO₂ emissions and encouraging recycling of waste. This research shows that MDP and RHA can be useful, eco-friendly options for making strong and affordable concrete.

Key Words: Marble Dust Powder (MDP), Rice Husk Ash (RHA), Waste Recycling, Waste Management, Concrete Durability, Cost-Effective Concrete

1. INTRODUCTION

The construction industry is one of the largest consumers of natural resources and a significant contributor to environmental pollution, particularly through the production of conventional concrete (Spasova, 2022). The manufacturing of Portland cements, a key ingredient in concrete, and is responsible for a substantial portion of global CO₂ emissions, exacerbating climate change. Additionally, the extraction and processing of natural aggregates lead to environmental degradation and depletion of finite natural resources (Langer & Arbogast, 2002). Furthermore, the situation is worsened by the increasing demand for materials occasioned by the phenomenal growth in world population and increase in development rate in the last several decades. This trend leads to the ever-increasing gap between demand and supply for virtually all materials. The problem is particularly critical for developing countries. Pozzolanas are very essential content in the general production of alternative cementing materials used in the

replacement or substitute for cement. Pozzolana is a siliceous and aluminous material which reacts with calcium hydroxide in presence of water (Keshav Bharadwaj et al., 2023). They are also materials containing reactive silica and/or alumina which on their own have little or no binding properties but when mixed with lime in the presence of water, will set and harden like cement. This form compounds possessing cementitious properties at room temperature which can set underwater. Modern pozzolanic cements are a mix of natural or industrial pozzolans and Portland cement. Once fully hardened, the Portland cement-Pozzolana blend may be stronger than Portland cement, due to its lower porosity, which also makes it more resistant to water absorption (Van et al., 2014).

Agricultural byproducts such as rice husk ash, cassava peel, doum palm shell ash, groundnut shell ash, and similar materials can serve as partial substitutes for cement in construction applications (Barbuta et al., 2015). Asia is the top producer of rice because the region's tropical climate and rainy season make it ideal for growing rice in flooded areas (Endale et al., 2022). Research by (Vigneshwari et al., 2018), shows that RHA works well when used as a substitute for cement because it is both cheaper and better for the environment. RHA is a pozzolanic material, which means it can mix with water and calcium hydroxide to form a stable, insoluble cement-like substance. Concrete made with RHA as a partial replacement for cement has higher compressive strength because the calcium silicate hydrate gel that forms in the cement makes the concrete less porous and more dense, which improves its strength and reduces cracking (Bansal & Antil, n.d.).

In parallel, the industrial sector generates vast amounts of waste, including the marble waste powder (MWP) from the marble processing industry, ground granulated blast furnace slag (GGBFS), silica fume, and fly ash, weld slag, among others (Salihu Sarki Ubayi1, 2024). Globally, the estimated marble reserves amount to approximately 15 billion cubic meters, with marble industries operating in nearly fifty countries (Kürşat Esat Alyamaç & Alp Buğra Aydin, 2015). Marble waste refers to the by-products generated during the extraction, processing, and shaping of marble stone. The primary quarrying technique for marble stone involves blasting, which results in the loss of approximately 50% of the stone. This waste presents environmental challenges, prompting the exploration of alternative materials to complement cement production (Khan et al., 2023).

Approximately 25% of the marble processed during sawing, shaping, and polishing ends up as dust or powder (Gesoglu et al., 2012). These by-products include marble slurry, dust, chips, and fragments. Marble waste is a significant concern in the marble industry due to its environmental impact and disposal challenges. As a solution to these negative impacts, some researchers recommended the use of marble waste in the construction sector as a substitute for binder, aggregate, and additives in concrete (Ulubeyli et al., 2016). Marble waste is commonly utilized as a filler material across various industries, including construction, paints, and ceramics. Proper management strategies, including recycling and reuse, are essential to minimize the environmental impact of discarded marble chips and fragments (Luis, A. et al., 2013).

THE OBJECTIVE OF THE STUDY

- Explore the potential of Marble Dust Powder and Rice Husk Ash as sustainable alternatives to traditional concrete materials.
- Investigate the mechanical properties of concrete incorporating Marble Dust Powder and Rice Husk Ash, including compressive strength, flexural strength, and water absorption.
- Analyze the economic benefits of using marble waste powder & rice husk ash in concrete production, focusing on cost savings and potential reductions in production costs.

2. LITERATURE REVIEW

The incorporation of both marble waste and RHA can lead to environmentally friendly (less CO₂ emission, conservation of natural resources, transformation of waste that causes diseases to a useful material) and economical (reduced cost of cement procurement) concrete (Dr. maria idrees & shimza jamil, 2015) (Raina et al., 2021) Explored the mechanical properties and cost implications of blending rice straw ash (RSA), marble waste, and micro silica in concrete. The findings indicated that replacing 15% of cement with silica fume and rice straw ash did not compromise concrete strength. Additionally, incorporating marble aggregate as a partial substitute for conventional aggregate led to strength enhancement, despite the higher cost compared to the conventional aggregate. Research by (Khan et al., 2023) to come up with a novel marble-based binding material. The author burned marble powder clay and mixed it separately with rice husk ash and fly ash (at varying proportions of 20%, 30%, and 40% by mass of marble cement). The results indicated that the compressive strength of the marble cement mortar was lower than that of ordinary Portland cement mortar. However, the later-age strength of mortar prepared with marble cement blended with 30% rice husk ash was slightly higher than that of ordinary Portland cement mortar. Additionally, incorporating marble waste, rice husk ash, and

fly ash as binding materials for manufacturing building materials promotes sustainability by addressing environmental disposal concerns. (Gencel et al., 2021) investigated how the inclusion of RHA as a secondary binding material (at 10% and 20%) and MWP as a fine aggregate replacement (at 25% and 50%) affects the microstructural, mechanical, and transport properties of foamed concrete subjected to high temperatures and freeze-thaw cycles. Foamed concrete was produced with foam contents of 40 kg/m³ and 80 kg/m³. The results indicate that the optimal percentages occur at 90 days with 10% RHA and 50% MWP at a foam content of 40 kg/m³. Moreover using 10% RHA and 25% MWP shows the lowest drying shrinkage and sorptivity. (Bu et al., 2022) Investigation delved into the influence of recycled aggregates on concrete properties. They explored permeability, drying shrinkage, carbonation, chloride ion penetration, acid resistance, and freeze-thaw resistance. The findings highlight the strong correlation between recycled material quality and the strength of concrete with recycled aggregates. Moreover, incorporating materials like rice husk ash (RHA), fly ash, and silica fume can enhance the durability of recycled aggregate concrete. The incorporation of MWP and RHA offers cost-effective and environmentally friendly benefits (K & S, 2023) (Adetoye Olubunmi A et al., 2023). (Dr. maria idrees & shimza jamil, 2015) Investigated the impact of RHA as a replacement for cement and MP as a replacement for sand. The study analyzed both individual effects and their combined influence. Results revealed that the 10% MP sample exhibited the highest strength, while the control sample and the RHA-MP combination had comparable compressive, tensile, and flexural strengths. Notably, the RHA sample showed reduced strength compared to the control. S. Varadharajan (2025) Concrete with 18% RHA, 36% WMS, and 1.5% steel fibres (RH18MD36SF1.5) improved compressive, split tensile, and flexural strengths by 47.6%, 45.8%, and 49.6%. LCA using ReCiPe showed 36.5% lower particulate emissions, 36.6% lower GHGs, and 41.7% lower fossil fuel use. Md Jihad Miah et al (2025) developed data-based models that accurately predicted stress-strain profiles ($R^2 \approx 0.9950-0.9993$) and compressive strength. The 10% RHA mix showed promising results, with lower strength reduction (8% at 90 days) and potential for reducing CO₂ emissions The utilisation of rice husk ash (RHA) in concrete has been extensively reviewed by Barbhuiya Salim et al (2025), highlighting its potential as a supplementary cementitious material. Ibrahim abdullahi et al, (2024) investigated the feasibility of incorporating an agricultural waste (RHA), and marble dust powder (MDP), an industrial waste, as partial replacements for cement and fine aggregate in concrete production, addressing environmental concerns and reducing construction costs. The incorporation of RHA has been found to impact fresh and hardened properties of concrete, with optimal replacement percentages varying depending on the application. Mezgebu Debas Yeshiwes et al (2025) found that combining rice husk ash (RHA) and waste marble powder (WMP) as partial cement replacements up to 20% improved mortar properties, including compressive

strength and water absorption. Venkata Naresh Kopur et al (2025) successfully developed lightweight rice husk ash aggregates (RHAA) meeting ASTM C330 standards, with optimal performance at 50% RHA content. The RHAA exhibited improved physical properties, including particle compressive strength and water.

3. MATERIAL USED

3.1 Cement: OPC 43 grade cement were used and obtained from Jaipur, Rajasthan. The physical and chemical properties of the cement were in according to (ORDINARY PORTLAND CEMENT, 43 GRADE — SPECIFICATION). The specific gravity and density of the cement were measured to be 3.15 and 1440kg/m³ respectively.

3.2 Fine Aggregate: The fine aggregate was obtained from banas river, Rajasthan. The fine aggregate used for this research work was in accordance to (IS: 383 (1970): Specification for Coarse and Fine Aggregates From Natural Sources For Concrete) Specification for coarse and fine aggregate.

3.3 Coarse Aggregate: The coarse aggregate was obtained from local market. The coarse aggregate used for this research work was in accordance to (IS: 383 (1970): Specification for Coarse and Fine Aggregates From Natural Sources For Concrete) Specifications for coarse and fine aggregate.

3.5 Marble Dust Powder: The marble dust powder used for this research work was obtained by the roadside at Kishangarh dumping yard. The sample undergoes sieving, passing through a 4.75mm B.S sieve (No. 4 sieve) i.e the maximum size of fine aggregate used is approximately 4.75mm. The physical properties of the marble dust powder are presented in table 3.1 below. Similarly, figure 3.5 below shows the picture of the marble dust powder used.



Figure 3.5: Marble dust powder

3.4 Rice Husk Ash: Rice husk is an agricultural by-product, it is generated in large volume and it is available in all parts of the world (Adetoye Olubunmi A et al., 2023). The RHA for this study was procured from a reputable company in Chennai, Tamilnadu. The physical and chemical properties of the rice husk ash used for the research work were in accordance to (IS: 1727 (1967): Methods of Test for Pozzolanic Materials) BIS Methods of test for pozzolanic materials. Figure 3.4 below

shows a picture of the rice husk ash added to aggregate prior to mixing.



Figure 3.4: Rice husk ash powder

Table 3.1: Physical properties coarse aggregate, fine aggregate and marble dust powder

Physical property	Coarse aggregate	Fine aggregate	Marble dust powder
Specific gravity	2.76	2.68	2.72
Water absorption	0.43%	1.77%	1.19%
Fineness modulus	-	3.02	2.77

3.6 Water: The potable water used for the experiment. The water used for mixing was in accordance to (IS: 10262: 2009): Guidelines for Concrete Mix Design Proportioning) Guidelines for concrete mix design proportioning.

3.7 Admixture: In this study, WP+200 was utilized as an admixture to enhance workability, modify setting time, boost durability, raise strength, decrease water content, and attain various specific properties in concrete.

4. MIX DESIGN

The grade of concrete chosen as per this research work was M30, and the mix design was done as per IS code (IS:10262: 2009): Guidelines for Concrete Mix Design Proportioning), and (IS:456:2000): Plain and Reinforce Concrete - Code of Practice below are the step by step procedure for the mix design.

4.1 Sample preparation

As per this research work five specimens are involved, the first specimen is the control which is made from conventional concreting materials. The other four specimens are RHA15MDP5, RHA15MDP10, RHA15MDP15 and RHA15MDP20. The notation RHA15 referred to concrete blend with 15% of cement being replaced with rice husk ash, while MDP5, MDP10, MDP15 and MDP20 are represent 5%, 10%, 15%, and 20% replacement of fine aggregate with marble dust powder respectively.

4.2 Mixing procedure

For the control mix, 1:2.07:3.62 were combined manually by hand for duration of 1 minute. Approximately one minute later, 0.45 times the cement quantity of tap water was recorded, with 75% incorporated into the mixture and blended for around 2 minutes. The remaining 25% of the water was combined with superplasticizer (0.5% of cement) and added to the concrete mixture. This mixture was then stirred for an additional 2 minutes, resulting in a cement concrete with a uniform consistency. The above procedure is being repeated for similar quantity of coarse aggregate, water content and admixture. While the cement present in the mix was replaced partially by RHA 15% and similarly the fine aggregate is replaced by 5%, 10%, 15%, and 20%.

4.3 Casting procedure

Prior to casting, the moulds were fastened tightly, and a light layer of engine oil was brushed on to facilitate demoulding after 24 hours. The cube molds measured 15×15×15 cm, while the beam molds were 15×15×70 cm. The moulds were situated close to the mixing area and filled with concrete in three tiers, with each tier getting 25 strikes from a tamping rod.

4.4 Curing

Curing was done 7 to 14 days to enhance the process of cement hydration which increases the strength over time.

5. RESULT & DISCUSSION

This chapter shows the findings acquired from different experiments performed on concrete samples incorporating marble dust powder (MDP) and rice husk ash (RHA) as partial substitutes for cement and fine aggregate, respectively. The outcomes consist of assessments for initial tests on substances, compressive strength, flexural strength, and water absorption test for solid concrete.

5.1 Compressive strength test result

The compressive strength of concrete is an essential factor; it indicates the highest compression load that concrete can endure before it fails. According to research, M30 concrete is selected, and Figure 5.1 shows the outcomes of the compressive strength test conducted. The goal is to examine the combined effect of MDP and RHA on the compressive strength of concrete at 7 and 28 days. The control blend does not include RHA or MDP, while all other blends incorporate a 15% substitution of cement with RHA, and the substitution rates of MDP are 5%, 10%, 15%, and 20% with fine aggregate.

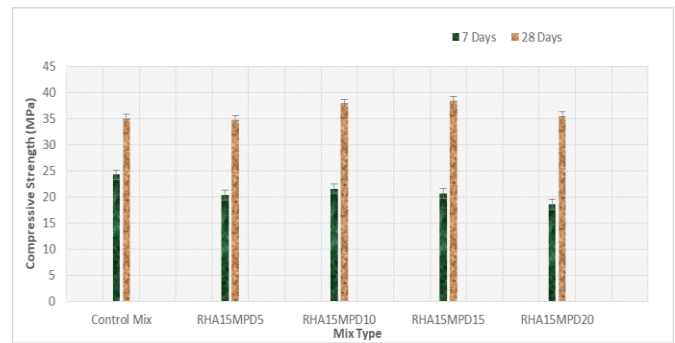


Figure 5.1: Graphical representation of compressive strength test result

From fig 5.1 we can see that at 7 days the compressive strength of the control mix was 24.24 MPa which is more than that of all the replaced samples, this shows that there is slow pozzolanic activity of RHA when combine with MDP at early age due to slower hydration process. The 28 days compressive strength of the control mix was outperformed by the 10%MDP and 15%MDP mixes. Beyond 15%, the compressive strength starts to reduce, as shown by the 20% MDP blend. The decrease in compressive strength at higher percentage replacement of fine aggregate with MDP may be attributed to the higher water requirement of such blend due to finer particles.

5.2 Flexural strength test result

The flexural strength, known as the modulus of rupture, is an essential factor in designing concrete elements subjected to bending or tensile forces, safeguarding the structural stability of concrete beams and slabs in constructions, bridges, and roadways. It signifies the peak stress endured by a member right before it fails under bending or flexure (Salihu Sarki Ubayi, et al 2024). Figure 5.2 below displays the results of the flexural strength test conducted at 7 and 28 days.

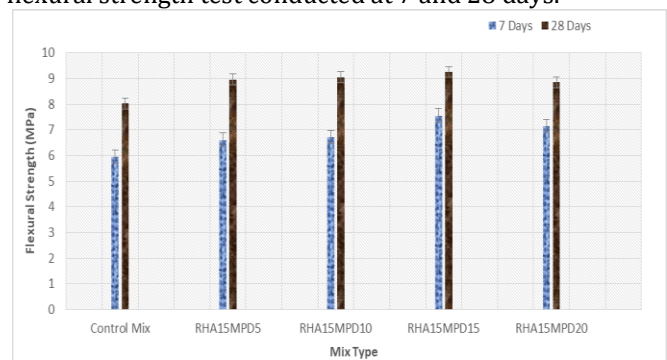


Figure 5.2: Graphical representation of flexural strength test result

From figure 5.2, we can see that, the incorporation of MDP and RHA resulted in higher early-age flexural strength development in comparison to the conventional blend. The MDP 15% mix shows the optimum flexural strength (7.56 MPa) approximately a 29% enhancement over the control. Similarly, the 5% and 10% MDP mixes showed significant enhancement, with 6.61 MPa and 6.72 MPa respectively. The

maximum flexural strength of 9.26MPa, (Approx. 15% increase compared to the control) was recorded for the 15% MDP blend at 28 days, producing concrete with superior tensile strength. Moreover, the 5% and 20% MDP mixes also showed notable improvements, recording strengths of 8.96 MPa and 8.85 MPa, respectively. The 10% MDP mix reached 9.05 MPa, indicating that both low and high MDP percentages generally contributed to strength improvements at 28 days.

5.3 Water Absorption

The water absorption test evaluates the porosity of a concrete specimen, where increased absorption signifies a larger number of voids in the material. This assessment measures the weight gain of a dry concrete cube following submersion in water. Increased water absorption results in lower durability, heightened permeability, weakened structural integrity, inferior concrete quality, and decreased long-term performance.

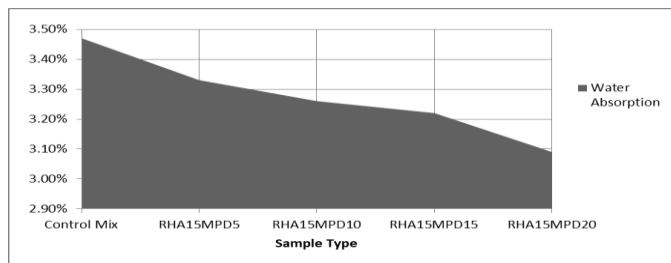


Figure 5.3: Graphical representation of water absorption test result

Figure 5.3 shows that the control sample has the highest water absorption value (3.47%), indicating greater porosity compared to the blends with RHA and MDP. As the percentage of MDP replacement increases, water absorption steadily decreases, with the lowest value recorded at 3.09% for the 20% MDP blend. This demonstrates that replacing 20% of fine aggregate with MDP produces a denser concrete, significantly reducing water absorption relative to the control. The results suggest that incorporating RHA and MDP enhances concrete performance by improving its resistance to water ingress, which benefits long-term durability and quality.

5.4 Economic benefit

The economic advantage of incorporating RHA and MDP in concrete manufacturing mainly comes from lower raw material expenses, decreased waste management costs, and enhancements in long-term durability. These elements not only decrease the short-term expense of concrete manufacturing but also diminish future upkeep costs and improve the appeal of sustainable concrete. In the cost analysis, the price variation between cement and RHA, along with that of fine aggregate and MDP, has been taken into account. The cost analysis for concrete per cubic meter includes the following material quantities: Cement: 350.48 kg, Fine Aggregate: 777.25 kg, where 15% of the cement is substituted with RHA in all mixtures, and different percentages of MDP (5%, 10%, 15%, and 20%) replace fine

aggregate. The results of the cost savings analysis for each blend are shown in Figure 5.4 shows the percentage savings of the substituted blend in relation to the control blend.

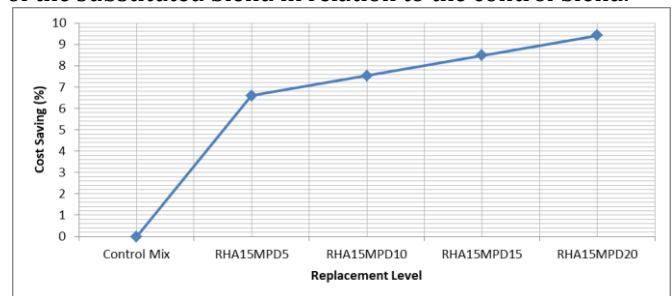


Figure 5.4: Graphical representation of percentage saving of the replaced blend as compared to control

Figure 5.4 above, depicted that using 15% RHA and increasing percentages of MDP from 5% to 20%, the cost of producing concrete per cubic meter decreases. The highest savings occur with 15% RHA and 20% MDP, offering a 9.42% reduction in cost compared to conventional concrete which accumulates into significant savings in large-scale projects. This demonstrates the economic benefit of using these materials as replacements, making concrete production more cost-efficient while maintaining structural integrity. (Dr. maria idrees & shimza jamil, 2015).

VI. CONCLUSION

Five concrete mixtures were created to assess the performance of concrete containing Marble Dust Powder (MDP) and Rice Husk Ash (RHA). These comprised a control mix without RHA or MDP, along with four experimental mixes where 15% of the cement was replaced with RHA and MDP was used as a fine aggregate at varying percentages: 5%, 10%, 15%, and 20%. The results of this research suggest that incorporating RHA and MDP as partial replacements for cement and fine aggregate in concrete provides numerous advantages. The main findings from the research can be summarized as follows:

- Concrete formulations with 15% RHA and 10% to 15% MDP exhibited superior compressive and flexural strengths compared to the standard mixture. The optimal mix, incorporating 15% RHA and 15% MDP, exhibited a compressive strength approximately 10% greater and a flexural strength 15% greater than the conventional blend. This indicates that the combination has improved structural strength and performance.
- The water absorption evaluation showed that incorporating RHA and MDP diminished the concrete's porosity, resulting in reduced water absorption. The blend with 20% MDP exhibited the lowest water absorption at 3.09%, indicating that the combination of RHA and MDP resulted in a denser and less permeable concrete structure, enhancing the material's long-term durability.
- The cost assessment revealed that substituting 15% of the cement with RHA and 20% of the fine

aggregate with MDP resulted in a cost decrease of about 9.42%. The most economical blend (15% MDP) achieved savings of approximately 3.18% in comparison to the standard blend. This suggests that utilizing these materials can render concrete production more cost-effective, particularly in regions with an abundance of agricultural and industrial by-products.

- The research highlights the ecological benefits of utilizing RHA and MDP. These materials reduce CO₂ emissions usually linked to cement production and promote the recycling of industrial and agricultural waste. This encourages more environmentally friendly building practices and backs worldwide efforts focused on reducing the ecological effect of construction operations.

REFERENCES

- [1] Alvee, A. R., Malinda, R., Akbar, A. M., Ashar, R. D., Rahmawati, C., Alomayri, T., Raza, A., & Shaikh, F. U. A. (2022). Experimental study of the mechanical properties and microstructure of geopolymer paste containing nano-silica from agricultural waste and crystalline admixtures. *Case Studies in Construction Materials*, 16, e00792. <https://doi.org/10.1016/j.cscm.2021.e00792>
- [2] Ameri, F., Shoaee, P., Bahrami, N., Vaezi, M., & Ozbakkaloglu, T. (2019). Optimum rice husk ash content and bacterial concentration in self-compacting concrete. *Construction and Building Materials*, 222, 796–813. <https://doi.org/10.1016/j.conbuildmat.2019.06.190>
- [3] Adesina, P. A., & Olutoge, F. A. (2019). Structural properties of sustainable concrete developed using rice husk ash and hydrated lime. *Journal of Building Engineering*, 25, 100804. <https://doi.org/10.1016/j.job.2019.100804>
- [4] Adetoye Olubunmi A, et al (2023). Suitability of using Marble Dust Powder and Rice Husk Ash in Production of SelfCompacting Concrete: A Review. *International Journal Of Multidisciplinary Research In Science, Engineering and Technology*, Volume 6(Issue 9), 11.
- [5] Cai, J., et al (2022). Influence of a Nano-Hydrophobic Admixture on Concrete Durability and Steel Corrosion. *Materials*, 15(19), 6842. <https://doi.org/10.3390/ma15196842>
- [6] Chik, F. A. W., Bakar, B. H. A., Johari, M. A. M., & Jaya, R. P. (2011). PROPERTIES OF CONCRETE BLOCK CONTAINING RICE HUSK ASH SUBJECTED TO GIRHA.
- [7] Chirag S. Mehta, et al(2019). A Review on Utilization of Waste Marble Powder in Concrete. *International Journal of Engineering Research*, Volume No.8(Issue Special 4), 75–77.
- [8] Chopra, D., Siddique, R., & Kunal. (2015). Strength, permeability and microstructure of self-compacting concrete containing rice husk ash. *Biosystems Engineering*, 130, 72–80. <https://doi.org/10.1016/j.biosystemseng.2014.12.005>
- [9] Dong, L., Meng, F., Feng, P., Ran, Q., Pan, C., & He, J. (2023). Effects of an Amphiphilic Micelle of Diblock Copolymer on Water Adsorption of Cement Paste. *Materials*, 16(6), 2190. <https://doi.org/10.3390/ma16062190>
- [10] Dr. maria idrees & shimza jamil(2015). Effect of rice husk ash and marble powder on mechanical behavior of concrete. Fifth International Conference on Sustainable Construction Materials and Technologies. <http://www.claisse.info/Proceedings.htm>
- [11] Gencel, O., Ozel, C., Koksall, F., Erdogmus, E., Martínez-Barrera, G., & Brostow, W(2012). Properties of concrete paving blocks made with waste marble. *Journal of Cleaner Production*, 21(1), 62–70. <https://doi.org/10.1016/j.jclepro.2011.08.023>
- [12] Gesoğlu, M., Güneyisi, E., Kocabağ, M. E., Bayram, V., & Mermerdaş, K. (2012). Fresh and hardened characteristics of self compacting concretes made with combined use of marble powder, limestone filler, and fly ash. *Construction and Building Materials*, 37, 160–170. <https://doi.org/10.1016/j.conbuildmat.2012.07.092>
- [13] Habibu, S., Ladan, M., Safana, A. A., Dandalma, Z. A., Saleh, I., & Abdullahi, S. R. (2023). Optimization of Methylene Blue Adsorption onto Activated Carbon derived from Pineapple Peel Waste using Response Surface Methodology. *UMYU Scientifica*, 2(4), 45–55. <https://doi.org/10.56919/usc.2324.006>
- [14] Ibrahim, I. A., A., E., D., S., N. G., M., S. I., U., Ubayi, S. S., & A. I., M. (2024). A Review on the Impact of Rice Husk Ash and Marble Waste Powder on Concrete Properties. *International Journal of Mechanical and Civil Engineering*, 7(1), 145–159. <https://doi.org/10.52589/IJMCE-DK2IHEJF>
- [15] IS 383 (1970): Specification for Coarse and Fine Aggregates From Natural Sources For Concrete. (n.d.).
- [16] IS 1124 (1974): Method of test for determination of water absorption, apparent specific gravity and porosity of natural building stones. (n.d.).
- [17] IS 1727 (1967): Methods of test for pozzolanic materials. (n.d.).
- [18] IS 2386-1 (1963): Methods of Test for Aggregates for Concrete, Part I: Particle Size and Shape. (n.d.).
- [19] Balraj, A., Jayaraman, D., Krishnan, J., & Alex, J. (2021). Experimental investigation on water absorption capacity of RHA-added cement concrete. *Environmental Science and Pollution Research*, 28(45), 63623–63628. <https://doi.org/10.1007/s11356-020-11339-1>
- [20] Bansal, S., & Antil, Y. (n.d.). Effect of Rice Husk on Compressive Strength of Concrete.
- [21] Barbuta, M., Bucur, R. D., Cimpeanu, S. M., Paraschiv, G., & Bucur, D. (2015). Wastes in Building Materials Industry. In V. Pilipavičius (Ed.), *Agroecology*. InTech. <https://doi.org/10.5772/59933>
- [22] Bu, C., Liu, L., Lu, X., Zhu, D., Sun, Y., Yu, L., OuYang, Y., Cao, X., & Wei, Q. (2022). The Durability of Recycled Fine Aggregate Concrete: A Review. *Materials*, 15(3), 1110. <https://doi.org/10.3390/ma15031110>
- [23] C09 Committee. (n.d.). Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. ASTM International. <https://doi.org/10.1520/C0618-22>
- [24] IS 2720-3-1 (1980): Methods of test for soils, Part 3: Determination of specific gravity, Section 1: Fine grained soils. (n.d.).
- [25] IS 8112 (1989): Specification for 43 grade ordinary Portland cement. (n.d.).
- [26] IS 10262 (2009): Guidelines for concrete mix design proportioning. (n.d.).
- [27] K, S., & S, K. (2023). Sustainable Utilization of Marble Dust and Rice Husk Ash as a Partial Substitute for Fine Aggregate in Concrete. *International Journal of Civil, Environmental and Agricultural Engineering*, 29–41. <https://doi.org/10.34256/ijceae2323>
- [28] Kabeer, K. I. S. A., & Vyas, A. K. (2019). Experimental investigation on utilization of dried marble slurry as fine aggregate in lean masonry mortars. *Journal of Building Engineering*, 23, 185–192. <https://doi.org/10.1016/j.job.2019.01.034>
- [29] Kartini, K, Dr. (2011). RICE HUSK ASH – POZZOLANIC MATERIAL FOR SUSTAINABILITY. *International Journal of Applied Science and Technology*, Vol. 1, No. 06.

- [30] Keshav Bharadwaj, O. Burkan Isgor, & W. Jason Weiss. (2023). Pozzolanic Reactivity of Supplementary Cementitious Materials. *ACI Materials Journal*, 120(4). <https://doi.org/10.14359/51738817>
- [31] Khan, M. A., Ayub Khan, S., Khan, B., Shahzada, K., Althoey, F., & Deifalla, A. F. (2023). Investigating the feasibility of producing sustainable and compatible binder using marble waste, fly ash, and rice husk ash: A comprehensive research for material characteristics and production. *Results in Engineering*, 20, 101435. <https://doi.org/10.1016/j.rineng.2023.101435>
- [32] Korotkova, T., Ksandopulo, S., Donenko, A., Bushumov, S., & Danilchenko, A. (2016). Physical Properties and Chemical Composition of the Rice Husk and Dust. *Oriental Journal of Chemistry*, 32(6), 3213–3219. <https://doi.org/10.13005/ojc/320644>
- [33] Kürşat Esat Alyamaç & Alp Buğra Aydın. (2015). Concrete properties containing fine aggregate marble powder. *KSCCE Journal of Civil Engineering*, 19, 2208–2216.
- [34] Langer, W. H., & Arbogast, B. F. (2002). Environmental Impacts Of Mining Natural Aggregate. In A. G. Fabbri, G. Gaál, & R. B. McCammon (Eds.), *Deposit and Geoenvironmental Models for Resource Exploitation and Environmental Security* (pp. 151–169). Springer Netherlands. https://doi.org/10.1007/978-94-010-0303-2_8
- [35] Lao, J.-C., Huang, B.-T., Xu, L.-Y., Khan, M., Fang, Y., & Dai, J.-G. (2023). Seawater sea-sand Engineered Geopolymer Composites (EGC) with high strength and high ductility. *Cement and Concrete Composites*, 138, 104998. <https://doi.org/10.1016/j.cemconcomp.2023.104998>
- [36] Li, S., Liu, X., Xu, Y., Lai, G., Ding, Y., Chen, Y., Xia, C., Wang, Z., & Cui, S. (2022). Synthesis and Performances of Shrinkage-Reducing Polycarboxylate Superplasticizer in Cement-Based Materials. *Materials*, 15(19), 7002. <https://doi.org/10.3390/ma15197002>
- [37] El Damatty, A. A., & Hussain, I. (2009). An Economical Solution for the Environmental Problem Resulting from the Disposal of Rice Straw. In E. K. Yanful (Ed.), *Appropriate Technologies for Environmental Protection in the Developing World* (pp. 15–23). Springer Netherlands. https://doi.org/10.1007/978-1-4020-9139-1_3
- [38] Endale, S. A., Taffese, W. Z., Vo, D.-H., & Yehualaw, M. D. (2022). Rice Husk Ash in Concrete. *Sustainability*, 15(1), 137. <https://doi.org/10.3390/su15010137>
- [39] Faé Gomes, G. M., Philipssen, C., Bard, E. K., Zen, L. D., & De Souza, G. (2016). Rice husk bubbling fluidized bed combustion for amorphous silica synthesis. *Journal of Environmental Chemical Engineering*, 4(2), 2278–2290. <https://doi.org/10.1016/j.jece.2016.03.049>
- [40] Fapohunda, C., Akinbile, B., & Shittu, A. (2017). Structure and properties of mortar and concrete with rice husk ash as partial replacement of ordinary Portland cement – A review. *International Journal of Sustainable Built Environment*, 6(2), 675–692. <https://doi.org/10.1016/j.ijbsbe.2017.07.004>
- [41] Font, A., Soriano, L., De Moraes Pinheiro, S. M., Tashima, M. M., Monzó, J., Borrachero, M. V., & Payá, J. (2020). Design and properties of 100% waste-based ternary alkali-activated mortars: Blast furnace slag, olive-stone biomass ash and rice husk ash. *Journal of Cleaner Production*, 243, 118568. <https://doi.org/10.1016/j.jclepro.2019.118568>
- [42] Ganesh Prabhu, G., Hyun, J. H., & Kim, Y. Y. (2014). Effects of foundry sand as a fine aggregate in concrete production. *Construction and Building Materials*, 70, 514–521. <https://doi.org/10.1016/j.conbuildmat.2014.07.070>
- [43] Gencel, O., Benli, A., Bayraktar, O. Y., Kaplan, G., Sutcu, M., & Elabade, W. A. T. (2021). Effect of waste marble powder and rice husk ash on the microstructural, physico-mechanical and transport properties of foam concretes exposed to high temperatures and freeze–thaw cycles. *Construction and Building Materials*, 291, 123374. <https://doi.org/10.1016/j.conbuildmat.2021.123374>
- [44] Luis, A., Rubio M. C., & Sánchez. (2013). Recycling of Waste Sludge: The Potential Use of Marble Waste as Filler in Adhesive Mixtures. *Journal of Cleaner Production*, 59, 221–230.
- [45] Memon, S. A., Shaikh, M. A., & Akbar, H. (2011). Utilization of Rice Husk Ash as viscosity modifying agent in Self Compacting Concrete. *Construction and Building Materials*, 25(2), 1044–1048. <https://doi.org/10.1016/j.conbuildmat.2010.06.074>
- [46] Molaei Raisi, E., Vaseghi Amiri, J., & Davoodi, M. R. (2018). Mechanical performance of self-compacting concrete incorporating rice husk ash. *Construction and Building Materials*, 177, 148–157. <https://doi.org/10.1016/j.conbuildmat.2018.05.053>
- [47] Salihi Sarki Ubayi1, D. E. A. (2024). A Review of the Impact of Jute Fiber Reinforcement on Mechanical Properties of Concrete. <https://doi.org/10.5281/ZENODO.12670017>
- [48] Saloni, Parveen, & Pham, T. M. (2020). Enhanced properties of high-silica rice husk ash-based geopolymer paste by incorporating basalt fibers. *Construction and Building Materials*, 245, 118422. <https://doi.org/10.1016/j.conbuildmat.2020.118422>
- [49] Sam, J. (2020). Compressive Strength of Concrete using Fly Ash and Rice Husk Ash: A Review. *Civil Engineering Journal*, 6(7), 1400–1410. <https://doi.org/10.28991/cej-2020-03091556>
- [50] Singh, A., Kumar, R., Mehta, P. K., & Tripathi, D. (2020). Effect of nitric acid on Rice Husk Ash steel fiber reinforced concrete. *Materials Today: Proceedings*, 27, 995–1000. <https://doi.org/10.1016/j.matpr.2020.01.310>
- [51] Singh, M., Choudhary, K., Srivastava, A., Singh Sangwan, K., & Bhunia, D. (2017). A study on environmental and economic impacts of using waste marble powder in concrete. *Journal of Building Engineering*, 13, 87–95. <https://doi.org/10.1016/j.jobe.2017.07.009>
- [52] Singh, M., Srivastava, A., & Bhunia, D. (2017). An investigation on effect of partial replacement of cement by waste marble slurry. *Construction and Building Materials*, 134, 471–488. <https://doi.org/10.1016/j.conbuildmat.2016.12.155>
- [53] Singhal, V., Nagar, R., & Agrawal, V. (2021). Use of marble slurry powder and fly ash to obtain sustainable concrete. *Materials Today: Proceedings*, 44, 4387–4392. <https://doi.org/10.1016/j.matpr.2020.10.572>
- [54] Spasova, A. (2022). *Construction Industry and Sustainability*. In S. Valaguzza & M. A. Hughes (Eds.), *Interdisciplinary Approaches to Climate Change for Sustainable Growth* (Vol. 47, pp. 261–287). Springer International Publishing. https://doi.org/10.1007/978-3-030-87564-0_15
- [55] Suhendro, B. (2014). Toward Green Concrete for Better Sustainable Environment. *Procedia Engineering*, 95, 305–320. <https://doi.org/10.1016/j.proeng.2014.12.190>
- [56] Suriya, D., Chandar, S. P., & Ravichandran, P. T. (2023). Impact of M-Sand on Rheological, Mechanical, and Microstructural Properties of Self-Compacting Concrete. *Buildings*, 13(5), 1126. <https://doi.org/10.3390/buildings13051126>
- [57] Thomas, B. S. (2018). Green concrete partially comprised of rice husk ash as a supplementary cementitious material – A comprehensive review. *Renewable and Sustainable Energy Reviews*, 82, 3913–3923. <https://doi.org/10.1016/j.rser.2017.10.081>
- [58] Muleya, F., Muwila, N., Tembo, C. K., & Lungu, A. (2021). Partial replacement of cement with rice husk ash in concrete production: An exploratory cost-benefit analysis for low-income communities.

- Engineering Management in Production and Services, 13(3), 127–141. <https://doi.org/10.2478/emj-2021-0026>
- [59] Oluseun Adejumo, I., & Adebukola Adebisi, O. (2021). Agricultural Solid Wastes: Causes, Effects, and Effective Management. In H. M. Saleh (Ed.), *Strategies of Sustainable Solid Waste Management*. IntechOpen. <https://doi.org/10.5772/intechopen.93601>
- [60] Pająk, M., & Ponikiewski, T. (2013). Flexural behavior of self-compacting concrete reinforced with different types of steel fibers. *Construction and Building Materials*, 47, 397–408. <https://doi.org/10.1016/j.conbuildmat.2013.05.072>
- [61] Raina, A., Kaur, G., & Tangri, A. (2021). Experimental Studies of Marble Concrete Prepared with Micro Silica and Rice Straw Ash. *IOP Conference Series: Earth and Environmental Science*, 889(1), 012048. <https://doi.org/10.1088/1755-1315/889/1/012048>
- [62] Ramezani-pour, A. A. (2009). The Effect of Rice Husk Ash on Mechanical Properties and Durability of Sustainable Concretes. 7(2).
- [63] Safiuddin, Md., West, J. S., & Soudki, K. A. (2010). Hardened properties of self-consolidating high performance concrete including rice husk ash. *Cement and Concrete Composites*, 32(9), 708–717. <https://doi.org/10.1016/j.cemconcomp.2010.07.006>
- [64] Tian, Z., Ren, J., Li, H., Wang, X., Feng, Y., Xiong, W., Yang, J., Xu, S., & Ren, Z. (2022). Synergistic Effect of Polycarboxylate Superplasticiser and Protein Retarders in Cementitious Materials Containing Na- Montmorillonite: Effect of Addition Methods. *Materials*, 15(19), 6614. <https://doi.org/10.3390/ma15196614>
- [65] Tomar, A. K., Gupta, S. K., Kumar, A., & Singh, A. (2016). Review on Utilization of Waste Marble Powder in Self-Compacting Concrete. *International Journal of Engineering Trends and Technology*, 37(2),
- [66] Van, V.-T.-A., Rößler, C., Bui, D.-D., & Ludwig, H.-M. (2014). Pozzolanic reactivity of mesoporous amorphous rice husk ash in portlandite solution. *Construction and Building Materials*, 59, 111–119. <https://doi.org/10.1016/j.conbuildmat.2014.02.046>
- [67] Varadharajan, S., Jaiswal, A., & Verma, S. (2020). Assessment of mechanical properties and environmental benefits of using rice husk ash and marble dust in concrete. *Structures*, 28, 389–406. <https://doi.org/10.1016/j.istruc.2020.09.005>
- [68] Vigneshwari, M., Arunachalam, K., & Angayarkanni, A. (2018). Replacement of silica fume with thermally treated rice husk ash in Reactive Powder Concrete. *Journal of Cleaner Production*, 188, 264–277. <https://doi.org/10.1016/j.jclepro.2018.04.008>
- [69] Ulubeyli, G. C., Bilir, T., & Artir, R. (2016). Durability Properties of Concrete Produced by Marble Waste as Aggregate or Mineral Additives. *Procedia Engineering*, 161, 543–548. <https://doi.org/10.1016/j.proeng.2016.08.689>
- [70] Vijaya Kumar Ym, Shruti D, Tharan SN, Sanjay SR, & Sricharan PM. (2016). Partial Replacement of Cement to Concrete by Marble Dust Powder. 2(05).
- [71] Yasmin, S., Khandaker, M. U., Nawi, S. N. M., Sani, S. F. A., Bradley, D. A., & Islam, M. A. (2021). The potential of decorative building materials (marble) for retrospective thermoluminescence dosimetry. *Applied Radiation and Isotopes*, 175, 109782. <https://doi.org/10.1016/j.apradiso.2021.1097>