ENHANCEMENT OF CONCRETE MECHANICAL STRENGTH USING RICE HUSK ASH AND RECYCLED AGGREGATES

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ABSTRACT

This study examines the potential substitution of naturally sourced coarse aggregates with recycled concrete aggregates in the production of concrete. It also examines the partial substitution of cement with rice husk ash. To achieve this aim, aggregates obtained from the demolition of slabs, abutments and pillars from old bridges in Dhaka city were collected. Additionally, rice husk ash, a discarded waste material often found in brick kilns was collected. A completely recycled aggregate is employed in the production modified concrete. Furthermore, in an effort to enhance the sustainability and performance of the concrete mixtures an innovative approach was implemented by substituting 15% of the cement with rice husk ash. This environmentally-friendly modification aimed to not only reduce the carbon footprint associated with cement production but also to explore the potential improvements in concrete properties. These modified concrete mixtures were meticulously prepared using a consistent ratio of 1:1.5:3 for cement, sand and aggregates respectively. To maintain uniform consistency and achieve optimal results, a water/cement (w/c) ratio of 0.45 was maintained throughout the mixing process. A total of 32 concrete cubes were meticulously cast to assess and compare the compressive and tensile strengths of both the conventional concrete and the newly developed modified concrete at two critical curing intervals specifically at 14 and 28 days. This comprehensive testing regime was carried out to evaluate the performance and durability of the modified concrete over time providing valuable insights into its long-term structural integrity and suitability for various construction applications. The findings indicate that the modified concrete containing 15% rice husk ash and 100% recycled aggregates exhibits notable enhancements in compressive and tensile strengths. After the completion of 28 days, a noticeable increase of 4.66% was observed in the compressive strength and a significant improvement of 7.9% was recorded in the tensile strength. The goal of this paper is to assess the strength properties of concrete containing recycled aggregate mixed with 15% rice husk ash and to contrast it with samples of conventional concrete.

***Keywords*:** *Rice Husk Ash, Recycle Aggregate, Eco-friendly, Tensile Strength, Compressive Strength*

1. INTRODUCTION

Recycled aggregates are pivotal in advancing eco-friendly and efficient construction practices, representing a critical resource in the construction industry's sustainability efforts. These aggregates result from processing and reclaiming various construction materials like concrete, asphalt, bricks and others that have reached the end of their lifecycle. Instead of being discarded, these materials undergo systematic crushing, screening and sorting to create recycled aggregates. The use of recycled aggregates in construction has gained significant attention and popularity recently. Incorporating recycled aggregates into new construction projects can reduce the demand for fresh natural resources, cut down on landfill waste and decrease the carbon footprint associated with conventional construction practices. Moreover, recycling construction materials into aggregates not only conserves valuable resources but also helps mitigate the environmental impact of mining and quarrying operations.The surge in construction and demolition waste (CDW) quantities in major Bangladeshi cities is a cause for concern due to its severe adverse impact on the environment. This waste accumulation not only occupies valuable land but also poses significant environmental risks. However, there exists a promising solution in repurposing this waste material as recycled aggregates in concrete. This approach not only mitigates the detrimental effects of construction and demolition waste (CDW) but also offers a twofold advantage by reducing the need for virgin resources in the construction industry and cutting down on waste disposal costs.

Rice husks have been a key fuel source for kilns in industries but they produce rice husk ash (RHA) as a byproduct. Unfortunately, rice husk ash (RHA) is often wasted as it lacks a specific purpose, leading to its disposal in open fields. This not only squanders a valuable byproduct but also contributes to environmental pollution. Global rice production in 2022/2023 was projected to reach 503.27 million metric tons (World Agricultural Production 2022).However, rice husk ash (RHA) typically lacks a practical application and is commonly discarded in open fields causing environmental pollution. Substantial efforts are underway to mitigate this environmental problem utilizing rice husk ash (RHA) as a supplementary cementing material (Chandrasekhar et al.). Rice husk ash is being explored as a mineral admixture for concrete and the source of the rice husk ash is considered crucial in determining the characteristics of the cementitious material (Chandrasekhar et al.). When rice husks are burned at controlled temperatures below 800°C the resulting silica is in an amorphous form (Reddy et al.).

Recognizing the environmental challenges posed by the accumulation of construction and demolition waste (CDW) and the underutilization of rice husk ash (RHA) it is imperative that concerted efforts be made to promote sustainable practices within the construction and industrial sectors. Embracing the recycling of construction and demolition waste (CDW) and exploring innovative applications for rice husk ash (RHA) can play a pivotal role in reducing environmental harm, conserving resources and fostering a more sustainable approach to development in Bangladesh and beyond. By doing so, we can not only address the issues of waste management but also promote economic growth while safeguarding the natural environment for future generations. The efficient use of construction and demolition waste (CDW) offers many advantages. Over the last two decades, research in the construction and demolition waste (CDW) field has concentrated on three key areas: the generation, reduction and recycling of waste.

The goal is to reduce the consumption of non-renewable resources such as virgin aggregates by recycling debris from demolished structures. This recycling process should be executed in a manner that allows it to serve as a replacement for virgin fine and coarse aggregate in cement concrete. Several studies have showed that in Brazilian cities, construction and demolition waste (CDW) accounts for 50% of all municipal waste generated. This issue is also significant in other countries like Hong Kong SAR, Canada and the UK, where it occupies a substantial part of existing landfill space, ranging from 33% to 65% (EPA 2002). Recycled aggregates differ from conventional ones mainly because of the leftover mortar. This distinction is responsible for the key variations in the physical properties of recycled aggregates, especially their increased ability to absorb moisture. The presence of leftover mortar and the moisture content have a notable impact on the water-to-cement ratio, influencing the properties of both freshly mixed and hardened concrete (L. Evangelista et al.).

Considering all these factors, this research project aims to investigate the mechanical properties of concrete when using rice husk ash as a supplementary material of cement alongside with recycled aggregate. The goal is to address environmental issues linked to construction and demolition waste (CDW) and rice husk ash from brick kilns, all while improving the qualities of concrete.

2. MATERIALS AND METHOD

2.1 Materials

In this study, Ordinary Portland Cement (OPC) was employed with the cement composition consisting of 95 to 100% clinker and 0 to 5% gypsum. The freshness of the cement was ensured by verifying its production date before purchase. In our experiments, locally sourced clean sylhet sand for the fine aggregates was chosen, ensuring it passed through the 4.75 mm sieve. Regarding the coarse aggregates, they were sourced from the Dhaka city market with a maximum size of 20 mm. Special attention was given to ensure that these coarse aggregates were clean and free from impurities.

In addition to recycle aggregates, we incorporated recycled coarse aggregates obtained from the demolition of slabs, abutment and pillars from bridge in Dhaka district. Before transporting them to our research site we dismantled these recycled aggregates into smaller more manageable pieces. Subsequently at the University, we further fragmented these pieces with a hammer to ensure they were of the proper size. It was a labour-intensive process to remove the cement coating from these recycled aggregates as this coating can impede the strong bond between cement and recycled materials potentially reducing the compressive and tensile strengths of hardened concrete. We used sieves with sizes of 1 inch, 3/4 inch and 1/2 inch to obtain the desired aggregate sizes.

As for the rice husk ash (RHA) used in our experiments, we collected it from local brick kilns near Faridpur district. Typically, rice husk ash (RHA) is a by-product of brick-making processes. We made sure to get clean rice husk ash (RHA) that was free from other substances and impurities. This rice husk ash (RHA) suitable for use in concrete. We used potable water from the structural laboratory for the preparation of all concrete mixtures. Also we performed a pH test on the water sample, resulting in a pH reading of 6.8 which is considered acceptable.

In the context of our experimental work and mix design, we prepared two types of concrete mixtures: a control mixture and a modified mixture. The modified mixture included 100% recycled aggregates and a 15% substitution of cement with rice husk ash (RHA), using a ratio of 1:1.5:3 with a water-to-cement ratio of 0.45. To assess the compressive strength of the concrete we cast a total of 32 cubes each measuring 150mm x 150mm x 150mm and subjected them to curing for 14 and 28 days. For each mixture, we prepared 16 cubes with 8 cubes designated for each of the two curing durations. The workability of all concrete mix designs, including both conventional and modified concrete, was assessed using the slump cone test. This test was conducted for both conventional concrete and modified concrete with rice husk ash to observe any differences. The objective was to achieve a slump measurement within the range of 75 to 100 mm. The results of the slump cone measurements are presented in Table 1. After being cast, the specimens were removed from their moulds after 24 hours and later placed in a consistently moist environment for the respective curing durations of 14 and 28 days.

Table 1: The recorded slump cone measurements for all the formulated concrete mix designs.

W/C Ratio	Concrete Mix Ratio	Slump of Conventional Concrete (mm)	Slump of RHA and RA Concrete (mm)
0.45	1:1.5:3	86	72

2.2 Concrete Mixing

Concrete was prepared using a mechanical mixer. Initially, the correct amounts of coarse aggregate, fine aggregates in a saturated surface-dry (SSD) condition and cement were combined in a dry mix for 2 minutes. Following that, the mixing water was added to the mixer. To ensure an even dispersion of rice husk ash (RHA) throughout the concrete, they were manually integrated into the mixture, which was then mixed for a total of 4 minutes. Following the mixing process, the workability of the concrete was assessed using the slump cone. The concrete was then placed into a custom-made mould and a tamping rod was used to compact it. Finally, a smooth steel trowel was employed to give the fresh concrete a polished finish.

2.3 Strength Testing

The concrete's strength was assessed by creating 150-mm cube samples which were after examined using a universal testing machine following a 14-days and 28-day curing period. A gradual application of force at a rate of 2.5 millimetres per minute continued until the specimen's reached failure. A strain rate of 2.5 mm/min might be chosen because it reflects a range that is pertinent to the actual conditions.

3. RESULTS & CONCLUSIONS

3.1 Compressive Strength

The Table 2 and Figure 1 present the outcomes of compressive strength assessments conducted at curing intervals of 14 and 28 days. These assessments were performed on cubes made from conventional concrete as well as made from modified concrete where 15% of the cement was replaced with rice husk ash (RHA) and all the aggregates were replaced with recycled aggregates.

Table 2: Results of compressive strength examinations conducted on conventional concrete and modified concrete altered with RHA (Rice Husk Ash) and RA (Recycled Aggregates).

Curing Time (Days)	Compressive Strength of Conventional Concrete (MPa)	Compressive Strength of RHA with RA Concrete (MPa)	Increase/Decrease of Compressive Strength than Conventional Concrete (%)
14 Days	20.53	21.02	2.38
28 Days	22.68	23.74	4.66

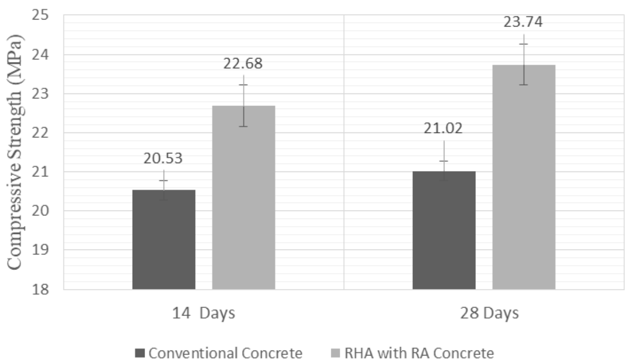

Figure 1: Compressive strength findings for conventional concrete and modified concrete incorporating Rice Husk Ash (RHA) with Recycled Aggregates (RA).

Table 2 and Figure 1 reveal that the modified concrete which involved substituting 15% of the cement with rice husk ash (RHA) and completely replacing the aggregates with recycled concrete shows higher compressive strength compared to conventional concrete at all two curing stages: 14, and 28 days. Specifically, at the 28-day curing point the modified concrete with the substitutions yielded a 4.66% higher compressive strength compared to the conventional concrete.

3.2 Tensile Strength

The outcomes of tensile strength assessments conducted at curing periods of 14 and 28 days are provided in Table 3 and Figure 2. These assessments were conducted on cubical specimens made from conventional concrete as well as modified concrete mixture in which 15% of the cement was substituted with rice husk ash (RHA) and all the aggregates were replaced with recycled materials.

Table 3: Results of tensile strength examinations conducted on conventional concrete and modified concrete altered with RHA (Rice Husk Ash) and RA (Recycled Aggregates).

Curing Time (Days)	Tensile Strength of Conventional Concrete (MPa)	Tensile Strength of RHA with RA Concrete (MPa)	Increase/Decrease of Tensile Strength than Conventional Concrete (%)
14 Days	2.94	3.13	2.38
28 Days	3.31	3.37	4.66

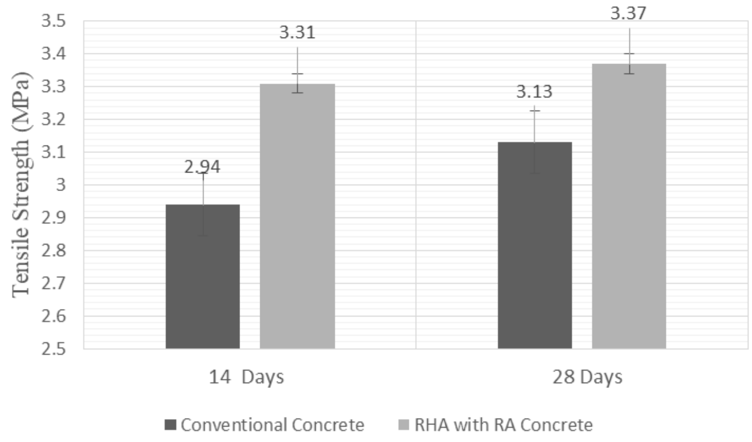

Figure 2: Tensile strength findings for conventional concrete and modified concrete incorporating Rice Husk Ash (RHA) with Recycled Aggregates (RA).

The data presented in Table 3 and Figure 2 show that the modified concrete mixture, which involved substituting 15% of the cement with rice husk ash and completely replacing the aggregates with recycled materials, shows higher tensile strength when compared to conventional concrete at all two curing durations: 14, and 28 days. Specifically, at the 28-day curing days, the modified mixture with the mentioned substitutions yielded a 7.9% greater tensile strength than the conventional concrete.

4. CONCLUSION

The paper presents experimental findings related to the utilization Rice Husk Ash (RHA) in Recycled Aggregate (RA) concrete when compared to conventional concrete. The following conclusion can be drown based on the results obtained in the experiments.

- The workability of the modified mixture which involved replacing 100% of the aggregates with recycled materials and 15% of the cement with rice husk ash is slightly lower when compared to the conventional mixture.

- After a 28-day curing period the modified concrete with 15% replacement of cement with rice husk ash and 100% replacement of aggregates with recycled materials showed a 4.66% higher compressive strength than the conventional concrete.

- At the same 28-day curing point, the modified concrete with 15% cement replacement by rice husk ash and complete substitution of aggregates with recycled materials demonstrated a 7.9% increase in tensile strength compared to the conventional concrete.

- The research findings indicate that substituting 100% of the aggregates with recycled materials and replacing 15% of the cement with rice husk ash leads to substantial enhancements in the mechanical properties of concrete.

- The incorporation of rice husk ash in recycled concrete offers a promising avenue for enhancing its strength and durability. The pozzolanic reaction between the amorphous silica in rice husk ash and the calcium hydroxide produced during cement hydration results in the formation of additional cementitious compounds. This process contributes to the development of a denser and more durable concrete matrix, showcasing the potential of rice husk ash as a valuable supplementary material for sustainable and resilient construction practices.

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