Investigating Conventional Concrete using Rice Husk Ash (RHA) as a Substitute for Finer Aggregate

Suganya Natarajan\textsuperscript{1*}, Syed Hamim Jeelani\textsuperscript{2}, Prashant Sunagar\textsuperscript{3}, Sushilkumar Magade\textsuperscript{4}, Sahil Sanjeev Salvi\textsuperscript{5}, Sumanta Bhattacharya\textsuperscript{6}

\textsuperscript{1}Department of Civil Engineering, Sri Sairam Engineering College, Chennai, Tamil Nadu 600044, India.
\textsuperscript{2}Department of Civil Engineering, Koneru Lakshmaiah Education Foundation (Deemed to be University), Vaddeswaram, 522502, Andhra Pradesh, India.
\textsuperscript{3}Department of Civil Engineering, M S Ramaiah Institute of Technology, Bengaluru, Karnataka 560054, India.
\textsuperscript{4}Department of Civil Engineering, MIT Academy of Engineering, Pune, Maharashtra 412105, India.
\textsuperscript{5}Department of Civil Engineering, Pimpri Chinchwad College of Engineering and Research, Ravet, Pune, Maharashtra 412101, India.
\textsuperscript{6}Department of Textile Technology, Maulana Abul Kalam Azad University of Technology, Bidhannagar, Kolkata, West Bengal 700064, India.

*Corresponding author: suganyanatarajan22@gmail.com

Abstract. The concrete industry introduces a variety of linked ways for integrating and using waste materials that are generally usable, readily accessible, and financially feasible for the everyday consumer. The use of such components in cementitious materials not just to saves greenhouse gas emissions, but also improves flowability and longevity significantly. This article discusses how rice husk ash (RHA), a byproduct of rice production, may be used with cementitious material. Because the density of concrete incorporating RHA is comparable to that of standard weight cement, it may also be used for a wide variety of applications. RHA concrete's impermeable substructure provides superior resistance against chemical attack, salt entry, and bubbling, among other things. RHA cementitious material has excellent contraction characteristics and increases the durability of the concretes. In this work, the RHA was used in progressive fractions such as, 0%, 10%, 20%, 30%, and 40% as a substitute for the fine sand in different periods. The outcomes evidenced that the incorporation of 20% replacement of RHA with fine sand showed a better increment in the compressive strength of the concrete.

Keywords: rice husk ash; fine aggregate; concrete; waste in concrete; compressive strength.

1. Introduction

There seem to be countless research studies recommended to enhance the characteristics of cementitious materials, regardless if they are natural or reprocessed substances or a mixture of 2 different artificial substances used in the cement mortar [1, 2]. If debris is not safely removed of, it will cause ecological crisis. The huge price of traditional constructional substances is a significant parameter influencing the new building projects. This prompted investigations into alternate materials for the cementitious substances [3, 4]. Rice husk ash (RHA) is frequently employed as a garbage material. To avert this, a variety of RHA reuse methodologies are conducted as per our need. With the
international economy in crisis and economic inflation patterns, the major constituents needed to create constructions have resulted in extremely expensive infrastructure costs [5, 6]. As a result, technology specialists are devoted to using indigenous resources to partly or completely substitute expensive traditional substances. Different studies had been conducted in this thrust field to determine the resilience of these elements [7, 8]. Potential savings and the capacity to make highly dense mortar are other advantages of these substances [9, 10].

Generally, cementitious aggregates accounted for nearly 80% of the mass of cement and contribute in various mortar characteristics like flowability, resilience, size consistency, and longevity. There is considerable attention with the use of solid wastes as substitutive aggregates, and considerable studies have focused on the utilization of an array of substances as concrete substitutes, including wood ash, quarry dust, and firewood ash [11, 12, 13]. This type of waste substance has the potential to alleviate cementitious shortages on numerous building projects and to mitigate ecological consequences associated with aggregate quarrying and disposal of debris. Nowadays, mortar is the most widely utilized construction material. It is strongly embracing a fundamental role in the formation and progress of the nation's setup [14, 15]. About all of the content is composed of coarser particles extracted from conventional stones. In light of this, the pollution of ordinary materials happens. To meet the whole demand for mortar in the future, it becomes an equally enticing undertaking to develop suitable replacements to typical minerals for mortar preparation. To address the aforementioned problem, garbage derived from optional resources is utilized [16, 17].

RHA are the debris after burn of rice husks that are traditionally regarded as agricultural residues and a potential source of pollution. Whenever husks are processed outside the paddy field, it produces a kind of by-product that can be used as fillings in polymers. Rice husk is the result of the paddy preparation processes [18, 19]. Due to the increasing rate of degradation of the environment and the concept of pragmatism, employing rice husk has become popular. The subsequent sections provide explanations on the usage of RHA as a possible substitute for masonry in robust assembling. To develop an appropriate concept for the incorporation of RHA into masonry, a thorough examination of its qualities should be completed [20, 21]. About a billion tonnes of rice yield generate responses worldwide. They have quite a modest mass density of around 200 kg per cubic metre. As a consequence, a more precise assessment of dried capacity is obtained. The husk does indeed have an uncompromising, rough surface [22, 23]. As a result, they are impervious to typical contamination. It could result in unscrupulous deportation concerns. Across all attempts to recycle the material, concrete and robust collecting initiatives are the most skilled way of using RHA in a widespread manner [24, 25]. RHA is created by firing a large quantity of rice husks. It creates an ecological crisis, but in certain cases, such losses can be utilized to benefit agriculture by lowering building costs and conserving the environment, by managing internal natural damage, and by generating components that improve the performance of building supplies. Over the previous two decades, more countries have been challenged with the usage of utilized river bed sand. The majority of the planet's people lack access to high-performance and capable building supplies due to their large price [26, 27]. When compared to all these high-priced resources, RHA is less expensive and readily available around the globe. Whenever a paddy plant begins to grow, it possesses the characteristic of absorbing silicate from the ground where it originates and retaining it inside its tissue and structures [28, 29]. Nonetheless, researchers must place a greater emphasis on the efficient use of affordable and readily available resources.

The novelty of the present investigation is that one among the aforementioned agricultural waste, RHA is studied as a substitute for the fine aggregates. It would help to reduce the consumption of the traditional and costlier fine aggregates substantially. The RHA of different fractions such as 10%, 20%, 30%, and 40% have been replaced for the fine aggregate the resulting compressive strength for the different curing period is assessed.
2. Materials

![Figure 1. (a) Fresh rice husk (b) Rice husk ash.](image)

The laboratory investigation used grade 54 cement. The fine aggregate used in the research analysis was the finely sieved river bed sand obtained from the local blue metal supplier. The sand was completely dry and cleaned to remove any impurities. The relative density was 2.45, modulus of fineness was 2.51, and unit weight was 1420 kg/m³ for the fine aggregative materials. The coarser aggregative materials were collected from the same blue metal supplier comprised of broken rocks with the mean size of 15 mm. The coarser aggregative material has a relative density of 2.62, modulus of fineness was 6.22, and a unit weight of 1630 g/cm³. The standards IS 8112 (2013) and IS 383:1970 were implemented during the preparation of cementitious materials [30, 31].

The RHA was acquired from the agricultural field as shown in Figure 1. The relative density of the RHA was 2.5, modulus of fineness and unit weight of the RHA were 2.39 and 545 kg/m³, respectively. The mortar mix design is decided as per Table 1.

![Table 1. Mix design of mortar](image)

| S.No. | Specimen | Cement material (gm) | RHA (%) | River bed sand (gm) | Broken rocks (gm) |
|-------|----------|----------------------|---------|---------------------|------------------|
| 1     | R0       | 1000                 | 0       | 1650                | 2920             |
| 2     | R10      | 1000                 | 10      | 1485                | 2920             |
| 3     | R20      | 1000                 | 20      | 1320                | 2920             |
| 4     | R30      | 1000                 | 30      | 1155                | 2920             |
| 5     | R40      | 1000                 | 40      | 990                 | 2920             |

3. Testing of the specimen

Compressive tests were performed in accordance with established guidelines on cube-shaped concrete block specimens measuring 0.15 m on every face. The trials were performed on samples that had been cured for seven, twenty-eight, or sixty days, correspondingly. Beforehand, the 3 samples were prepared for the each composition of RHA in the concrete slab. The tests were carried out with the assistance of a universal test machine with the digital read-out facility.
4. Results and discussion

Figure 2. Compression strength of the mortar with diversified fraction of RHA after 7 days curing.

The compression strength of the mortar specimens after 7 days of curing period is illustrated in Figure 2. The compression testing was conducted for three samples from each specimen to ensure the exactness and precision of the result. It could be noted that the compression strength of the specimen after 7 days of curing enhanced with the increment in RHA fraction in the mortar till 20% of RHA instead of river bed sand. Further, the strength values declined beyond 20% addition of RHA within the cement. It showed that the excessive increment of RHA adversely improved the porosity of the mortar, which caused in the reduction of the compression strength.

Figure 3. Compression strength of the mortar with diversified fraction of RHA after 28 days curing.
Figure 4 elucidates the compression strength of the RHA mixed concrete after 28 days of curing time. In general, the compression strength of the specimens showed around 20% increment in compression strength irrespective of the RHA composition, comparing to the 7 days curing time. However, similar to the previous discussion, the maximum compression strength was observed for the specimen with 20% fraction of RHA and the strength was noticed to be deteriorative after increasing RHA beyond 20%.

Figure 4 presents the compression strength trends of the mortar containing various RHA content. Once again, the increased curing time enhanced the compression strength of the concrete slab to another fold. However, the concrete with RHA replacement more than 20% couldn’t enhance the compressive strength of the mortar, rather it showed the depreciation in results. Altogether, the results have proved that the substitution of RHA instead of finer sand could be a fruitful solution. However, the content of the RHA in the cement is the critical factor. In this work, the substitution of 20% RHA with the finer sand improved the compressive strength of the mortar by around 20% in all the curing periods. Hence, around 20% replacement of RHA with the finer aggregates are recommended for better results.

5. Conclusion
The experimental investigation has been carried-out to assess the influence of rice husk ash (RHA) as the substitute for the finer aggregates in the ordinary cement based mortar. The different fractions of the RHA was tested such that, 0%, 10%, 20%, 30%, and 40%, respectively for 7 days, 28 days, and 60 days curing time, correspondingly. The results evidenced that the replacement of finer aggregates with 20% of RHA would give a better outcome without compromising the quality of the mortar. It was noticed that the 20% replacement of RHA in the cement improved the compressive strength by around 20%. However, other mechanical and physical examinations are to be conducted to quantify the full-pledged utilization of the RHA with the cement.

The study can be extended using other kind of suitable waste materials as the substitute for the finer aggregates in future.
References

[1] Selvasofia, S.A., Sarojini, E., Moulica, G., Thomas, S., Tharani, M., Saravanakumar, P.T. and Kumar, P.M. 2021. Study on the mechanical properties of the nanoconcrete using nano-TiO$_2$ and nanoclay. Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.08.242

[2] Benemaran, R.S. and Esmaeili-Falak, M. 2020. Optimization of cost and mechanical properties of concrete with admixtures using MARS and PSO. Computers and Concrete 26(4):309-316.

[3] Balaji, M., Dinesh, S.N., Raja, S., Subbiah, R. and Kumar, P.M. 2021. Lead time reduction and process enhancement for a low volume product. Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.12.240

[4] Liu, J., Yu, C., Shu, X., Ran, Q. and Yang, Y. 2019. Recent advance of chemical admixtures in concrete. Cement and Concrete Research 124:105834.

[5] Balaji, M., Dinesh, S.N., Kumar, P.M. and Ram, K.H. 2021. Balanced Scorecard approach in deducing supply chain performance. Materials Today: Proceedings. doi: 10.1016/j.matpr.2021.05.541

[6] Jindal, B.B. 2019. Investigations on the properties of geopolymer mortar and concrete with mineral admixtures: A review. Construction and Building Materials 227:116644.

[7] Nandhakumar, S., Kanna, K.M., Riayas, A.M. and Bharath, M.N. 2021. Experimental investigations on natural fiber reinforced composites. Materials Today: Proceedings 37:2905-2908.

[8] King, M.F.L., Rao, P.N., Sivakumar, A., Mamidi, V.K., Richard, S., Vijayakumar, M., Arunprasath, K. and Kumar, P.M. 2021. Thermal performance of a double-glazed window integrated with a phase change material (PCM). Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.09.099

[9] Thirumalai, R., Senthilkumar, J. S. 2013 Multi Criteria Decision Making in the selection of machining parameters for Inconel 718. Journal of Mechanical Science and Technology 27 (4):1109-1116.

[10] Mohan Kumar, A., Rajasekar, R., Manoj Kumar, P., Parameshwaran, R., Karthick, A. and Muhibullah, M. 2021. Comparative analysis of drilling behaviour of synthetic and natural fiber-based composites. Advances in Materials Science and Engineering 2021. doi.org/10.1155/2021/9019334

[11] Naresh Kumar, T., Saravanan, A.K., Jose, S.S.H., Ravikumar, L. and Sudhakar, M. 2019. Reinforcing Adhesive Plastic-Coated Grins through FRP Compounds.

[12] Saravanan, A.K., Prasad, A.R., Muruganandam, D., Saravanan, G., Vivekanandan, S. and Sudhakar, M. 2021. Study on natural fiber composites of jute, pine apple and banana compositions percentage of weight basis for thermal resistance and thermal conductivity. Materials Today: Proceedings 37:147-151.

[13] Kumar, P.M., Chauhan, P., Sharma, A.K., Rinawa, M.L., Rahul, A.J., Srinivas, M. and Tamilarasan, A. 2022. Performance study on solar still using nano disbanded phase change material (NDPCM). Materials Today: Proceedings. doi.org/10.1016/j.matpr.2022.01.050

[14] Nandhakumar, S., Thirumalai, R., Viswaaaswaran, J., Senthil, T.A., Vishnuvardhan, V.T. 2021. Investigation of production costs in manufacturing environment using innovative tools. Materials Today: Proceedings, 37:1235-1238.

[15] Ramya, D., Krishnakumari, A., Dineshkumar, P.T., Srivastava, M.P., Kannan, L.V., Puthilibai, G. and Kumar, P.M. 2021. Investigating the influence of nanoparticle disbanded phase changing material (NDPCM) on the working of solar PV. Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.11.419

[16] Balaji, M., Dinesh, S.N., Vetivel, S.V., Kumar, P.M. and Subbiah, R. 2021. Augmenting agility in production flow through ANP. Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.06.053

[17] Dinesh, S.N., Ravi, S., Kumar, P.M., Subbiah, R., Karthick, A., Saravanakumar, P.T. and Pranav, R.A. 2021. Study on an ETC solar water heater using flat and wavy diffuse...
reflectors. Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.05.561

[18] Jung, S.H., Saraswathy, V., Karthick, S., Kathirvel, P. and Kwon, S.J. 2018. Microstructure characteristics of fly ash concrete with rice husk ash and lime stone powder. International Journal of Concrete Structures and Materials, 12(1):1-9.

[19] Saravanakumar, P.T., Arunkumar, S.P., Mansingh, B.B., Kumar, P.M., Subbiah, R. and Eswaral, V.K. 2021. Investigating the effect of thermal cycling on thermal characteristics of the nano-silica based phase changing material (PCM). Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.09.095

[20] Gautam, A., Batra, R. and Singh, N. 2019. A study on use of rice husk ash in concrete. Engineering Heritage Journal 01-04.

[21] Kumar, P.M. and Mylsamy, K. 2020. A comprehensive study on thermal storage characteristics of nano-CeO2 embedded phase change material and its influence on the performance of evacuated tube solar water heater. Renewable Energy 162:662-676. doi.org/10.1016/j.renene.2020.08.122

[22] Kaushik, N., Saravanakumar, P., Dhanasekhar, S., Saminathan, R., Rinawa, M.L., Subbiah, R., Sharma, R. and Kumar, P.M. 2021. Thermal analysis of a double-glazing window using a Nano-Disbanded Phase Changing Material (NDPCM). Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.11.537

[23] Rinawa, M.L., Pitchandi, P., Vigneshkumar, N., Sharma, R., Singh, M.K., Subbiah, R. and Kumar, P.M. 2021. Experimental analysis of the metal roofed industrial building using nano-silica disbanded crude wax (NDCW). Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.12.253

[24] Nandhakumar, S., Thirumalai, R., Viswaaswaran, J., Senthil, T.A. and Vishnuvardhan, V.T. 2021. Investigation of production costs in manufacturing environment using innovative tools. Materials Today: Proceedings 37:1235-1238.

[25] Kumar, P.M., Arunthathi, S., Prasanth, S.J., Aswin, T., Antony, A.A., Daniel, D., Mohankumar, D. and Babu, P.N., 2021. Investigation on a desiccant based solar water recuperator for generating water from atmospheric air. Materials Today: Proceedings 45:7881-7884. doi.org/10.1016/j.matpr.2020.12.506

[26] Gunasekaran, N., Kumar, P.M., Raja, S., Sharavanan, S., Avinas, K., Kannan, P.A. and Gokul, S. 2021. Investigation on ETC solar water heater using twisted tape inserts. Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.04.586

[27] Kumar, P.M., Mukesh, G., Naresh, S., Nitthilan, D.M. and Kumar, R.K. 2021. Study on performance enhancement of SPV panel incorporating a nanocomposite PCM as thermal regulator. In Materials, Design, and Manufacturing for Sustainable Environment 587-597. doi.org/10.1007/978-981-15-9809-8_44

[28] 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.

[29] Prakash, K.B., Fageehi, Y.A., Saminathan, R., Manoj Kumar, P., Saravanakumar, S., Subbiah, R., Arulmurugan, B. and Rajkumar, S. 2021. Influence of fiber volume and fiber length on thermal and flexural properties of a hybrid natural polymer composite prepared with banana stem, pineapple leaf, and S-glass. Advances in Materials Science and Engineering 2021.

[30] Boobalakrishnan, P., Kumar, P.M., Balaji, G., Jenaris, D.S., Kaarthik, S., Babu, M.J.P. and Karthik, K., 2021. Thermal management of metal roof building using phase change material (PCM). Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.05.012

[31] Anandaraj, S., Deepa, N., Kumar, P.M., Anusha, G., Gobinath, R., Krishnaraja, A.R., Harikanandan, M. and Karthick, S.S. 2021. An Experimental Investigation of Marble Dust in Luffa Fibre Reinforced Concrete. In IOP Conference Series: Materials Science and Engineering 1145(1):012100. doi:10.1088/1757-899X/1145/1/012100