Muhammed Alamgir, S.M. Tariqul Islam, Mahmudul Hasan, N.J. Pollen (Eds.)
ISBN: 978-984-35-7297-4

Full Paper of the WasteSafe 2025 – 9th International Conference on Sustainable Solutions for Waste Management in Developing Countries
22-23 February 2025, Dhaka, Bangladesh

VARIATION OF STRENGTH IN CONCRETE DUE TO EXERTION OF RICE HUSK ASH AS SUBSIDIARY CEMENTITIOUS MATERIAL – A CONCISE REVIEW

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ABSTRACT

"Subsidiary"- the term, is mostly used by 21st century's researchers, scientists, green activists, climate analysts and many. The common reason behind, is the minimization carbon emission or broadly, environment pollution. Now, it will be absurd if all nations put a direct ban on all these carbon emitting industries worldwide! Instead of that, researchers are delivering ideas and plans to mitigate the damage that takes place due to these industries. A fitting example is the cement industries from where a huge amount of carbon dioxide is being emitted regularly. Researchers used Rice Husk Ash, a waste-turned blessing, in some percentage and got quite satisfactory results that helped them abate the use of cement. The review precisely describes the optimum results from some of the prominent research works on the topic and compares the outcomes and discrepancies to provide a brief view to future writers.From the literatures, different percentages of RHA were used in cement and different values of compressive strengths were found. Usually, a drop of compressive strength was seen when RHA was used compared to normal use of cement. But some discrepancies were also seen in some literatures. Here, a graph of highest strengths according to corresponding journals are shown in Fig-1.

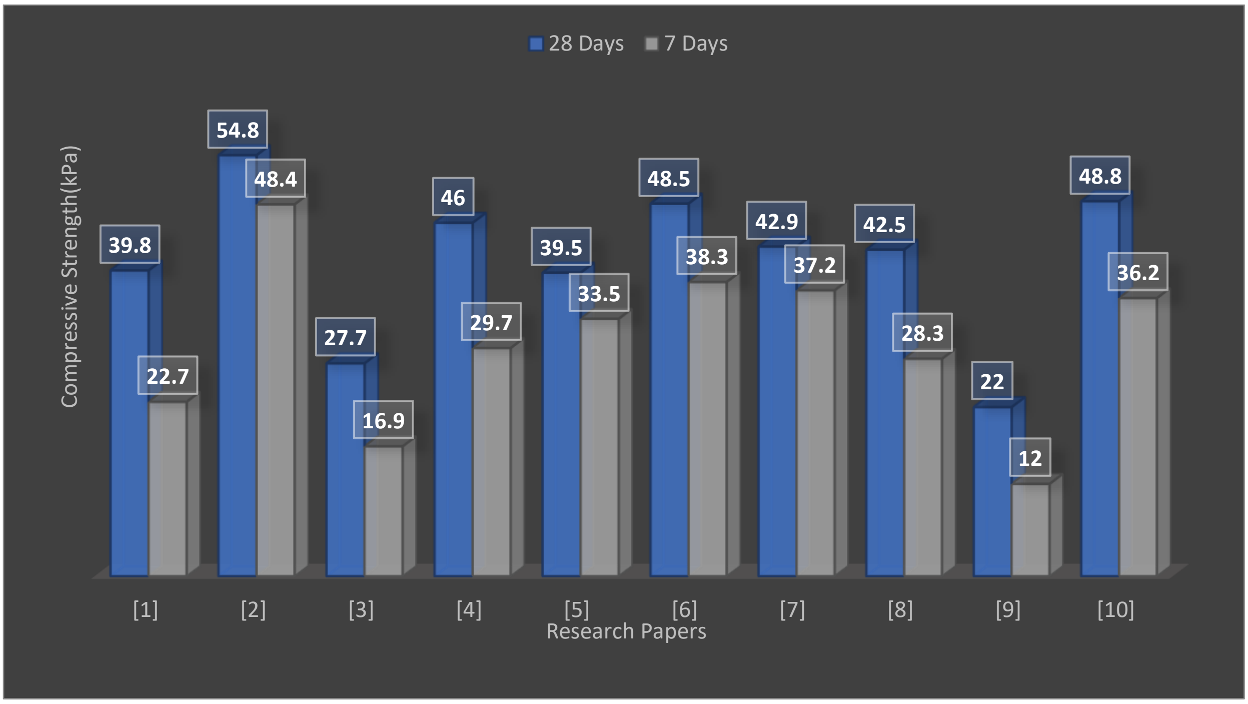

Figure 1 Highest Compressive Strengths vs. Corresponding Journals Graph

Keywords: *Rice Husk Ash, Concrete, Compressive Strength*

INTRODUCTION

Global urbanization and industrialization have brought some serious concerns worldwide although these two terms were expected to bring good only.[12] One of the most concerning issues from an engineering point of view is the demand for construction materials. Demand for construction materials has placed a tremendous strain on natural resources which raises concerns about environmental impacts also. Traditionally, cement is the most widely used construction material for its affordability, durability and versatility.[25] Yet, the use of cement at this much amount makes it one of the largest contributors to global CO_2 emissions.[8] As the demand for concrete continues to grow, the utilization of sustainable construction materials that reduce the dependency on natural resources is getting significant. Consequently, the construction industries are facing intense pressure to adopt more sustainable practices rather than nature harming ones.[31]

In response to this challenge, significant researches have been conducted to fetch subsidiary materials that can replace or at least reduce the wide use of conventional cement. Supplementary cementitious materials (SCMs), derived from industrial by-products and waste materials, have emerged as promising subsidiary cementitious materials.[2] The materials not only are reducing the consumption of natural resources but also are offering environmental benefits which also includes the reduction of was and associated disposal problems. Varieties of SCMs have been developed throughout the world among which Rice Husk Ash (RHA) has garnered considerable attention due to its pozzolanic properties.[10]

Simply, RHA is a byproduct of rice milling that is produced in a large quantity worldwide.[5] After rice husks are burned, they leave behind ash that is rich in silica, making it a suitable material to replace a portion of OPC in concrete.[15] RHA-based concrete also offers a cost-effective alternative, as it lowers material costs while delivering concrete with comparable or even superior performance to traditional concrete mixes.[19]

Researches have shown that RHA can replace up to 25-30% of OPC in concrete mixtures, with optimal performance observed within this replacement range.[24] This review puts emphasis on the optimum percentage of RHA used with concrete that makes it to achieve highest compressive strength. It explores the discrepancies that have been founded by the researchers. Additionally, it addresses how the chemical properties of different cement samples can have effect on compressive strengths of concrete.

OBJECTIVES

1. To provide an overview of physical and chemical properties of RHA to the future researchers.
2. Describing the pozzolanic activity of RHA in simpler form for the coming writers.
3. To brief the variation of strengths from different points of view when RHA is exerted.
4. Allowing the researchers to have pre-conception about the discrepancies of the work.

METHODOLOGY

This paper aims to brief the overall characteristics, properties, exertion, application, advantages and drawbacks of RHA in concrete as subsidiary element. In case of properties, the paper throws an inclusive summary from some of the prominent works with similar foci. Firstly, it provides an average of chemical properties of RHA. Then, it continues to go through physical properties such as bulk density, specific gravity, specific surface area and pozzolanic activity of RHA from quality researches. Finally, the paper advances to its main objective that concisely gives all about the variation of compressive strengths of concrete with different percentages of RHA used. At last, the paper describes the discrepancies the author found from overviewing a bunch of quality literatures and provides the future writers an easier path to work on the topic effectively.

PROPERTIES OF RHA

1.Chemical Properties

Conventionally, RHA consists of high percentage of silicon dioxide that exists in amorphous form. In addition to SiO_2, RHA also contains smaller quantities of calcium oxide, aluminum oxide and iron oxide. Here calcium oxide takes its part in binding properties of RHA although excessive amount can lead to detrimental expansion of concrete.[16] Aluminum oxide effectively helps in the formation of aluminosilicate hydrates and enhances strength and lastly, iron oxide contributes to concrete's overall composition and influences on coloration of the concrete.[4]

The trace elements in RHA, including potassium oxide (K_2O) and sodium oxide (Na_2O), can have a mixed impact on its applications. These alkali oxides may cause adverse reactions, such as alkali-silica reactions (ASR), when used in concrete with reactive aggregates. Sulfur oxides (SO_x), present in smaller amounts, can also influence binding properties, while magnesium oxide (MgO) contributes to the overall chemical profile with minimal impact on reactivity.[17]

Another critical factor in the characterization of RHA is its loss on ignition (LOI), which measures the weight loss when the material is subjected to high temperatures. LOI is primarily an indicator of unburned carbon or residual organic matter in the ash.[11] A high LOI value typically reflects incomplete combustion during the production process, which can reduce RHA's effectiveness as a pozzolanic material.[15] The unburned carbon interferes with hydration reactions, decreasing its overall reactivity. To maximize the quality and performance of RHA, it is essential to control the incineration process and minimize the LOI.[18] These chemical properties collectively determine the suitability of RHA for various industrial applications, especially in the construction sector.

However, numerous research has revealed that the amorphous nature of RHA is suitable to develop high strength in concrete. On the other hand, crystalline RHA groups have shown higher mechanical strength than the amorphous one with higher strength area because of crystal networks of RHA particles that provides high stiffness in concrete matrix.[10] Thus, basic chemical composition of RHA from various researches is shown to get a broader idea of the constituents.

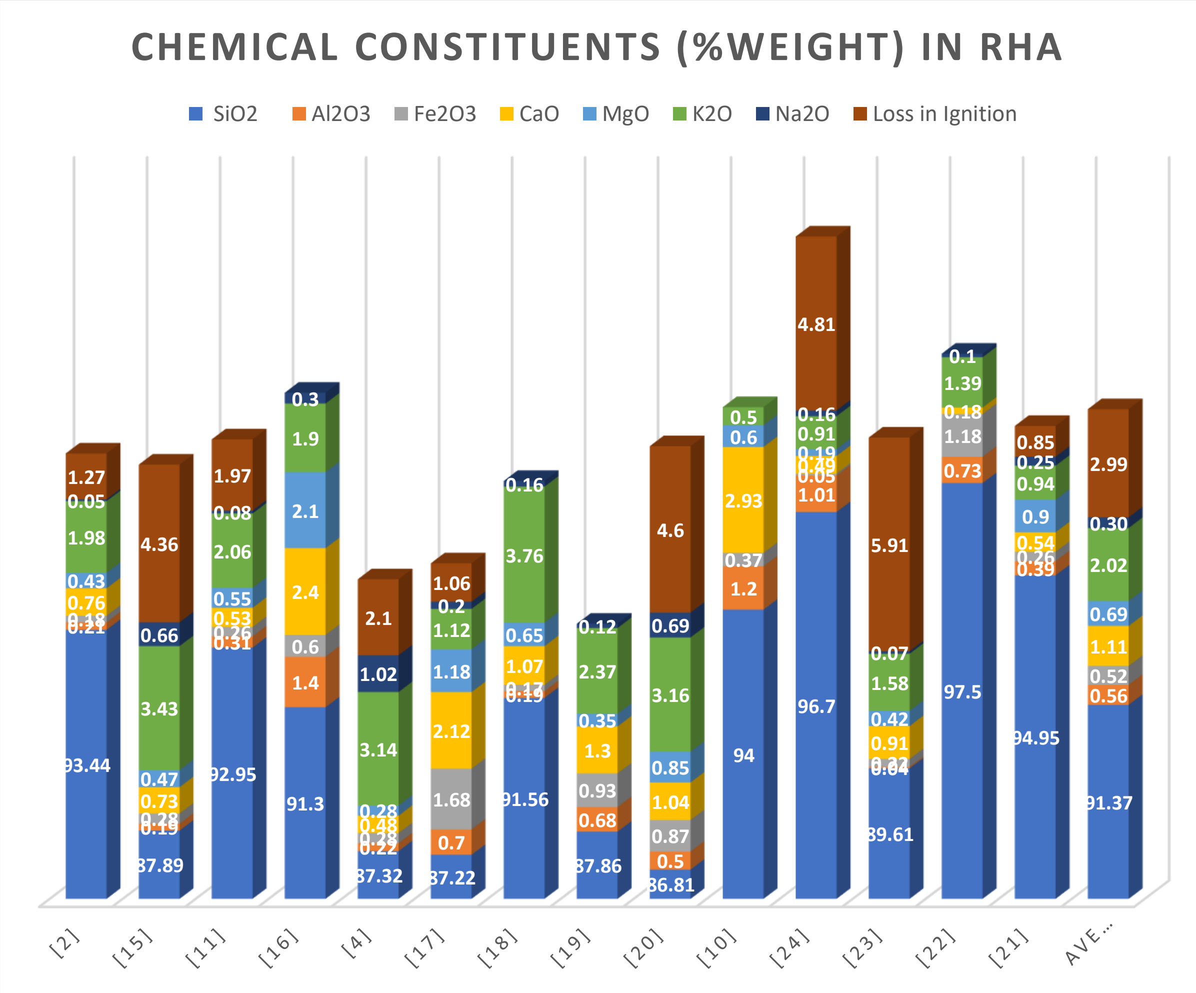

Figure 2 Constituents (%weight) in RHA from different literatures and average

2. Physical Properties

Coming to the physical properties of Rice Husk Ash, these depend on its production process, particle size and structure. In case of its application as such subsidiary cementitious material, the properties play a crucial role in determining the effectiveness of the blended concrete.

2.1. Particle Size and Fineness

RHA is typically composed of fine particles with a high specific surface area, which increases its reactivity when used in concrete.[21] The particle size depends on the grinding and milling processes, and finer RHA particles are more effective as a pozzolanic material. Studies suggest that higher fineness improves the material's binding and pozzolanic performance in cementitious systems. [25]

2.2. Bulk Density

RHA is a lightweight material, with a bulk density typically ranging between 180 and 350 kg/m³.[28] Its low density, attributed to its porous structure, makes it a useful additive in lightweight construction materials. [26]

2.3. Porosity and Specific Surface Area

RHA is highly porous, with a large specific surface area that enhances its water absorption capacity and interaction with cement hydration products. This property improves workability and pozzolanic reactions in concrete mixtures. [25]

2.4. Specific Gravity

The specific gravity of RHA ranges from 2.0 to 2.3, which is lower than that of Portland cement.[2] This lower density makes RHA a desirable material for reducing the overall weight of concrete while maintaining its strength. [27]

Table 1 Physical Properties of RHA from different literatures

Literature	Particle Size(mm)	Specific Gravity	Specific Surface Area(m^2/g)
[21]	11.5-63.8	-	25.3-30.4
[28]	5.7-15.6	-	22.36-25.21
[4]	6.27	2.08	36.47
[2]	39.34	2.24	0.37
[15]	3.80	2.06	36.47
[29]	6	2.1	2.33

3. Pozzolanic Activity

The pozzolanic activity of Rice Husk Ash has been extensively studied, and its effectiveness as a subsidiary cementitious material (SCM) is well-documented in the literatures. Below is a summary of findings from various research studies, along with proper references.

Table 2 Pozzolanic Activity findings summary

Literature	Findings
[30]	Amorphous silica in RHA exhibits high pozzolanic reactivity.
[31]	Finer RHA enhances reactivity and reduces permeability.
[32]	Low-carbon RHA has higher pozzolanic activity.
[33]	RHA outperforms fly ash in early-stage pozzolanic reactions.
[4]	RHA contributes to long-term strength development and durability of concrete.

EFFECT OF RHA IN COMPRESSIVE STRENGTH

Overviewing numerous papers, RHA's effect on the compressive strengths has significantly varied. Typically, it was assumed that the strength of the concrete will lessen when some amount of RHA will be mixed with the concrete. However, it has been found that the strengths get decreased in most of the cases but still get increased in some papers when RHA is used. With that, significant impact is also seen in case of gain in strengths between 7 days and 28 days. Thus, a table on all the perspectives is given below that will explain all the variations in brief.

Table 3 Variation of strengths of concrete from multiple perspectives

Paper No.	Percentage of Rice Husk Ash Used	Highest Compressive Strength		% gained in 21 days	% difference with no RHA used	
		7 Day	**28 Day**		**7 Day**	**28 Day**
[1]	**0%**	**36.5**	**37.8**	**3.56%**	**-37.8%**	**+5.3%**
	15%	**22.7**	**39.8**	**75.33%**		
[2]	**0%**	**55.9**	**65.0**	**16.27%**	**-13.41%**	**-15.69%**
	10%	**48.4**	**54.8**	**13.22%**		
[3]	**0%**	**17.51**	**29.15**	**66.47%**	**-3.48%**	**-4.97%**
	5%	**16.9**	**27.7**	**63.90%**		

[4]	0%	27.2	38.3	40.80%	+9.19%	+20.1%
	20%	29.7	46	54.88%		
[7]	0%	32.8	48.5	47.86%	+13.41%	-11.54%
	20%	37.2	42.9	15.32%		
[8]	0%	27.8	41.70	50%	+1.79%	+1.92%
	7.5%	28.3	42.5	50.17%		
[10]	0%	29.0	36.7	26.55%	+24.82%	+32.97%
	15%	36.2	48.8	34.8%		
[11]	0%	27.22	36.45	33.9%	+21.56%	+8.5%
	25%	33.09	39.55	19.52%		
[12]	0%	20.58	30.3	47.23%	-6.22%	+3.96%
	5%	19.3	31.5	63.21%		
[13]	0%	23.8	32.1	34.88%	+3.78%	+11.52%
	10%	24.7	35.8	44.94%		
[14]	0%	48.31	59.37	22.89%	-13.06%	-5.0%
	5%	42.0	56.40	34.28%		

RESULTS & DISCUSSIONS

As the main objective of the literature was to provide the variation of strength of concrete when RHA used, Table-3 describes it all. In the table, compressive strengths of concrete are mentioned when no RHA was used (0% RHA) which can be stated as the normal OPC concrete strengths. Then it advances to strengths when different percentages of RHA were used (Highest strengths from the literatures). Not to mention, both the strengths of 7 days and 28 days were emphasized as these describe the overall condition of the concrete. The table has mentioned the variation of compressive strengths in two categories.

- Percent of strength gained in 21 Days (between 7 and 28 days) for both type of concretes (when no RHA was used and when RHA was used)
- Percent difference of RHA mixed concrete with respect to non-RHA mixed concrete for after both 7 Days and 28 Days

For 1st category, in some of the cases, strengths do not have mentionable gain in 21 days. Though literature no. 1, 3, 4, 8, 12 (Blue Marked) shows anomalous results having significantly increase of strengths in 21 days.
For 2nd category, in most of the cases, strengths have decreased for both 7 days and 28 days or somewhat increased. Such papers are 1, 2, 3, 7, 12, 14. Mentionable scenarios have been seen for paper no. 4, 8, 10, 11, 13 (Green Marked) where a significant gain in strengths have been seen with the use of RHA.

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