EXPERIMENTAL ASSESSMENT OF UNPROCESSED RICE HUSK ASH EFFECTS ON CONCRETE CHARACTERISTICS

Junaid Bashir Khan[1], Jagbir Singh[2], Yuvraj Singh[3]

[1]M.Tech (Structural Engineering), GNDEC Ludhiana, Punjab, India
[2]Professor and Head, Dept. Of Civil Engineering, GNDEC Ludhiana, Punjab, India
[3] Assistant Professor, Dept. Of Civil Engineering, GNDEC Ludhiana, Punjab, India

***

Abstract - *The manufacturing of concrete is of paramount importance in the construction sector, yet it is accompanied by significant environmental challenges. The extraction and processing of traditional cement constituents such as limestone and clay have a considerable impact on finite resources due to their widespread use. Moreover, the chemical reactions inherent in cement production result in substantial emissions of carbon dioxide, a prominent greenhouse gas responsible for climate change and global warming. This study aims to address these environmental concerns associated with conventional cement production by investigating the viability of incorporating Unprocessed Rice Husk Ash (UPRHA) as a partial substitute for cement in concrete formulations. The research explores various concrete properties, including workability, compressive strength, split tensile strength, and water absorption, to assess the feasibility of utilizing unprocessed RHA. A comprehensive comparative analysis was undertaken, involving different substitution levels of unprocessed RHA, ranging from 10% to 30% of the cement's weight. The findings reveal that the inclusion of unprocessed rice husk ash resulted in a reduction in the workability of the concrete. Furthermore, it was observed that unprocessed RHA had a more pronounced adverse effect on the overall properties of the concrete.*

***Key Words*: Unprocessed Rice Husk Ash, M20 Grade Concrete, Compressive Strength, Split Tensile Strength, Water Absorption**

1. INTRODUCTION

The conventional process of producing concrete is associated with significant utilization of natural resources and subsequent energy consumption, resulting in various environmental challenges. Notably, the production of 1 kg of aggregate is linked to an approximate emission of 0.012 kg CO_2-eq, while the production of 1 kg of cement contributes to approximately 981 kg CO_2-eq (de Brito and Kurda, 2020). The enormous global demand for aggregate and cement is evident, with approximately 48.3 billion tonnes and 4.1 billion tonnes utilized in 2018, respectively (de Brito and Kurda, 2020). Efforts to mitigate the environmental impact of concrete production have prompted research endeavours directed at creating more environmentally friendly concrete using waste materials and minimizing energy consumption. Consequently, researchers have explored the integration of supplementary cementitious materials as alternatives to Ordinary Portland Cement (OPC) in concrete production (Juenger and Siddique, 2015; Qin et al., 2019). This strategic shift towards incorporating supplementary cementitious materials aims to reduce the reliance on OPC and its associated high carbon footprint. Rice husk ash (RHA) presents itself as a promising supplementary cementitious material, offering an alternative to Ordinary Portland Cement (OPC) in concrete production. Notably, RHA is generated through the combustion of rice husks, often during biomass energy generation, a practice prevalent in rice-producing nations. A significant amount of RHA, however, is disposed of in landfills, lacking value addition. Recognizing this potential waste, researchers have extensively investigated the utilization of RHA in concrete production as a supplementary cementitious material. The characteristics of RHA, both chemical and physical, exhibit variability due to factors such as the rice husk type, combustion rate, and fineness of the ash particles (Bui et al., 2005; Ganesan et al., 2008; Nair et al., 2008). Notably, optimal conditions, such as controlled scalding, can yield highly reactive RHA, with amorphous silica content ranging from 85% to 95% (Cordeiro et al., 2009; Darsanasiri et al., 2018; Tharshika et al., 2019). Achieving such conditions is challenging, as precise control over burning temperatures during biomass energy generation is complex. RHA produced under uncontrolled burning conditions might have relatively higher carbon content and lower pozzolanic reactivity. To enhance the reactivity of RHA, a common approach involves grinding the ash to achieve finer particles, thereby increasing its effectiveness (Chao-Lung et al., 2011; Venkatanarayannan and Rangraju, 2015). However, it's important to note that this refinement process necessitates additional energy consumption and incurs supplementary costs in the production of concrete incorporating RHA. Hence, the direct utilization of unprocessed rice husk ash (UPRHA) as a cementitious material in concrete demands a comprehensive and systematic investigation. Therefore, the primary objective of this study was to assess the influence of incorporating unprocessed rice husk ash (RHA) on various essential properties of concrete, spanning its fresh, hardened, and durability aspects. These properties encompassed parameters such as workability, compressive strength, split tensile strength, and water absorption. The investigation aimed to determine the viability of utilizing rice husk ash in concrete as a direct substitute for cement, without any prior processing.

2 EXPERMENTAL PROGRAMME

The subsequent sections encompass the elucidation of the characterization process undertaken for the constituent materials employed in the concrete mixes, the adopted mix designs, as well as the delineation of the procedures employed for testing both the fresh and hardened properties of the concrete.

2.1 MATERIALS USED

2.1.1 CEMENT

The research employed 43-grade Ordinary Portland cement (OPC), namely UltraTech OPC 43, in strict accordance with the IS: 269-2015 standards. Procured from a local supplier in Ludhiana, Punjab, the cement underwent a thorough evaluation of its physical attributes, revealing Consistency 30%, Fineness (Retained on 90 µm Sieve) 3.2%, Initial setting time 120 min, final setting time 223 min, and specific gravity 3.13. It is noteworthy that utmost consistency and uniformity were maintained by sourcing all cement bags from a single batch for the study.

Fig -1: OPC 43 Cement

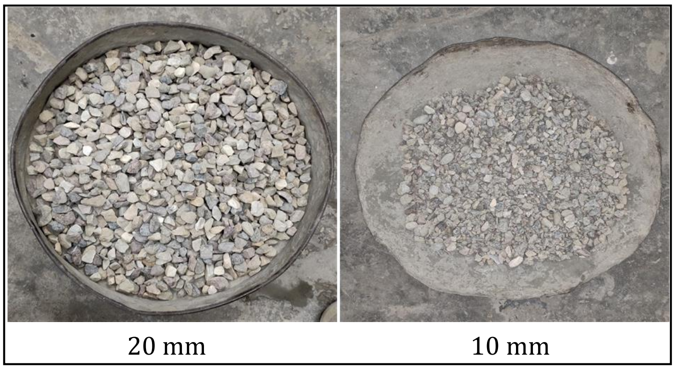
2.1.2 FINE AGGREGATE

All aggregates employed in this study were locally sourced from Ludhiana, Punjab. For the fine aggregates, natural sand adhering to the specifications of IS 383 (2016) and categorized as Zone II was selected. The pertinent physical attributes of the fine aggregates, encompassing parameters such as fineness modulus, specific gravity, and water absorption, were methodically ascertained through appropriate testing procedures. The values obtained for this aggregate batch were 2.61 for fineness modulus, 2.55 for specific gravity, and 1.07% for water absorption.

Fig -2: Fine Aggregate

2.1.3 COARSE AGGREGATES

For coarse aggregates, crushed stone adhering to the specifications outlined in IS 383 (2016) was specifically selected. This choice encompassed a blend of 20 mm and 10 mm sizes, orchestrated at a mass ratio of 60% and 40%, correspondingly. This particular proportion was strategically chosen to optimize the pore structure of the concrete in its hardened state. The practice of incorporating a mixture of 20 mm and 10 mm crushed stone stands as a conventional approach embraced by contemporary practitioners, as it has demonstrated the capacity to yield concrete with enhanced performance characteristics. The specific attributes of the coarse aggregates were as follows: the fineness modulus of the 20mm coarse aggregate measured at 6.98, the specific gravity at 2.72, and the water absorption at 0.70%. For the 10 mm coarse aggregates, the corresponding values were reported as 6.44 for fineness modulus, 2.65 for specific gravity, and 0.84% for water absorption.



20 mm 10 mm

Fig -3: Coarse Aggregates

2.1.4 RICE HUSK ASH

The ash utilized in this study was sourced from "Mohanlal Thapar & Bros." located in Ludhiana, Punjab. The rice husk ash, obtained directly from the rice mill following combustion, was incorporated into the concrete without any subsequent treatment. The rice husks were incinerated at temperatures around 500–600°C, a standard practice for boiler heating in rice mills, resulting in unprocessed rice husk ash (UPRHA) as a by-product. No further refinement was applied to the UPRHA. In its natural state, raw rice husk ash comprises coarser particles with a comparatively lower surface area. The visual representation of unprocessed RHA is depicted in Fig. 4.

Fig -4: Unprocessed Rice Husk Ash

For a comprehensive understanding of the physical attributes and chemical composition of the RHA samples, Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS) analyses were conducted at "SAI Labs Thapar University, Patiala, Punjab, India". The results are meticulously documented in tabular form. The SEM image, magnified to x150, distinctly illustrates the irregular shape of RHA particles. The particle size distribution characterization involved measurements extracted from various locations on the SEM images of UPRHA, presented in Fig. 5, utilizing AxioVision Software.

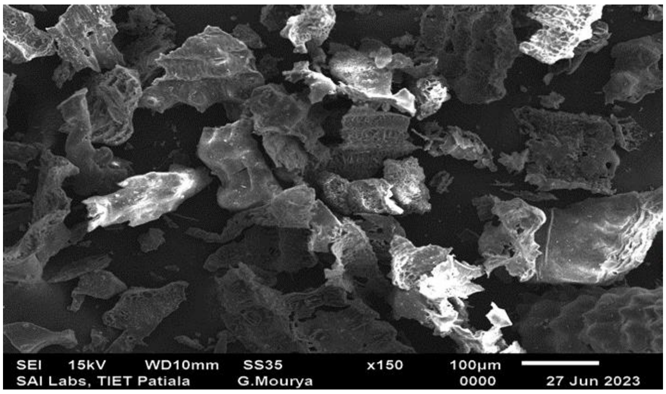


Fig -5: SEM Image of UPRHA

The SEM investigations unveiled that UPRHA possesses an angular and micro-porous structure with a diverse range of particle sizes and multilayers. The analysis further indicated that the particle size of unprocessed rice husk ash (UPRHA) spans from 60.95 µm to 201.86 µm, with a mean size of 110.90 µm. The physical characteristics of UPRHA are summarized in Table 1.

Table-1: Physical Characteristics of UPRHA

Property	Observation
Colour	Black
Mean Particle Size (µm)	110.90
Loss On Ignition (Mass %)	3.59
Specific Gravity	1.42
Fineness (90 µm Sieve)	78.10%

Additionally, Energy-Dispersive X-ray Spectroscopy (EDS) was employed for elemental analysis, a pivotal technique to discern the chemical elements present within Unprocessed Rice Husk Ash (UPRHA). EDS reports for UPRHA, depicted in Fig.6, visually depict the elemental composition of the material.

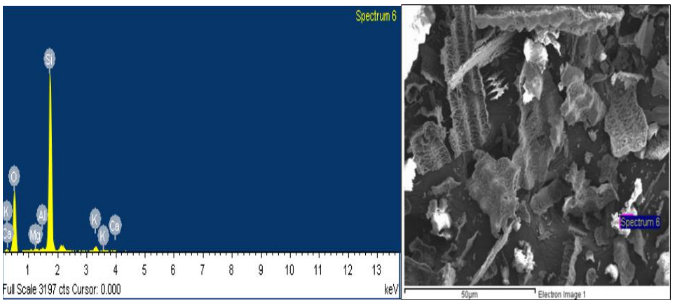


Fig -6: EDS Image of UPRHA

The acquired data from these analyses has been methodically compiled and presented in Table 2, offering a comprehensive breakdown of the identified elements and their respective concentrations in UPRHA.

Table-2: Chemical Properties of UPRHA

Property	Observation (%Mass)
Silicon dioxide (SiO_2)	45.80
Potassium oxide (K_2O)	8.96
Calcium oxide (CaO)	2.20
Ferric oxide (FeO)	1.01
Magnesium oxide (MgO)	0.35
Aluminum oxide (Al_2O_3)	0.31
Sodium oxide (Na_2O)	0.05

2.2 MIX DESIGN

The research conducted herein was centered around the utilization of M20-grade concrete. Adhering to the guidelines stipulated in IS:10262-2019, the concrete mix proportions were upheld at a ratio of 1:1.9:3.21 by weight, accompanied by a water-to-cement ratio of 0.54. Unprocessed Rice Husk Ash (UPRHA) was introduced as partial replacement for cement at varying proportions of 10%, 20%, and 30% by weight respectively. Essential tests were subsequently conducted to ascertain the optimum replacement percentages for UPRHA. This research work utilized a total of four different mixes, and you can find the specific details of each mix in the provided Table 3.

Table-3: Concrete Mix Proportion

Mix Name	Cement (kg/m³)	Fine Agg. (kg/m³)	Coarse Agg. (kg/m³)	UPRHA (kg/m³)	Water (L/m³)
RC	355	678.00	1140.00	0.00	192.00
UPRHA10	319.50	678.00	1140.00	35.50	192.00
UPRHA20	284.00	678.00	1140.00	71.00	192.00
UPRHA30	248.50	678.00	1140.00	106.50	192.00

2.3 TESTING METHODOLOGY

The workability of the concrete was evaluated through the slump test, conducted in accordance with the specifications stipulated in IS:1199 (Part 2):2018. This widely recognized industry standard provides a comprehensive framework for assessing concrete workability.

To determine the compressive strength of concrete specimens, the testing protocol outlined in IS 516 (Part 1/Sec 1):2021 was meticulously followed. The tests were executed using a HEICO automatic electric Compression Testing machine with a maximum capacity of 3000 kN. Precise recording of the peak load was ensured, applying a uniform loading rate until the peak load was achieved. The specimens, cubic in shape, measured 150mm x 150mm x 150mm. Tests were conducted at two distinct curing durations, namely 7 and 28 days.

Tensile strength, a critical indicator of concrete's resistance to tensile forces, was evaluated following IS 516 (Part 1/Sec 1):2021 standards. Cylindrical concrete specimens measuring 150 mm x 300 mm were tested after 28 days of curing, utilizing a high-precision Compression Testing Machine by HEICO, boasting a capacity of 3000 kN.

To assess the water absorption capacity of concrete, pivotal for gauging its resistance to environmental degradation, the water absorption test followed the guidelines of ASTM C642 (2013). This involved testing three 150 mm x 150 mm cubes from each concrete mix after 28 days of curing. The aim of this test was to comprehensively understand the concrete's ability to absorb water.

3. RESULTS AND DISCUSSION

3.1 WORKABILTY

In order to investigate the impact of Unprocessed Rice Husk Ash (UPRHA) on concrete workability, a slump cone test was performed according to the specifications detailed in IS:1199 (Part 2):2018. The outcomes of this test, depicting variations in slump measurements across different UPRHA concrete mixes, are documented in Table 4. To enhance clarity and enable thorough examination, these results have also been visually represented in graphical format in Fig. 6.

Table-4: Slump Value of UPRHA

MIX	RC	UPRHA10	UPRHA20	UPRHA30
Slump(mm)	85	60	45	20

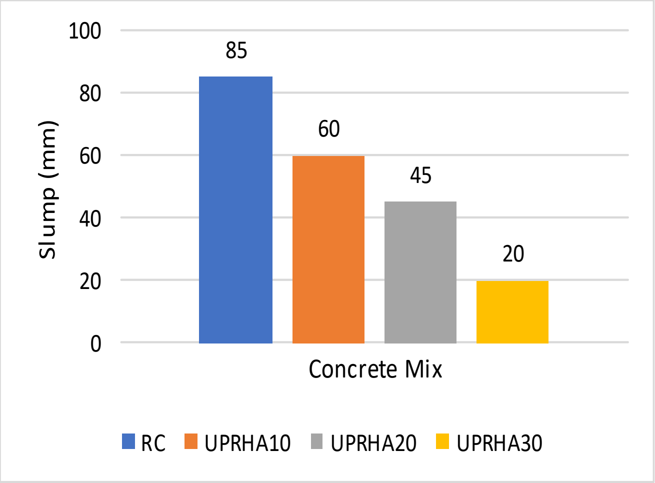


Fig -6: Slump Value of UPRHA

The research outcomes consistently demonstrated a decline in the slump value as the proportion of cement replacement with RHA increased. The reduction in slump value can be attributed to several factors inherent to Unprocessed Rice Husk Ash (UPRHA): Unprocessed RHA contains a substantial proportion of unburned husk fragments, which impairs workability. These fragments introduce internal voids, disrupting the cohesiveness and flow of the concrete matrix, thereby diminishing its workability. Characterized by irregular shapes and larger sizes compared to processed RHA, UPRHA particles hinder particle packing and elevate water demand. Consequently, the observed decrease in workability, as indicated by the slump value, can be attributed to these factors.

3.2 COMPRESSIVE STRENGTH

Concrete cubes containing different proportions of UPRHA were subjected to compressive strength testing. The obtained strength values for UPRHA-incorporated concrete after 7 days and 28 days of water curing are compiled in Table 5. Furthermore, a comparative assessment was conducted between the strength outcomes of UPRHA-blended concrete at 7 days and 28 days, visually represented in Fig. 6.

Table-5: Compressive Strength of UPRHA Concrete

Name of Mix	7 Days		28 Days	
	Compressive Strength (MPa)	Average Strength (MPa)	Compressive Strength (MPa)	Average Strength (MPa)
RC	16.5 18.5 19.0	18.0	26.0 28.0 28.5	27.5
UPRHA10	15.5 15.5 15.5	15.5	24.0 25.0 24.5	24.5
UPRHA20	13.5 13.0 13.0	13.0	19.5 19.5 20.0	19.5
UPRHA30	7.0 7.0 6.5	7.0	16.0 16.5 16.5	16.5

Upon scrutinizing the correlation between curing duration and the efficacy of concrete mixtures, a number of significant insights have surfaced. Principally, a conspicuous pattern has emerged indicating that the compressive strength of concrete undergoes a reduction with escalating proportions of Unprocessed Rice Husk Ash (UPRHA) replacement. This decrement can be ascribed to multiple intrinsic factors associated with UPRHA. UPRHA generally lacks the effective pozzolanic properties required for optimal cementitious reactions. Consequently, the formation of additional hydration products crucial for enhancing interparticle bonding is constrained. This deficiency in pozzolanic reactivity notably compromises the overall concrete strength. Additionally, UPRHA particles' irregular shapes and larger sizes hinder the achievement of proper particle packing. This leads to a greater number of voids within the concrete matrix, directly impacting density and causing a reduction in compressive strength. Furthermore, the suboptimal fineness of URHA particles limits their capacity to serve as efficient fillers within the concrete matrix. As a result, increased porosity ensues, leading to reduced compressive strength due to inadequate particle packing.

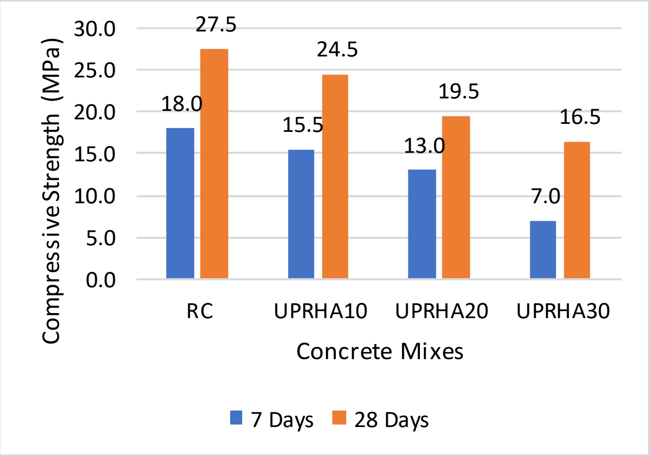


Fig -6: Compressive Strength of UPRHA Concrete

3.3 SPLIT TENSILE STRENGTH

Concrete cylinders, incorporating varying proportions of UPRHA, underwent split tensile strength testing. The resultant strength values for UPRHA-blended concrete following 28 days of water curing are summarized in Table 6. Additionally, these outcomes are graphically depicted in Fig. 7 for enhanced visualization.

Table-6: Split Tensile Strength of UPRHA Concrete

Name of Mix	Split Tensile Strength (MPa)	Average Strength (MPa)
RC	2.40 2.35 2.40	2.40
UPRHA10	1.95 1.95 2.15	2.00
UPRHA20	1.80 1.75 1.75	1.75
UPRHA30	1.65 1.50 1.60	1.60

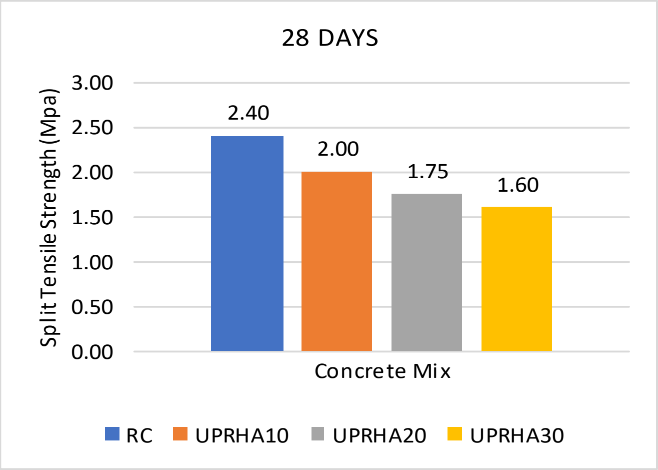


Fig -7: Split Tensile Strength of UPRHA Concrete

Emanating from the findings presented in Table 4.6, it was deduced that the split tensile strength of concrete incorporating Unprocessed Rice Husk Ash (UPRHA) mirrors a comparable trend to the compressive strength pattern observed for UPRHA. Across all curing durations, a consistent trend emerged wherein the split tensile strength of concrete exhibited a decline with ascending proportions of Unprocessed Rice Husk Ash (UPRHA) replacement for Ordinary Portland Cement (OPC). Significantly, the most pronounced decrease in split tensile strength was conspicuous at the juncture when the replacement level of OPC by Unprocessed Rice Husk Ash (UPRHA) reached 30%.

3.4 WATER ABSORPTION

The water absorption test was executed on three 150 mm x 150 mm cubes for every concrete mixture subsequent to 28 days of curing. This test served the purpose of assessing the concrete's water absorption capacity, a pivotal determinant influencing its resilience against environmental degradation. The obtained water absorption values for concrete blended with Unprocessed Rice Husk Ash (UPRHA) after 28 days of water curing are concisely presented in Table 7. Furthermore, for improved visual comprehension, these results have been graphically illustrated in Fig. 8.

Table-7: Water Absorption of UPRHA Concrete

Mix Name	Water Absorption (Mass %)	Average Water Absorption (Mass%)
RC	4.59 5.15 4.24	4.66
UPRHA10	4.53 5.10 4.78	4.80
UPRHA20	5.16 5.28 5.05	5.17
UPRHA30	4.96 5.96 4.79	5.24

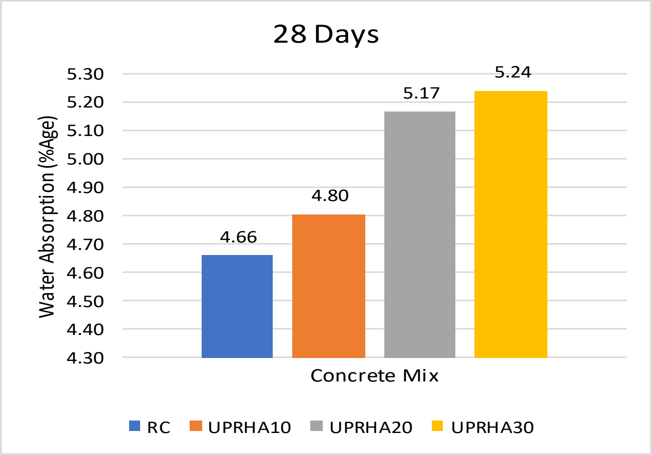


Fig -8: Water Absorption of UPRHA Concrete

In the scenario involving Unprocessed Rice Husk Ash (UPRHA), it was evident that the water absorption of concrete increased proportionally with the escalation of cement replacement by UPRHA. This can be attributed to the coarser particle size and heightened porosity commonly associated with UPRHA, promoting a greater propensity for water absorption. The presence of larger and more porous particles within UPRHA leads to the creation of additional void spaces within the concrete matrix, thereby facilitating the infiltration and absorption of water. Furthermore, the uneven surface texture of UPRHA particles can serve as sites for water absorption, further contributing to the overall heightened water absorption capacity of the concrete.

4. CONCLUSIONS

The study's conclusions, drawn from its comprehensive findings, can be summarized as follows:

i. A consistent reduction in slump value was observed as the proportion of cement replaced by RHA increased. This decrease can be attributed to inherent factors associated with Unprocessed Rice Husk Ash (UPRHA).

ii. Upon a detailed analysis of the relationship between curing duration and concrete mixture efficacy, a notable trend emerged. Specifically, an evident pattern demonstrated that the compressive strength of concrete diminishes with rising levels of Unprocessed Rice Husk Ash (UPRHA) substitution.

iii. In alignment with the study's findings, it was determined that the split tensile strength of concrete containing Unprocessed Rice Husk Ash (UPRHA) mirrors the observed compressive strength trend. This consistent pattern, observed across various curing periods, underscores a decline in split tensile strength with increasing levels of UPRHA replacement for Ordinary Portland Cement (OPC).

iv. The study highlighted that the water absorption of concrete is directly influenced by the extent of cement replacement with Unprocessed Rice Husk Ash (UPRHA), leading to an increase in water absorption as UPRHA content rises.

v. The research findings unequivocally demonstrate that substituting cement with Unprocessed Rice Husk Ash (UPRHA) adversely impacts both the strength and durability of concrete at all curing stages. As such, this practice is deemed unfavorable for cement replacement, bearing significant implications for concrete's overall performance.

REFERENCES

[1] Ahsan, M. B., & Hossain, Z. (2018). Supplemental use of rice husk ash (RHA) as a cementitious material in concrete industry. Construction and Building Materials, 178, 1-9.

[2] ASTM C642 - 13 “Standard Test Method for Density, Absorption, and Voids in Hardened Concrete” (Vol.642). West Conshohocken, PA: ASTM International.

[3] Bie, R. S., Song, X. F., Liu, Q. Q., Ji, X. Y., & Chen, P. (2015). Studies on effects of burning conditions and rice husk ash (RHA) blending amount on the mechanical behavior of cement. Cement and Concrete Composites, 55, 162-168.

[4] BIS 269: 2015 (Reviewed In: 2020) “Ordinary Portland cement - Specification (Sixth Revision)” Bureau of Indian Standards, New Delhi.

[5] BIS 383: 2016 “Coarse and Fine Aggregate for Concrete-Specification” Bureau of Indian Standards, New Delhi.

[6] BIS 456: 2000 (Reviewed In: 2021) “Plain and reinforced concrete - Code of practice (Fourth Revision)” Bureau of Indian Standards, New Delhi.

[7] BIS 516 (Part 1/Sec 1): 2021 “Hardened Concrete methods of test. Part 1 Testing of Strength of Hardened Concrete Section 1 Compressive, Flexural and Split Tensile Strength” Bureau of Indian Standards, New Delhi.

[8] BIS 10262: 2019 “Concrete Mix Proportioning — Guidelines” Bureau of Indian Standards, New Delhi.

[9] BIS 1199 (Part 2): 2018 “Fresh Concrete — Methods of Sampling, Testing and Analysis Part 2 Determination of Consistency of Fresh Concrete” Bureau of Indian Standards, New Delhi.

[10] Bui, D. D., Hu, J., & Stroeven, P. (2005). Particle size effect on the strength of rice husk ash blended gap-graded Portland cement concrete. Cement and concrete composites, 27(3), 357-366.

[11] Chao-Lung, H., Le Anh-Tuan, B., & Chun-Tsun, C. (2011). Effect of rice husk ash on the strength and durability characteristics of concrete. Construction and building materials, 25(9), 3768-3772.

[12] Cordeiro, G. C., Toledo Filho, R. D., & de Moraes Rego Fairbairn, E. (2009). Use of ultrafine rice husk ash with high-carbon content as pozzolan in high performance concrete. Materials and structures, 42, 983-992.

[13] Darsanasiri, A. G. N. D., Matalkah, F., Ramli, S., Al-Jalode, K., Balachandra, A., & Soroushian, P. (2018). Ternary alkali aluminosilicate cement based on rice husk ash, slag and coal fly ash. Journal of Building Engineering, 19, 36-41.

[14] de Brito, J., & Kurda, R. (2021). The past and future of sustainable concrete: A critical review and new strategies on cement-based materials. Journal of Cleaner Production, 281, 123558.

[15] Ganesan, K., Rajagopal, K., & Thangavel, K. (2008). Rice husk ash blended cement: Assessment of optimal level of replacement for strength and permeability properties of concrete. Construction and building materials, 22(8), 1675-1683.

[16] Juenger, M. C., & Siddique, R. (2015). Recent advances in understanding the role of supplementary cementitious materials in concrete. Cement and concrete research, 78, 71-80.

[17] Nair, D. G., Fraaij, A., Klaassen, A. A., & Kentgens, A. P. (2008). A structural investigation relating to the pozzolanic activity of rice husk ashes. Cement and concrete research, 38(6), 861-869.

[18] Padhi, R. S., Patra, R. K., Mukharjee, B. B., & Dey, T. (2018). Influence of incorporation of rice husk ash and coarse recycled concrete aggregates on properties of concrete. Construction and Building Materials, 173, 289-297.

[19] Qin, L., Gao, X., & Li, Q. (2019). Influences of coal fly ash containing ammonium salts on properties of cement

paste. Journal of environmental management, 249, 109374.

[20] Siddique, R., Singh, K., Singh, M., Corinaldesi, V., & Rajor, A. (2016). Properties of bacterial rice husk ash concrete. Construction and Building materials, 121, 112-119.

BIOGRAPHIES

JUNAID BASHIR KHAN
M.TECH (Structural Engineering), Guru Nanak Dev Engineering College Ludhiana, Punjab, INDIA

JAGBIR SINGH
Professor and Head, Department of Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, Punjab, INDIA

YUVRAJ SINGH
Assistant Professor, Department of Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, Punjab, INDIA