International Journal of Mechanical and Civil Engineering
ISSN: 2689-940X
Volume 7, Issue 3, 2024 (pp. 145-159)
www.abjournals.org

A REVIEW ON THE IMPACT OF RICE HUSK ASH AND MARBLE WASTE POWDER ON CONCRETE PROPERTIES

Ibrahim Abdullahi Ibrahim[1*], Esar Ahmad (Ph.D.)[2], Shashivendra Dulawat[3],

Mustapha Nuhu Garko[4], Umar Shehu Ibrahim[5], Salihu Sarki Ubayi[6],

and Muhammad Auwal Ibrahim[7]

[1]Department of Civil Engineering, Mewar University, Chittorgarh, Rajasthan, India. And Works, Physical Planning and Development Dept. University of Maiduguri, Borno state, Nigeria.

[2-7]Department of Civil Engineering, Mewar University, Chittorgarh, Rajasthan, India.

[*]Corresponding Author's Email: ibrahimagck@unimaid.edu.ng

Cite this article:

I. A. Ibrahim, Esar A., Shashivendra D., Mustapha N. G., Umar S. I., S. S. Ubayi, Muhammad A. I. (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. DOI: 10.52589/IJMCE-DK2IHEJF

Manuscript History

Received: 18 May 2024

Accepted: 19 Jul 2024

Published: 13 Aug 2024

ABSTRACT: *Cement has been a staple in the construction industry for decades, performing admirably when properly mixed. However, cement production is accompanied with a lot of* CO_2 *emissions, contributing to environmental pollution and ozone layer depletion. To mitigate these effects and reduce reliance on conventional concrete materials, exploration of alternative materials is essential. Researchers have investigated industrial and agricultural waste as potential cement supplements, but many of these waste products pose disposal and health challenges. Instead of discarding these materials, their proper utilization can yield positive environmental benefits. This review focuses on the feasibility of incorporating rice husk ash (RHA) and marble waste (MW) into concrete production. It examines the environmental, and economic advantages of using RHA and MW, as well as their impact on mechanical and durability properties of concrete like the compressive strength, durability, splitting tensile strength, permeability, water-cement ratio, workability and thermal properties. Additionally, the review explores various approaches and methodologies for integrating these materials into concrete mixes. Numerous research studies have evaluated the effectiveness of utilizing MDP and RHA in manufacturing concrete. Key findings indicate that the maximum benefit of replacing cement with RHA occurs at a 15% substitution level. Furthermore, marble waste, owing to its high calcium oxide (CaO) content, can also serve as a cement supplement. Marble powder, with its fine particle size, can replace fine aggregates in concrete, enhancing filler effects and reducing porosity, resulting in denser and more durable concrete. Additionally, marble waste can potentially substitute for coarse aggregates in concrete production.*

KEYWORDS: Rice husk ash, Marble waste, Concrete, Sustainable material.

Article DOI: 10.52589/IJMCE-DK2IHEJF
DOI URL: https://doi.org/10.52589/IJMCE-DK2IHEJF

INTRODUCTION

Cement is the most expensive binding material in the construction industry and it is employed as cementitious material worldwide. The high demand for cement is as a result of its incredible performance and efficiency in binding aggregate. Cement production results in significant emissions of harmful substances such as CO_2 and NO_2, contributing to environmental pollution. Consequently, there is a need for research into alternative materials that can complement cement (Adetoye et al., 2023). Agricultural wastes such as the RHA, cassava peel, doum palm shell ash among others can be used as partial replacements for cement. Similarly, industrial waste materials like the ground granulated blast furnace slag (GGBFS), marble waste, silica fume, and fly ash among others can also be used as cementation materials in construction (Barbuta et al., 2015). Improper disposal of the aforementioned (agricultural and industrial) wastes leads to several drawbacks to the environment among which include: causing diseases to the occupants nearby, occupying some portions of river beds, pits, forest land, and often dumps on the side of the road which leads to deterioration of the ecosystem of the environment (Adejumo & Adebiyi, 2021). The assimilation of agricultural and industrial wastes in concrete will not only enhance its performance but will also help in attaining a friendly environment and retards the dependency on conventional construction materials.

For decades, marble has been used in the construction industry and performs wonderfully across the world (Yasmin et al., 2021). Globally, the estimated marble reserves amount to approximately 15 billion cubic meters, with marble industries operating in nearly fifty countries (Alyamaç & 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., 2017). Figure 1 below shows the marble extraction site.

Figure 1: Marble extraction site (Bacarji et al., 2013)

Approximately 25% of the marble processed during sawing, shaping, and polishing ends up as dust or powder (Gesoğlu 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 slurry, a semi-liquid blend of water and fine marble particles produced during marble cutting and polishing, is frequently discarded as waste. Improper management of marble slurry can lead to environmental risks. Notably, it may contain elevated levels of heavy metals and other pollutants, highlighting the importance of proper disposal (Tomar et al., 2016). When marble stone is cut, ground and finished, it produces fine marble dust, a powder that can be easily carried by winds, this airborne dust can lead to various health issues (Alvee et al., 2022a). Marble waste is commonly utilized as a filler material across various industries, including construction, paints, and ceramics. However, significant quantities of marble dust are generated as waste, necessitating proper disposal or recycling methods to minimize environmental impact (Mehta et al., 2019). Marble chips and fragments represent irregular pieces of marble stone remaining after cutting and shaping processes. While some find reuse in applications like landscaping or terrazzo flooring, a significant portion becomes waste. Proper management strategies, including recycling and reuse, are essential to minimize the environmental impact of discarded marble chips and fragments (Luis et al., 2013). The oxides composition of marble waste from previous research works are presented in table 1 below.

Table 1: Oxides compositions of marble wastes from previous works

Chemical Compositions	**References**				
	(Idrees & Jamil, 2015)	(M. A. Khan et al., 2023)	(Vijaya Kumar Ym et al., 2016)	(Ranjan Kumar & Shyam Kishor Kumar, 2015)	(Varadharajan et al., 2020)
SiO_2	1.33	0.38	28.35	13.8	5.87
Al_2O_3	0.32	0.23	0.42	4.50	0.56
Fe_2O_3	0.09	0.01	9.72	1.90	0.80
CaO	55.5	49.98	40.45	43.20	41.54
SO_3	0.00	NA	NA	NA	0.11
P_2O_5	NA	0.03	NA	NA	NA
MgO	1.16	2.69	16.25	2.70	15.55
TiO_2	NA	0.01	NA	NA	NA
Na_2O	0.17	0.02	NA	NA	0.07
K_2O	0.13	0.04	NA	NA	0.07
LOI	41.05	NA	NA	NA	NA

LOI – Loss on Ignition, NA – Not Available

The oxide compositions of the marble waste, as presented in the table, are evaluated against the requirements outlined in C09 Committee (n.d.) to assess their suitability for concrete production. Vijaya et al. (2016) demonstrate a notably higher SiO_2 content, potentially indicating favorable pozzolanic reactivity, in line with C09 Committee (n.d.) specifications. Conversely, Kumar and Kumar (2015) and Idrees and Jamil (2015) exhibit relatively higher Al_2O_3 content, warranting further scrutiny due to potential implications on pozzolanic activity. Iron oxide (Fe_2O_3) levels across all samples meet ASTM limits, suggesting compatibility with concrete applications. However, Idrees and Jamil (2015) exceed the maximum CaO content specified by C09 Committee (n.d.), potentially affecting concrete properties. Sulfur trioxide (SO_3) and phosphorus pentoxide (P_2O_5) levels fall within acceptable ranges, aligning with C09 Committee (n.d.) standards. Also the elevated loss on ignition (LOI) in (Idrees & Jamil, 2015) raises concerns regarding organic or carbonaceous materials. Overall, while some marble waste samples demonstrate promising characteristics for concrete production, others may require further evaluation or processing to ensure compliance with ASTM standards and optimize their beneficial contributions to concrete properties.

Asia leads in rice production due to its suitability for cultivating rice in flooded tropical regions during the rainy season (Endale et al., 2022). Rice husk is obtained in abundance and the rice processors often set fire to the husk as a method of disposal. RHA has become another challenge to the environment, and its proper disposal is crucial for environmental sustainability (El Damatty & Hussain, 2009). According to research by Vigneshwari et al. (2018), it was concluded that RHA performs good when used as a substitute to cement as it possesses economical as well as environment-friendly performance. RHS is considered as a pozzolanic material meaning that it has the ability to form a stable and insoluble cementitious substance when combined with water and CaOH. Concrete made incorporating RHA as partial substitute to cement has an enhanced compressive strength because of calcium silicate hydrate gel that is formed in the cement fragments, it makes the concrete less porous and more denser thereby enhancing the strength of the concrete as per cracking is considered (Bansal & Antil, n.d.) .

The burning of the rice husk should be given intensive care to ensure the optimum pozzolanic behavior of the ash, the RHA visual appearance should be within the limit of white gray to black (Sam, 2020). The oxides composition of rice husk ash from previous research works were presented in table 2 below.

Table 2: Oxides composition of rice husk ash from previous researches (Sam, 2020)

Chemical compositions	**References**								
	(A. Singh et al., 2020)	(Faé Gomes et al., 2016)	(Ramezanianpour, 2009)	(Van et al., 2014)	(Font et al., 2020)	(Sumadi & Loon, n.d.)	(Korotkova et al., 2016)	(Saloni et al., 2020)	(Kartini. K, 2011)
SiO_2	96.7	86.0	89.61	87.4	85.58	97.5	93.4	90.0	96.7
Al_2O_3	1.01	5.12	0.04	0.4	0.25	0.73	0.05	0.46	1.01
Fe_2O_3	0.05	1.12	0.22	0.3	0.21	1.18	0.06	0.43	0.05
CaO	0.49	1.26	0.91	0.9	1.83	0.18	0.31	1.10	0.49
SO_3	NA	2.79	NA	0.4	0.26	0.49	NA	NA	NA
P_2O_5	NA	0.48	NA	NA	0.67	NA	0.8	2.43	NA
MgO	0.19	0.48	0.42	0.6	0.50	NA	0.35	0.77	0.19
TiO_2	NA	0.17	NA	NA	NA	NA	NA	NA	0.16
Na_2O	0.16	0.05	0.07	0.04	NA	0.10	0.1	NA	0.26
K_2O	0.91	1.82	1.58	3.39	3.39	1.39	1.4	4.60	0.91
LOI	4.81	NA	5.91	4.60	6.99	NA	NA	3.90	4.81

LOI – Loss on Ignition NA – Not Available

Article DOI: 10.52589/IJMCE-DK2IHEJF
DOI URL: https://doi.org/10.52589/IJMCE-DK2IHEJF

To evaluate the table and compare it to the standard specifications for RHA as outlined in C09 Committee (n.d.), several key parameters are considered. The SiO_2 content in RHA is crucial as it determines its pozzolanic reactivity. The values in the table range from 85.58% to 97.5%, all of which exceed the minimum requirement of 50% specified by C09 Committee (n.d.). This suggests that the RHA samples exhibit excellent potential for pozzolanic activity in concrete. LOI represents the presence of organic or carbonaceous materials in RHA. While most values in the table fall within acceptable limits, Font et al. (2020) exhibit an LOI of 6.99%, slightly exceeding the maximum threshold of 6% specified by C09 Committee (n.d.). This indicates a potential concern regarding organic content in this particular sample. The other oxides from table 2 show varying levels of these oxides across different RHA samples. While C09 Committee (n.d.) does not provide strict limits for these constituents in RHA, it emphasizes the importance of controlling certain elements to prevent adverse effects on concrete properties. The values in the table generally appear within acceptable ranges, with some samples exhibiting slightly higher levels of potassium oxide (K_2O) and sodium oxide (Na_2O). However, further evaluation is necessary to determine their potential impact on concrete performance. Also, the presence of SO_3 and P_2O_5 are minimal in RHA, Most samples in the table have negligible or undetected levels of these oxides, aligning with C09 Committee (n.d.) specifications.

Overall, the oxide composition of the RHA samples, as depicted by Table 2, generally aligns well with the standard specifications outlined by C09 Committee (n.d.) for RHA. The high SiO_2 content and relatively low levels of impurities suggest that the RHA samples have excellent potential as supplementary cementitious substances of producing concrete, contributing to improved strength, durability, and sustainability of concrete structures.

Effect of RHA and MW

Economic and Environmental Impact

The RHA and MWP are industrial byproducts that present challenges for disposal. However, acquiring these waste materials incurs minimal cost, limited to transportation expenses. (Varadharajan et al., 2020). According to a review by Olubunmi et al. (2023), marble, a widely used material worldwide, generates significant waste during its production approximately 30% to 70% due to various techniques employed from quarrying to polishing. According to the cost analysis by the University of Engineering and Technology (2019), concrete made with MWP and quarry dust replacement is more cost-effective than ordinary concrete. The cost of making 100 m^3 of ordinary M50 concrete is $ 3391, while for concrete with the same strength made MWP and quarry dust cost $ 3398.

Utilizing marble dust powder offers advantages in terms of cost-effectiveness and environmental impact. Fine marble particles can be easily taken by air, potentially causing health issues such as skin problems, respiratory and vision diseases (Alvee et al., 2022b). Incorporating marble dust powder into the construction industry yields benefits such as energy conservation, cost reduction, and enhanced durability while minimizing environmental impact (Özkılıç et al., 2023). In a research investigation by Khan et al. (2023), marble powder was assessed as a cement substituting material, the author reveals that 15% is the maximum replacement level. The study yielded favorable outcomes, leading to the conclusion that incorporating marble dust powder into concrete mitigates environmental risks associated with its disposal. Singh et al. (2017) made use of MWP to supplement cement; they found very good results and stated that Marble Powder prevents environmental hazards. From Table 2, we can see that marble contains a higher percentage (above 40%) of calcium oxide making it a very good binding substance. Hence to reduce the environmental hazards of the marble wastes, it is strongly recommended to incorporate it in the construction industry.

Globally, rice cultivation yields a staggering 150 billion metric tons, leading to significant waste production that adversely affects the environment (Varadharajan et al., 2020). RHA is a byproduct of agricultural waste, possessing binding properties that make it a valuable addition to concrete. By incorporating RHA into concrete mixtures, we can reduce reliance on cement while simultaneously benefiting both economically and environmentally (Chopra et al., 2015). In a cost study conducted by Khan et al. (2012), RHA was partially used to replace cement in a two-room concrete structure. Each blend consisted of 75% cement and 25% RHA by weight. Remarkably, the author observed a 31.5% reduction in cement costs while maintaining standard strength for each structural element. The total cost for building the structure drops by 14.2% without compromising strength. Therefore, RHA's replacement with cement proved to have a significant benefit economically. In the context of rice husk ash blend concrete with a water-to-cement (w/c) ratio of 0.5, Figure 2 illustrates the cost reduction diagram.

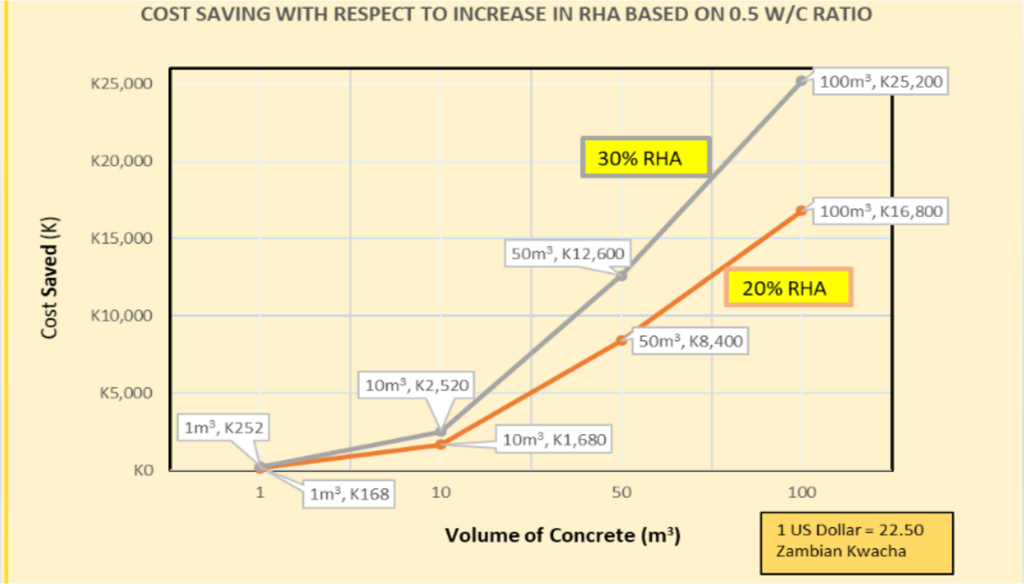
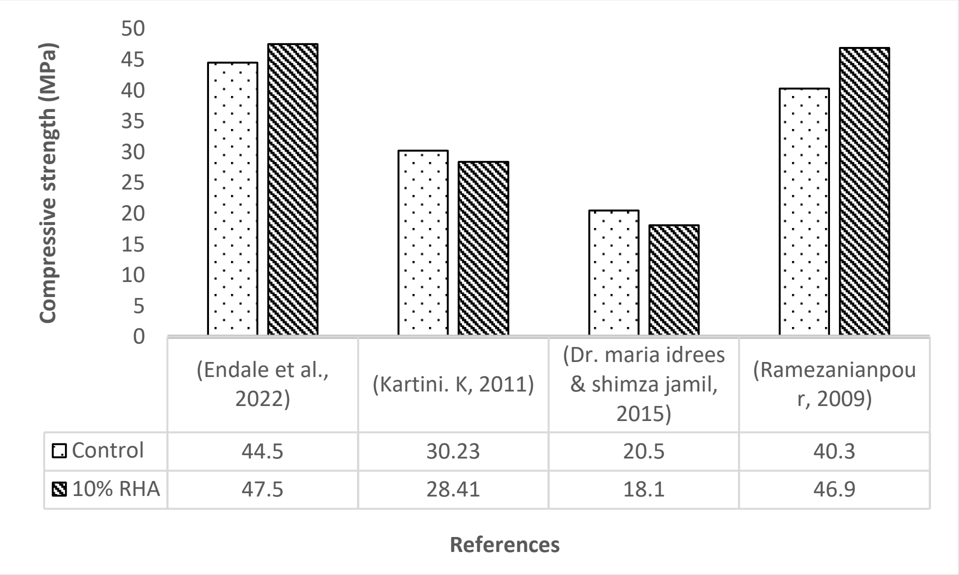


Figure 2: Cost reduction diagram (Muleya et al., 2021)

According to Varadharajan et al. (2020), the environmental impact assessment of the material mixtures studied experimentally, using the recipe method at both midpoint and endpoint levels, demonstrated significant benefits. Incorporating RHA and MWP yield a substantial drop of carbon dioxide release and particulate matter, while also positively affecting ozone layer depletion. Additionally, this approach led to reduced fossil fuel consumption and an increase in agricultural land usage. The mixtures with RHA 20%, MWP 30%, and Steel fiber 1.5% show optimum environmental advantage in relation with the control sample. The incorporation of rice husk ash and MWP into the construction industry results in environmentally friendliness (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 (Idrees & Jamil, 2015).

Compressive Strength

According to research by Adesina and Olutoge (2019), a 45% increase in compressive strength is observed when 15% of the binder (cement) is substituted with RHA. Similarly, Kannan and Ganesan, 2014) investigated the compressive strength of concrete blended with rice husk ash; the author recorded an enhancement in compressive strength up to 15 percent substitution of the binder with rice husk ash. However, beyond that point, the authors recorded a reduction in compressive strength. Idrees and Jamil (2015) reported a reduced strength result when 10% and 15% cement replacement with poorly grinded RHA. On the other hand, the research shows an improved performance of concrete when incorporated with MWP. Marble, due to its high concentration of calcium oxide (above 55%) and its extremely tiny particles contain inherent cementitious properties, and exhibits enhanced bonding ability. Concrete containing leftover crushed marble had a compressive strength that was similar to conventional blend (Kore & Vyas, 2016). In a research by Olutoge and Adesina (2019), the authors supplement conventional binder with RHA at varying percentages (0% to 15% with an increase of 5%) to create RHA-Concrete. The experimental findings indicate that this replacement led to a degradation in strength (compression and tensile) of resulting concrete. Figure 3 below presents a comparison of the compressive strength of different grades of R.H.A concrete ranges from M20 to M40 of control blend and optimum replacement level respectively.



	(Endale et al., 2022)	(Kartini. K, 2011)	(Dr. maria idrees & shimza jamil, 2015)	(Ramezanianpour, 2009)
☐ Control	44.5	30.23	20.5	40.3
▨ 10% RHA	47.5	28.41	18.1	46.9

Figure 3: Compressive strength of control in comparison to 10% RHA blend

Fig. 3 above elucidated the compressive strength of concrete incorporating 10% RHA in comparison to that of conventional concrete. The figure above presents that at higher concrete grade (above m M30), 10% RHA blend shows more compressive strength as compared to the control mixture. While at lower grade (below M30), the control blend resulted in higher compressive strength. The reason behind this is due to the high content of RHA at higher grades of concrete. The RHA with its finer particles helps to enhance pore filling in concrete and make it more durable as well as less permeable for toxic substances. Kartini et al. (2010) and Varadharajan et al. (2020) reported a similar trend.

Durability

The binding capacity of the cementitious matrix is enhanced by the interaction of $3CaOAl_2O_3$ in binder and CaO in marble. Additionally, the cementitious blends ability to bond is further strengthened by the creation of carbanoaluminates as a result of an interaction involving limestone and the alkaline (calcium hydroxide) portion of the binder (Munir et al., 2017; Bonavetti et al., 2001). The continuous hydration and filler impact of rice husk ash and marble waste powder improve the interface between marble and cement. This results in a compact structure that reduces porosity, ultimately enhancing durability (Hooton, 2015). The durability performance of concrete incorporating RHA is promising in comparison with other concrete containing admixtures (Shin, Sang-Yeop & Kim, 2013).

Permeability and Corrosion Resistance

A research by Varadharajan et al. (2020) shows that when RHS and MW supplement binder, there is an improvement in both compressive strength and splitting tensile strength of the concrete samples. This enhancement occurred when the replacement percentage did not exceed 15%. With an increase in the proportion of rice husk ash (RHA) and marble waste powder (MWP), the porosity and sorptivity of the concrete material decreased. The improvement in compressive strength and splitting tensile strength was due to the decreasing in porosity and improvement in strength of both cement paste matrix, and the interfacial transition zone (Khodabakhshian et al., 2018). The addition of RHA and marble waste affects a number of concrete's characteristics, including water absorption, porosity, and permeability (Ajwad et al., 2022). The concrete matrix's microstructure is thickened and the filler effect is improved by MWP, which has particle sizes ranging from 1.18mm to 300 µm (Karim et al., 2012). Kartini et al. (2010) investigated and reported the result of durability performance of normal strength concrete specimens containing 20% or 30% RHA by cement weight, with or without the addition of a superplasticizer. The findings indicate that replacing cement with RHA reduces initial surface absorption, permeability, and absorption characteristics. Additionally, RHA incorporation leads to longer capillary suction time, resulting in lower sorptivity values and improved resistance to chloride ion penetration compared to control concrete. Overall, the study highlights the positive impact of RHA in concrete's absorption and permeability properties (Olutoge & Adesina, 2019) observed that saturated water absorption and apparent porosity increased, while bulk density decreased, especially with higher levels of RHA content.

Water Cement Ratio and Workability

A research by Varadharajan et al. (2020) shows a reduction of water absorption of 16.3% when RHA replaces cement by 20% and MWP replaces fine aggregate by 30%. The author attributed the aforementioned decrease in water absorption to the improvement in pore sealing due to blending with RHA and MWP; it also enhances the durability of the concrete mixture. Incorporation of marble waste, rice husk ash and steel fibers reduces the workability significantly with minimum magnitude at RHA 20%, MWP 30%, and Steel fiber 1.5%, blends in relating to the control. Similarly, Varadharajan et al. (2020) performed a slump test to determine the workability of concrete blends incorporating RHA, MWP and steel fibers. The slump test result shows a decrease in workability with increase in substitution level of binder and aggregate with rice husk ash and marble waste. As per Kang et al. (2019), increasing the RHA content results in greater water absorption, which reduces workability. Reducing rice husk ash size and addition of loading lead to enhancement in bulk density and surface area,

Article DOI: 10.52589/IJMCE-DK2IHEJF
DOI URL: https://doi.org/10.52589/IJMCE-DK2IHEJF

resulting in decreased water absorption during concrete curing. Moreover, replacing 20% of cement with RHA causes a threefold reduction in water absorption capacity in comparison to conventional concrete (Balraj et al., 2021). Concrete properties such as workability, compressive strength, tensile strength, flexural strength, and water permeability were investigated. Standard concrete samples in the form of cubes, cylinders, and beams were cast. Additionally, a cost comparison study was conducted. The results indicate that workability of fresh concrete improves with increasing RHA content. Most concrete properties studied in this research yielded more favorable outcomes at a 6% replacement level compared to the control mix (Ajwad et al., 2022). Kore and Vyas (2016) conducted a study on using marble waste as a substitute for coarse aggregate. By replacing 75% of the conventional aggregate with marble waste, the research found that the compressive strength was similar to that of regular concrete. Additionally, the workability of the concrete improved, water absorption decreased by 17%, and abrasion resistance slightly increased by 2% compared to the control concrete.

Splitting Tensile Strength

In a study by Varadharajan et al. (2020), the concrete mix achieved optimal splitting tensile strength by incorporating RHA and MWP. When 15% of the cement was replaced with RHA, an average splitting tensile strength of 21% was observed. Additionally, the study found that increasing the percentage of MWP replacing fine aggregate led to enhanced splitting tensile strength. Specifically, a 30% MWP replacement resulted in a 20% increase in splitting tensile strength at 7 days compared to the control. Hebhoub et al. (2011) recorded an optimum enhancement of 33% in splitting tensile strength for concrete produced by supplementing fine aggregate with marble waste. Kabeer and Vyas (2018) measured 18% enhancement of splitting tensile strength for 20% MWP substituting fine aggregate for cement mortar cubes. Contrastingly, some researchers have measured a degradation in mechanical properties. For instance, Sakalkale et al. (2014) and Silva et al. (2014) reported a reduction of 45% and 18.18%, respectively, for a 50% substitution of fine aggregate with marble waste. According to research by Idrees and Jamil (2015), an enhancement in splitting tensile strength was observed with the most significant benefit achieved at a 10% replacement of cement with MWP. The author also noted that RHA with larger particle size exhibited reduced splitting tensile strength, leading to the recommendation that the RHA used in the research may not be fine enough to fully replace cement.

Thermal Properties

The effect of RHA and marble waste powder MWP on the thermal properties of concrete has been studied in various research articles. One such study is conducted by Hadipramana et al. (2019), the authors investigated the impact of incorporating RHA and MWP on the thermal conductivity of concrete and finds that incorporation of RHA and MWP into concrete mixtures led to a reduction in thermal conductivity compared to conventional concrete. This reduction in thermal conductivity indicates improved thermal insulation properties of concrete containing RHA and MWP. The author added that the pozzolanic nature of RHA and the fine particle size of MWP contribute to the densification of the concrete matrix, resulting in reduced porosity and increased resistance to heat transfer. As a result, concrete with RHA and MWP exhibits improved thermal performance, making it suitable for applications where thermal insulation is crucial. RHA helps reduce plastic shrinkage cracking in fresh concrete. Similarly, the use of RHA as partial replacement of cement modifies the hydration process of a concrete mixture, as such the risk of thermal cracking in hardened concrete is minimized (Idrees & Jamil, 2015).

From Table 1 above, it can be seen that in all the articles reviewed, the percentage of CaO in marble waste powder is above 40%. According to Varadharajan et al. (2020), the presence of higher contents of CaO in MWP contributes to its thermal insulating characteristics. Substituting fine aggregate with MWP improves the concrete's ability to resist temperature changes and thermal stress (Sarika et al., 2023).

CONCLUSION

In conclusion, the exploration of alternative materials such as RHA and MW shows a promising avenue for improving the sustainability and performance of concrete in the construction industry. The findings discussed herein underscore several key points. Firstly, both RHA and MWP offer significant economic and environmental benefits when incorporated into concrete production. RHA, derived from agricultural waste, not only reduces reliance on cement but also contributes to reduced CO_2 emissions, positive effects on the ozone layer, and decreased fossil fuel consumption. Furthermore, RHA can serve as a good supplement to cement, enhancing the binding properties of concrete mixes. Similarly, MWP serves as a cost-effective and environmentally friendly alternative, mitigating hazards associated with disposal while enhancing durability and energy conservation. Notably, marble waste due to its high content of CaO (above 40% as from Table 1) can replace cement in powder form, offering a sustainable solution to reduce the environmental impact of traditional concrete production. Additionally, MWP can replace fine aggregate, enhancing filler effects and reducing porosity, resulting in denser and more durable concrete structures. Moreover, MWP can also replace a percentage of coarse aggregate, further optimizing the utilization of this waste material in concrete production. Regarding concrete properties, the studies reviewed demonstrate noteworthy improvements in compressive strength, durability, permeability, corrosion resistance, water absorption, workability and thermal insulation, with the incorporation of RHA and MW. Optimal substitution levels and mixtures have been identified, such as a 15% substitution of cement with RHA resulting in a 45% enhancement in compressive strength. Similarly, MW enhances binding capacity and contributes to comparable compressive strength to control concrete. Moreover, the influence of RHA and MW on splitting tensile strength has been examined, with notable increases observed with their incorporation. However, variations in mechanical properties have been reported, emphasizing the importance of careful selection of substitution levels and particle sizes.

Among the opportunities for promoting innovation in sustainable materials is resource conservation. By incorporating rice husk ash (RHA) and marble waste powder, concrete properties can be improved. RHA acts as a pozzolanic material, enhancing strength, durability, and workability. Marble waste powder contributes to better workability and reduced water demand. However, RHA and marble waste powder are often more cost-effective than traditional cement. Their availability as waste products makes them economically attractive. Additionally, there are challenges related to variability in RHA and marble waste powder composition, which affects concrete performance.

Overall, the findings highlight the potential of RHA and MW to revolutionize concrete production, offering a sustainable solution to mitigate environmental impacts while improving performance and longevity. Continued research and development in this field are essential to optimize the utilization of these alternative materials and facilitate their widespread adoption

Article DOI: 10.52589/IJMCE-DK2IHEJF
DOI URL: https://doi.org/10.52589/IJMCE-DK2IHEJF

in the construction industry. By harnessing the benefits of RHA and MW, we can pave the way for a more sustainable and resilient built environment, contributing to global efforts towards mitigating climate change and promoting environmental stewardship.

REFERENCES

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.jobe.2019.100804

Adetoye Olubunmi A, Sani Aliyu, & Ibrahim Hassan. (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.

Ajwad, A., Ahmad, S., Abdullah, Jaffar, S. T. A., Ilyas, U., & Adnan, M. A. (2022). Effect of Using Rice Husk Ash as Partial Replacement of Cement on Properties of Fresh and Hardened Concrete. *Architecture, Civil Engineering, Environment*, *15*(2), 85–94. https://doi.org/10.2478/acee-2022-0017

Alvee, A. R., Malinda, R., Akbar, A. M., Ashar, R. D., Rahmawati, C., Alomayri, T., Raza, A., & Shaikh, F. U. A. (2022a). 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

Alvee, A. R., Malinda, R., Akbar, A. M., Ashar, R. D., Rahmawati, C., Alomayri, T., Raza, A., & Shaikh, F. U. A. (2022b). 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

Bacarji, E., Toledo Filho, R. D., Koenders, E. A. B., Figueiredo, E. P., & Lopes, J. L. M. P. (2013). Sustainability perspective of marble and granite residues as concrete fillers. *Construction and Building Materials*, *45*, 1–10. https://doi.org/10.1016/j.conbuildmat.2013.03.032

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

Bansal, S., & Antil, Y. (n.d.). *Effect of Rice Husk on Compressive Strength of Concrete*.

Barbuta, M., Bucur, R. D., Cimpeanu, S. M., Paraschiv, G., & Bucur, D. (2015). Waste in the Building Materials Industry. In V. Pilipavičius (Ed.), *Agroecology*. InTech. https://doi.org/10.5772/59933

Bonavetti, V. L., Rahhal, V. F., & Irassar, E. F. (2001). Studies on the carboaluminate formation in limestone filler-blended cements. *Cement and Concrete Research*, *31*(6), 853–859. https://doi.org/10.1016/S0008-8846(01)00491-4

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

Chirag S. Mehta, Dr. Jayeshkumar R. Pitroda, & Dr. S. K. Dave. (2019). A Review on Utilization of Waste Marble Powder in Concrete. *International Journal of Engineering Research*, *Volume No.8*(Issue Special 4), 75–77.

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

Douglas Hooton, R. (2015). Current developments and future needs in standards for cementitious materials. *Cement and Concrete Research*, *78*, 165–177. https://doi.org/10.1016/j.cemconres.2015.05.022

Idrees & 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

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

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

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

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

Gesoğlu, M., Güneyisi, E., Kocabağ, M. E., Bayram, V., & Mermerdaş, K. (2012). Fresh and hardened characteristics of self compacting concrete 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

Hadipramana, J., Riza, F. V., Ali, N., Somad, A. A. A., & Basri, N. H. (2019). Thermal conductivity of aerated concrete containing rice husk ash as partially sand replacement. *IOP Conference Series: Materials Science and Engineering*, *674*(1), 012023. https://doi.org/10.1088/1757-899X/674/1/012023

Hebhoub, H., Aoun, H., Belachia, M., Houari, H., & Ghorbel, E. (2011). Use of waste marble aggregates in concrete. *Construction and Building Materials*, *25*(3), 1167–1171. https://doi.org/10.1016/j.conbuildmat.2010.09.037

Kabeer, K. I. S. A., & Vyas, A. K. (2018). Utilization of marble powder as fine aggregate in mortar mixes. *Construction and Building Materials*, *165*, 321–332. https://doi.org/10.1016/j.conbuildmat.2018.01.061

Kang, S.-H., Hong, S.-G., & Moon, J. (2019). The use of rice husk ash as reactive filler in ultra-high performance concrete. *Cement and Concrete Research*, *115*, 389–400. https://doi.org/10.1016/j.cemconres.2018.09.004

Kannan, V., & Ganesan, K. (2014). Chloride and chemical resistance of self compacting concrete containing rice husk ash and metakaolin. *Construction and Building Materials*, *51*, 225–234. https://doi.org/10.1016/j.conbuildmat.2013.10.050

Karim, M. R., Zain, M. F. M., Jamil, M., Lai, F. C., & Islam, M. N. (2012). *Strength of Mortar and Concrete as Influenced by Rice Husk Ash:*

Kartini. K, Dr. (2011). RICE HUSK ASH – POZZOLANIC MATERIAL FOR SUSTAINABILITY. *International Journal of Applied Science and Technology, Vol. 1*, No. 06.

KARTINI, K., MAHMUD, H.B., & HAMIDAH, M.S. (2010). ABSORPTION AND PERMEABILITY PERFORMANCE OF SELANGOR RICE HUSK ASH BLENDED GRADE 30 CONCRETE. *Journal of Engineering Science and Technology, Vol. 5, No. 1*, 1–16.

Khan, E. A., Khan, S. W., Gul, A., Seif ElDin, H. M., Alqaryouti, Y., Azab, M., Khan, F. A., Irfan Badrashi, Y., & Shahzada, K. (2023). Utilization of waste marble powder as partial replacement of cement in engineered cementitious composite. *Cogent Engineering*, *10*(1), 2243749. https://doi.org/10.1080/23311916.2023.2243749

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

Khan, R., Jabbar, A., Ahmad, I., Khan, W., Khan, A. N., & Mirza, J. (2012). Reduction in environmental problems using rice-husk ash in concrete. *Construction and Building Materials*, *30*, 360–365. https://doi.org/10.1016/j.conbuildmat.2011.11.028

Khan, Z., Umar, M., Shahzada, K., & Ali, A. (2017). *UTILIZATION OF MARBLE DUST IN FIRED CLAY BRICKS*.

Khodabakhshian, A., De Brito, J., Ghalehnovi, M., & Asadi Shamsabadi, E. (2018). Mechanical, environmental and economic performance of structural concrete containing silica fume and marble industry waste powder. *Construction and Building Materials*, *169*, 237–251. https://doi.org/10.1016/j.conbuildmat.2018.02.192

Kore, S. D., & Vyas, A. K. (2016). Performance Evaluation of Concrete using Marble Mining Waste. *Selected Scientific Papers - Journal of Civil Engineering*, *11*(2), 53–66. https://doi.org/10.1515/sspjce-2016-0018

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

Kürşat Esat Alyamaç & Alp Buğra Aydin. (2015). Concrete properties containing fine aggregate marble powder. *KSCE Journal of Civil Engineering*, *19*, 2208–2216.

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.

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

Munir, M. J., Kazmi, S. M. S., & Wu, Y.-F. (2017). Efficiency of waste marble powder in controlling alkali–silica reaction of concrete: A sustainable approach. *Construction and Building Materials*, *154*, 590–599. https://doi.org/10.1016/j.conbuildmat.2017.08.002

Oluseun Adejumo, I., & Adebukola Adebiyi, 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

Olutoge, F. A., & Adesina, P. A. (2019). Effects of rice husk ash prepared from charcoal-powered incinerators on the strength and durability properties of concrete. *Construction and Building Materials*, *196*, 386–394. https://doi.org/10.1016/j.conbuildmat.2018.11.138

Özkılıç, Y. O., Zeybek, Ö., Bahrami, A., Çelik, A. İ., Othuman Mydin, M. A., Karalar, M., Hakeem, I. Y., Roy, K., & Jagadesh, P. (2023). Optimum usage of waste marble powder to reduce use of cement toward eco-friendly concrete. *Journal of Materials Research and Technology*, *25*, 4799–4819. https://doi.org/10.1016/j.jmrt.2023.06.126

Ramezanianpour, A. A. (2009). *The Effect of Rice Husk Ash on Mechanical Properties and Durability of Sustainable Concretes*. *7*(2).

Ranjan Kumar & Shyam Kishor Kumar. (2015). *Mr. Ranjan Kumar*, Shyam Kishor Kumar*.* *5*(8).

Sakalkale, A. D., Dhawale, G. D., & Kedar, R. S. (2014). *Experimental Study on Use of Waste Marble Dust in Concrete*. *4*(10).

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

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

Sarika Verma, Harsh Bajpai, S. Suresh, Medha Mili, Ritesh Kumar Gupta, Rohit Shetty, & Mohd. Akram Khan. (2023). Synthesis of advanced asbestos-free material using rice husk ash and marble waste for thermal insulation applications. *Biomass Conversion and Biorefinery*, *Volume 13*, 8985–8998.

Shin, Sang-Yeop, & Kim, Young-Su. (2013). Durability Performance of Concrete using Rice Husk Ash. *Journal of the Korea Institute of Building Construction*, *13*(2), 139–147. https://doi.org/10.5345/JKIBC.2013.13.2.139

Silva, D., Gameiro, F., & De Brito, J. (2014). Mechanical Properties of Structural Concrete Containing Fine Aggregates from Waste Generated by the Marble Quarrying Industry. *Journal of Materials in Civil Engineering*, *26*(6), 04014008. https://doi.org/10.1061/(ASCE)MT.1943-5533.0000948

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

Singh, M., Srivastava, A., & Bhunia, D. (2017). An investigation on the 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

Sumadi, S., & Loon, L. Y. (n.d.). *DEVELOPMENT OF BLENDED CEMENTS FOR WATERPROOFING APPLICATION*.

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), 122–124. https://doi.org/10.14445/22315381/IJETT-V37P219

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

University of Engineering and Technology, Lahore, Pakistan, Idrees, M., Faiz, A., & University of Engineering and Technology, Lahore, Pakistan. (2019). *Utilization of waste quarry dust and marble powder in concrete*. 302–314. https://doi.org/10.18552/2019/IDSCMT5035

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

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

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

Vijaya Kumar Ym, Shruti D, Tharan SN, Sanjay SR, & Sricharan PM. (2016). *Partial Replacement of Cement to Concrete by Marble Dust Powder*. *2*(05).

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.2021.109782