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Investigating the Effect of Cardamom Husks as a Partial Replacement of Cement in Mortar

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Abstract: The demand for concrete with superior performance and durability has grown significantly in recent decades. However, the Novelty of using high-quality, sustainable materials like cardamom husk powder has increased and encouraged building technology researchers to find new alternatives. In many cases, and potentially always, concrete requires the incorporation of at least one additional component, such as admixtures, supplementary cementitious materials, or fibers, to improve its strength and durability characteristics. The combined application of chemical and mineral admixtures empowers concrete specialists to design concrete formulations for diverse performance demands. The present investigation evaluated the compressive strength of mortar cubes containing varying levels of cardamom husk as a cement replacement (0%, 10%, 20%, and 30%). Cubes were cured in water for 90, 150, and 210 days after standard curing times of 7, 14, and 28 days to assess their suitability for subsequent corrosion rate testing. Mortar cubes containing 10% cardamom husk replacement exhibited the highest compressive strength at each curing age. However, compressive strength decreased across all mixtures with increasing cardamom husk content. Exposure of the samples to environments with different pH values (3, 5, 7, 9, and 11) and sodium chloride levels (5% and 10%) was carried out over the specified time intervals. A clear trend was observed where longer exposure durations resulted in higher compressive strength, indicating that extended water immersion positively influenced strength development. Among all tested pH environments, the neutral pH 7 yielded the maximum compressive strength and the minimum corrosion rate across all mortar specimens. In addition, elevating the salt concentration led to a decline in compressive strength and an acceleration in corrosion activity. The samples immersed in a pH 7 solution containing 5% sodium chloride for 28 and 90 days displayed the most favorable balance between increased compressive strength and reduced corrosion rate. The optimal cement formulation identified in this investigation comprised 90% wt. Cement and 10% wt. Cardamom husk.

Keywords: Cardamom Husks, pH test, Compressive strength, Corrosion rate, Cement mortar.

1. Introduction

The conventional definition of concrete characterizes it as a composite material formed by combining aggregates (both fine and coarse), Portland cement, and water. This combination triggers a chemical reaction known as hydration [1]. Compressive strength is typically considered the most critical property of concrete. However, other characteristics, such as durability, workability, and permeability, are also crucial considerations [2]. The binding agent in concrete is a paste formed by the reaction of cement and water, which surrounds and adheres to the aggregate particles, the inert fillers within the concrete matrix.

Traditional concrete is often not sustainable because it uses up so much virgin, non-renewable substances [3]. Conventional concrete uses Portland cement as its primary binder, a significant source of greenhouse gas emissions contributing to climate change and global warming [4]. This highlights the importance of investigating renewable and less ecologically destructive alternatives, like making use of pulverized rice husk, a standard agricultural waste product [5]. Some early efforts to substitute some of the Portland cement in concrete with RHA (rice husk) have proved fruitful. This is since RHA is a pozzolanic substance with a high concentration of silicon dioxide and is, therefore, very reactive [6].

Grith [7] states that RHA may be used as a partial matrix substitute for up to 12.5% of the Portland cement without lowering the concrete's strength or durability standards, which can lead to lower manufacturing costs. The controlled combustion procedure needed to generate RHA from rice husks without releasing greenhouse gases into the air is a significant problem [8]. Furthermore, the authors stated that no research has been done to determine the precise temperature at which rice husk might be cooked to provide the ideal properties needed to improve concrete. The study aimed to investigate the potential suitability of ground, unburnt rice husk as a partial substitute for cement in reinforced applications [9].

In Minna, Nigeria, Oyetola and Abdullahi (2004) examined the impact of compressive strength on a variety of commercial sandcrete blocks. RHA was produced by burning firewood to create charcoal. An initial examination was carried out to determine whether the component materials of ordinary OPC (Ordinary Portland Cement) and RHA hollow sandcrete blocks are suitable for constructing blocks. Sandcrete blocks with hollow cores were manufactured, allowed to harden, and then subjected to crushing tests after being cured for various periods (1, 3, 7, 14, 21, and 28 days). The crushing tests were conducted at multiple replacement levels (0, 10, 20, 30, 40, and 50 percent). Evaluation findings reveal that the majority of sandcrete blocks available in Minna Town do not meet the required quality standards. The compressive strength of the OPC/RHA sandcrete blocks is directly proportional to the duration of curing and inversely proportional to the amount of RHA component. The research determined that the ideal replacement amount is 20% [10].

In their 2007 study, Saraswathy and Ha-Won investigated RHA as a promising pozzolanic material for blending with Portland cement. Simultaneously, it was a product that provided additional value. The use of rice husk in Portland cement enhances the initial strength of concrete. It generates a CSH (calcium silicate hydrate) gel that envelops the cement particles, resulting in highly compact and less permeable structures. This might enhance the durability of concrete by reducing its susceptibility to cracking. However, a systematic and in-depth exploration of the corrosion performance of RHA-blended concrete remains largely absent in the current research landscape. This study adopted a practical approach, employing a combination of established techniques to evaluate the effectiveness of the concrete. Compressive, bond, and split tensile strength were assessed to gauge the mechanical properties. Corrosion effectiveness was investigated through rapid chloride ion permeation test, open circuit potential estimation, and an impressed voltage test. The findings from these tests are subsequently discussed [11].

Employing concrete technology, Ahmad et al. (2015) added rice husk to concrete compositions. Still, little research has been done on utilizing raw rice husk. With emphasis on porosity and density, this work offers an experimental study on the characteristics of cement mortar made from raw rice husks. Different proportions of rice husk mixed with mortar produced specimens. An investigation was conducted to determine the density, compressive strength, water absorption, and porosity of 10 mixtures. For the rice husk cement mortar to serve its primary function as a drainage medium, it must possess two essential properties: porosity and lightweight. The findings demonstrated that using a larger amount negatively impacts the compressive strength, density, and porosity of rice husk cement mortar [12].

To determine the most practical method for reducing the long-term corrosion of RCC (reinforced cement concrete) in the presence of any hostile environment, Junaid and Ganesh (2022) conducted separate investigations. Their use as an admixture now includes inhibitors to circumvent this consequence. The research focuses on the inhibitor and its varieties, the benefits and downsides of commercial organic, inorganic, and hybrid inhibitors, and their usage in RCC. Additionally, it offers comprehensive details on GCIs, or green corrosion inhibitors, which are various plant-based components. This study synthesizes the findings of other studies utilizing a variety of GCIs; its primary emphasis is on the use of plant extracts in concrete or RCC specimens, an area that promises to make substantial, long-term strides in corrosion prevention [13].

2. Related Works

2.1 Materials Characteristics

The selection of appropriate construction materials is crucial for a structure's performance. This study adheres to the Iraqi specification IQS 1984 for evaluating material properties employed in the investigation.

2.1.1 Cement

The study employed OPC Type I acquired from the Iraqi Mass Bazan Company, ensuring compliance with the Iraqi IQS 5-1984 specification. The chemical and physical properties of the cement were subsequently evaluated at the Center for Organizational Standardization and Quality Control laboratory.

2.1.2 Fine Aggregate

The investigation utilized natural sand originating from Al-Ukhaider, possessing a maximum particle size of 4.75 mm. The material met the grading and physical property requirements outlined in Iraqi Specification No. 45/1984 Zone 2. The Center for Standardization and Quality Control performed chemical and physical analyses of the materials. The laboratory testing was conducted at the concrete laboratory of the University of Technology.

2.1.3 Cardamom

Analysis of the cardamom revealed the following composition: 6.72% ash, 8.51% moisture, 10.03% oleoresin, 9.29% crude protein, 24.14% crude fiber, 8.01% essential oil, and 41.08% total carbohydrates. Analysis revealed a rich macro- and micro-mineral profile of the sample. This included calcium (Ca) at 109.87 mg/100 g, potassium (K) at 843.28 mg/100 g, magnesium at 102.76 mg/100 g, phosphorus at 151.29 mg/100 g, sulfur (S) at 37.14 mg/100 g, manganese (Mn) at 29.32 mg/100 g, iron (Fe) at 11.66 mg/100 g, and zinc (Zn) at 1.573 mg/100 g [14].

2.1.4 Mix Proportions

Mixing for all specimens lasted five minutes. Following casting in steel molds, the samples were compacted and allowed to cure for 24 hours before demolding (Figure 1). Subsequent curing occurred in a 20°C ± 2°C water tank. Notably, the water absorption of both coarse and fine aggregate was factored into the mixing process.

(**a**)

(**b**)

Figure 1. a) Cardamom powder, b) Mortar cubes**.**

3. Test Methods

3.1. PH measurement

The testing specimens were submerged in varying pH solutions to investigate the influence of solution pH on corrosion and mechanical properties. The testing included alkaline, neutral, and acidic environments to assess their impact on the specimens' corrosion rates and compressive strength. The specimens underwent curing in sodium chloride solutions over periods of 7, 14, 28, 90, 150, and 210 days. Following this process, drying and weighing were conducted, with the reduction in mass indicating the influence of corrosion rate.

Compressive strength testing was also carried out under identical conditions [15]. Table 1 lists the mixture details.

Table 1. Mixtures details

Cardamom wt%	Cement Kg/m3	w/b ratio	Fine agg. Kg/m3
0	250	0.5	500
10	225	0.5	500
20	200	0.5	500
30	175	0.5	500

3.2. Compressive Strength Test

The test was conducted using a compressive strength device with a capacity of 100 kN. Every test was conducted to ascertain the device's maximal load capacity. Compressive strength is a measure of a material's resistance to a compressive force, expressed as the stress (force per unit area) applied to the specimen's surface during testing. It may then be estimated using Equation (1) below [15, 16].

$$Compressive\ strength = \frac{\text{Ultimate load}}{\text{cross−sectional area}} \text{ -- (1)}$$

Cross-sectional area = 5 cmx5 cm = 25 cm^2

3.3. Corrosion Rate Test

The mortar samples were weighed after drying. After that, the corrosion rates were calculated based on the variations in weight between the sample taken before and after it had been immersed in water with the additives, as well as the factor mentioned before. The corrosion rate was calculated depending on Equation (2) [17, 18].

$$Corrosion\ Rate\ \left(\frac{mm}{year}\right) = \frac{Weight\ Loss\ x\ K}{Density\ x\ Area\ x\ Time} \quad (2)$$

In which,

K = constant (8.76×10^4),

Carbon steel density = 7.85 g/cm^3

Area = 5cmx5cm = 25 cm^2

4. Results and Discussion

Mortar specimens immersed for 7, 14, 28, 90, 150, and 210 days underwent evaluation for corrosion rate and compressive strength, respectively. As illustrated in Figure 2, a correlation was observed between different weight percentages of cardamom powder and the compressive strength of mortar over 7, 14, and 28 days. Maximum compressive strength at all immersion intervals was achieved with 10 wt. % cardamom. Figure 3 presents the corrosion rate, which increased progressively with extended immersion durations of 90, 150, and 210 days, while the most favorable performance occurred at a 10% cardamom powder content.

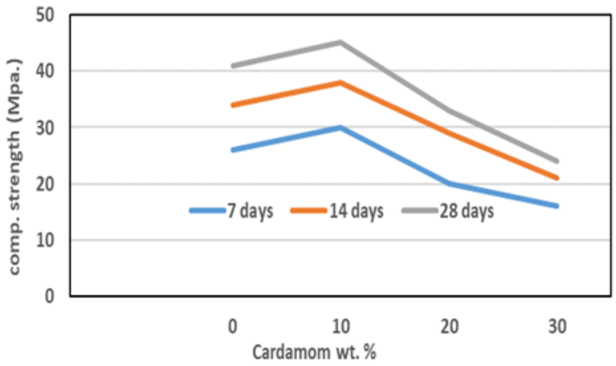

Figure 2. Influence of Cardamom powder (Wt. %) on the mortar's compressive strengths.

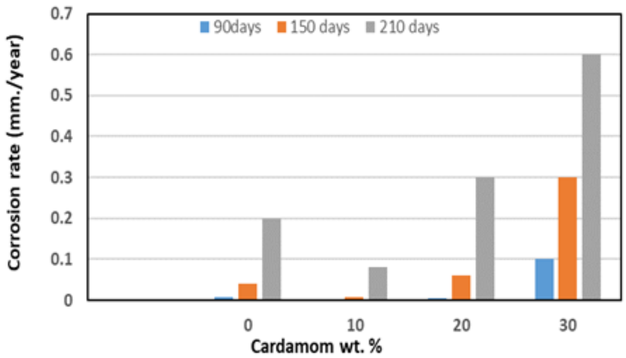

Figure 3. Influence of Cardamom powder (Wt. %) on the mortar's corrosion rate.

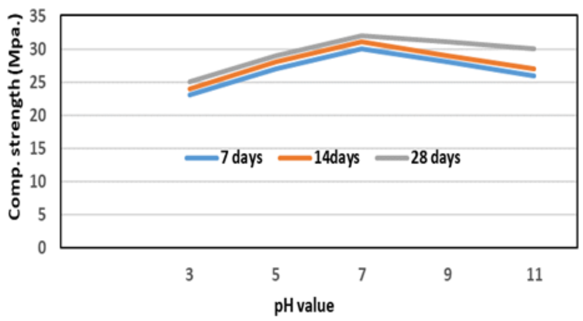

Figure 4. pH impact on mortars' compressive strength.

The most effective specimens in the investigation, characterized by the highest compressive strength and the lowest corrosion rate, were prepared by incorporating 10% by weight of cardamom husk powder into the mortar. This selected mixture underwent additional evaluation under "3, 5, 7, 9, and 11" pH concentrations of across 7-210 days immersion durations. During compressive strength measurements, the neutral pH uniformly yielded the highest values across all immersion intervals (days 7, 14, and 28), as presented in Figure 4. Furthermore, the lowest corrosion rate was recorded in the neutral environment for the extended immersion durations of 90, 150, and 210 days, as displayed in Figure 5.

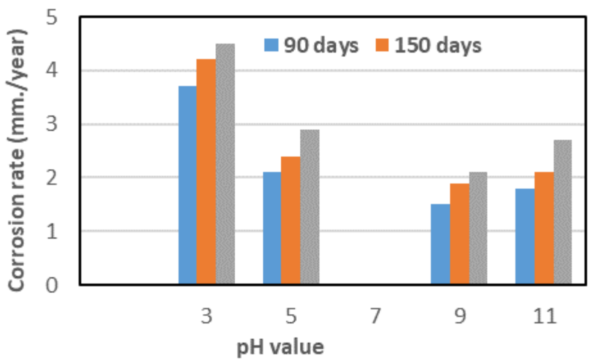

Figure 5. Mortar corrosion rate as a function of pH.

The ultimate specimens underwent additional analysis in sodium chloride solutions at 5% and 10% concentrations. For compressive strength assessment, immersion periods were set for 7, 14, and 28-day. Simultaneously, the rates of corrosion evaluation were conducted after exposure durations of 90, 150, and 210 days. Figure 6 illustrates the influence of 5% and 10% NaCl solutions on the compressive strength of mortar specimens. A reduction in compressive strength was observed with higher salt concentrations. Nevertheless, a consistent trend of increased strength with extended immersion time was maintained.

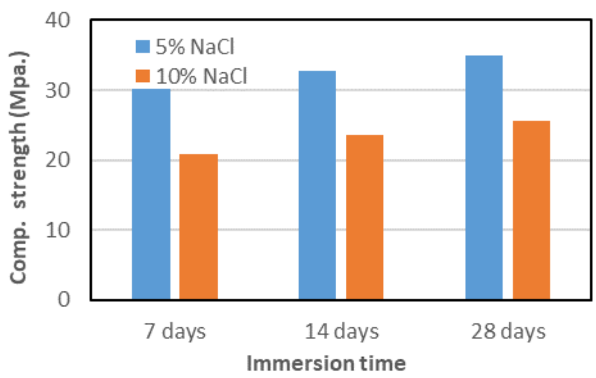

Figure 6. Mortars' compression as a function of sodium chloride concentration

The corrosion behavior of the mortar specimen was examined in sodium chloride solutions of varying concentrations over immersion periods of 90, 150, and 210 days (Figure 7). Findings indicate that higher salt concentrations have a marked effect on the corrosion rate. Moreover, prolonged exposure durations in both solutions resulted in increased corrosion rates.

Durability refers to a material's ability to withstand prolonged use without weakening due to various operating conditions, including corrosion and chemical agents. The value of compression refers to a material's capacity to withstand physical loadings (moments, forces) without experiencing damage. So, there is a direct relationship between them, where durability increases with strength, which was at 10% wt. of cardamom husk powder.

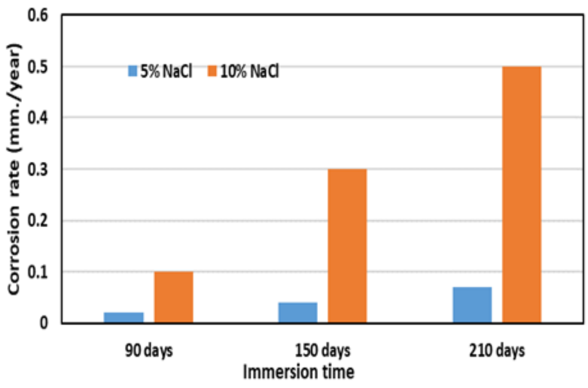

Figure 7. Mortar corrosion rate as a function of sodium chloride concentration

5. Conclusion

The primary objective of the present research is to examine whether the use of mortar blocks made from cardamom husk instead of cement can enhance the strength of concrete mortars and reduce corrosion rates. The 10% cardamom husk mortar sample showed high compressive strength and a low corrosion rate in a neutral solution (pH 7). The highest compressive strength was achieved at 28 days, and the lowest corrosion rate was measured at 90 days. As a conclusion, using cardamom husk powder was effective in:

1 Disposal of agricultural waste

2 Reducing the use of the weight percentage of cement in the mortar because it is heavy

3 To obtain environmentally friendly concrete.

As a comparison, using agricultural waste to produce environmentally friendly cement results in a stronger, more durable, and lighter material that reduces corrosion. The current research showed that the best properties were when adding cardamom husk powder, Hybrid Fibers, and adding lemon peel powder, respectively, which proves that the best results were when using cardamom husks, noting that it was recently used in some research to improve the mechanical properties of cement, as olive leaves powder used for the same purpose. So they have similar results.

Cardamom husk reduces the effect of corrosion on the mortar by acting as an inhibitor that prevents the entry of materials that increase the rate of corrosion, such as acidic water and water containing high levels of salts, into the models.

Furthermore, investigating the impact of various environmental factors, such as weather conditions and geographical terrain, on the performance of fault detection systems could provide valuable insights for optimizing system resilience. Continued research and innovation in this field hold the potential to revolutionize the reliability and efficiency of electrical grid operations in the future, leveraging the power of LightGBM and advanced wireless communication technologies.

References

[1] M.N. Al-Khalaf, H.A. Yousif, Use of Rice Husk Ash in Concrete. The International Journal of Cement Composites and Lightweight Concrete, 6(4), (1984) 241-248. https://doi.org/10.1016/0262-5075(84)90019-8

[2] M. Anwar, T. Miyagawa, M. Gaweesh, Using Rice Husk Ash as Cement Replacement Material in Concrete. Waste Management Series, Elsevier, 1, (2000) 671- 684. https://doi.org/10.1016/S0713-2743(00)80077-X

[3] ASTM. (1978). ASTM C618: Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete. Philadelphia, PA: ASTM International.

[4] ASTM International. (2007). ASTM C114-07: Standard test methods for chemical analysis of hydraulic cement. West Conshohocken, PA: ASTM International

[5] U.A. Birnin-Yauri, (2009) Private Communications. Cement Company of Northern Nigeria (CCNN). A Publication of Cement Company of Northern Nigeria, Sokoto, pp 20 – 25

[6] I.I. Dashan, E.E.I. Kamang, Some characteristics of RHA/OPC Concretes: A Preliminary Assessment, Nigerian Journal of Construction Technology and Management, 2(1), (1999) 22-28.

[7] D.H. Grith, (1974). *Rice*, 2nd Edition, Longman Limited, London. pp12-18. P.C. Hewlett, (Ed.) (1998). *Lea's Chemistry of Cement and Concrete*. 4th Ed, Arnold, London pp 299-342.

[8] A.A. Ikpong, the Relationship between the Strength and Non-Destructive Parameters of Rice Husk Ash Concrete. Cement and Concrete Research, 23(2), (1993) 387-398. https://doi.org/10.1016/0008-8846(93)90104-H

[9] N. Jackson, R.K. Dhir, *Civil Engineering Materials*, 4th Edition, Macmillan ELBS, Hong Kong, (1991) 144 –160.

[10] E.B. Oyetola, M. Abdullahi, The Use of Rice Husk Ash in Low-Cost Sandcrete Block Production, Leonardo Electronic Journal of Practices and Technologies, 8, (2006) 58-70.

[11] V. Saraswathy, S. Ha-Won, Corrosion performance of rice husk ash blended concrete. Construction and building materials, *21*(8), (2007) 1779-1784. https://doi.org/10.1016/j.conbuildmat.2006.05.037

[12] M.M. Ahmad, F. Ahmad, M. Azmi, M.Z.A. Mohd Zahid, Properties of cement mortar consisting raw rice husk. Applied Mechanics and Materials, 802, (2015) 267-271. https://doi.org/10.4028/www.scientific.net/AMM.802.267

[13] J. Ahmed ES, G.M. Ganesh, A Comprehensive Overview on Corrosion in RCC and Its Prevention Using Various Green Corrosion Inhibitors. Buildings, 12(10), (2022) 1682. https://doi.org/10.3390/buildings12101682

[14] S. Abera, B. Gezahegn, B. Hirko, Nutritional composition of cardamom (Elettaria Cardamoum) seed cultivated in Ethiopia. International Journal of Pharmaceutical Research, 3(5), (2019) 50-53.

[15] H.J.M. Al Jaaf, M.A.A.W. Ali, R.S. Al-Jadiri, (2019). Effect of pH Solutions on Using Waste Marble powder to Enhance Mortar Compressive Strength. In IOP Conference Series: Materials Science and Engineering, 561(1), (2019) 012130.

[16] I.H. Saif M.F. Nada, Behavior of Reactive Powder Concrete reinforced with Hybrid Fibers containing Sustainable Materials. Engineering, Technology & Applied Science Research, 14(3), 13878-13882. https://doi.org/10.48084/etasr.7167

[17] K. Salhi, B. Mezghiche, Evaluation of the mechanical properties and durability of cement mortars containing Algerian met kaolin. Ceram. Silikaty, 61, (2017) 65-73. https://doi.org/10.13168/cs.2016.0062

[18] H.J. Meerza Al-Jaaf, R.S. Al-Jadiri, L. Ghalib, Using Lime Peels Powder to Eliminate Corrosion Rate and Improve the Compressive Strength of Carbon Steel Mortar. Egyptian Journal of Chemistry, *65*(9), (2022) 415-420.

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Authors Contribution Statement

Rand Salih Al-jadiri: Editing, Validation, Supervision, Writing-Review & Editing, Supervision, Methodology. Hyman Jafar Meerza Al-Jaaf: Writing-Original draft, Methodology, Investigation, Conceptualization. Both the authors approved the final version of the work.

Competing Interests

The authors state no conflicting interests.

Data Availability

The data supporting the findings of this study can be obtained from the corresponding author upon reasonable request.

Has this article screened for similarity?

Yes

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