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Rice Husk Ash and Marble Powder are used to replace cement in concrete and Investigate the Strength

Narendra Singh

PG Scholar Department of Civil Engineering Mewar University, Gangrar,312901

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ABSTRACT

The rapid urbanization in India has significantly increased the demand for materials used in building construction, especially for high-rise buildings. Traditional brick-making processes have led to environmental and health issues, necessitating the exploration of alternative materials such as aerated concrete. This study focuses on Non-Autoclaved Aerated Concrete (NAAC), a lightweight, porous material known for its high acoustic and thermal insulation properties. NAAC is manufactured using aluminium powder as an air-entraining agent, eliminating the energy-intensive autoclaving process. This research thoroughly examines the properties of NAAC blocks, incorporating rice husk ash (RHA) and marble powder as partial cement replacements. The comprehensive experimental methodology encompasses the material collection, batching, mixing, moulding, curing, and testing for properties such as density, water absorption, compressive strength, and split tensile strength. The results indicate that NAAC blocks with RHA and marble powder exhibit satisfactory water absorption and density performance while providing adequate compressive and tensile strength. The compelling findings from our research strongly indicate that Non-Autoclaved Aerated Concrete (NAAC) blocks have the potential to be a practical and sustainable alternative to traditional bricks in construction. This suggests that the use of NAAC blocks could lead to a significant reduction in environmental impact and improve overall construction efficiency.

Keywords: Aerated Concrete, construction, density, water absorption, compressive strength, and split tensile strength.

1. INTRODUCTION

India is a developing country due to which the rapid urbanization has increased the demand for house construction resulting in the increased demand for construction materials. However, due to space constraints, the demand for high-rise buildings has increased. The increased demand for high-rise buildings has led to an increase in demand for better-performing materials such as high-strength materials, low-density etc. Bricks are widely used as one of the most essential and versatile building materials in construction. Their durability, insulation properties, and availability in various sizes and colours make them a popular choice for building projects around the world.

Additionally, bricks are known for their ability to withstand diverse weather conditions and provide structural support in a wide range of architectural designs. The brick-making process directly or indirectly caused a series of environmental and health problems for the people living near the brick kiln and people working in the kiln. The environmental pollution caused by brick-making operations endangers human health, animals, and plant life. Nowadays aerated concrete is an innovative construction material used in the construction industry 60% to 80% of its volume contains pore space. Properties like strength, durability, toughness, heat transfer and wetness are affected by the pore dimension and microstructure. This porous material will provide high acoustic insulation and thermal insulation functions. However, due to increased pores, the compressive strength of cubes reduces. It is lower weight than the conventional clay bricks with a dry density ranging between 600 kg/m3 to 1600 kg/m3. Based on the method of curing, aerated concrete can be of two types which are autoclaved aerated concrete (AAC) and non-autoclaved aerated concrete (NAAC). In this study, the focus is on non-autoclaved concrete (NAAC) in which water curing of blocks has been done. Non-autoclaved aerated concrete can be created either by using a foaming agent or by an entraining mediator.

In this research, aluminium powder has been used as an air-entraining agent. Various chemical reactions are involved in aerating concrete to make blocks lighter in weight from fresh mortar. The effect of aluminium powder with the hydroxide of calcium and alkali from cement and lime releases hydrogen, which causes bubbles in the mixture. The bubbles enlarge the mixture and concrete augments. Aerated concrete blocks (AC) may be one of the solutions to replace bricks. Aerated concrete is lightweight concrete. Lightweight concrete can be divided into two main types based on the method of curing such as. Autoclaved aerated concrete (AAC) and Non-autoclaved aerated concrete (NAAC). Curing of AAC block undergoes in autoclave whereas in case of NAAC curing of sample is conducted in water. Non-autoclaved aerated concrete (NAAC) has two main benefits one is efficient material usage due to a porous structure and the second one is less energy consumption due to the elimination of autoclaving. The aeration of NAAC is mainly due to the result of the chemical reaction of aluminium with water to produce hydrogen gas, which becomes entrapped in the concrete slurry and forms voids in NAAC. The reaction that will take place is as follows: (Hamad, 2014)

$2Al+3Ca(OH)_2+6H_2O \quad 3CaO.Al_2O_3.6H_2O+3H_2$

Aerated concrete is lightweight compared to ordinary concrete due to the large number of voids present in it. These pores will affect the properties such as strength, durability, density, water absorption etc. in concrete. Porous concrete is a good thermal insulation and acoustic insulation. Since aerated concrete consists of voids it is less dense than traditional concrete and uses less material. Thus, the project goal is to develop a form of concrete block with optimum compressive strength and the elimination of autoclaving.

Nowadays, the demand for construction materials is continuously increasing with the increase in buildings for housing and commercial purposes in both urban and rural areas. The resources used to manufacture large amounts of construction materials have adverse effects on the environment and human health by depleting natural resources, using energy, and creating pollution.

2. METHODOLOGY

The methodology used for producing Non-Autoclaved Aerated Concrete is illustrated in Figure 1. The first step involved collecting all the materials needed for the experimental work. After collecting the materials, batching was performed. Batching is a critical process, as even slight variations can affect the strength of the samples obtained. Following batching, the materials were mixed, and the moulds were filled to the required height. After 24 hours, the demoulding process was carried out, and the samples were taken out for curing. Finally, the cured samples were taken for testing.

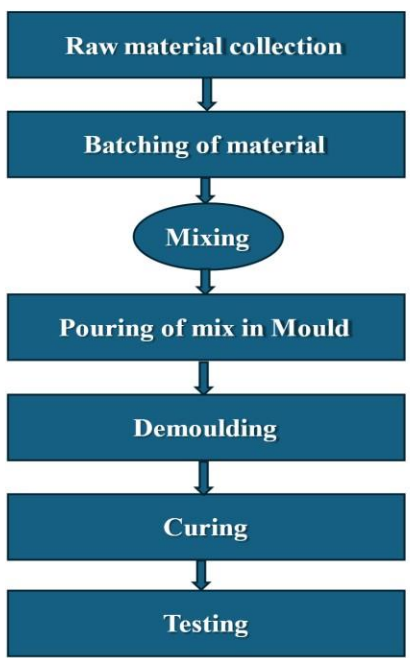

Figure 1: Research Methodology.

3. EXPERIMENTAL WORK

3.1. Material used.

To conduct the experimental work various materials are required such as cement, fine aggregate, and water provided by the university rice husk ash was collected from the locality, and marble powder id collected from the local marble industry of Chittorgarh. Marble powder is available in large quantities because it is a waste product of the marble industry. Utilization of this waste in construction will help to reduce the impact of waste on the environment and prevent contamination of groundwater.

Aluminium Powder: The addition of aluminium powder in concrete helps in increasing strength as well as increasing the volume to make concrete lightweight Aluminium powder has been ordered from the local market. The size of the particles is 250 mesh, and the price is 290/kg.

Cement: The cement used for the experiment was Ordinary Portland Cement (UltraTech) Grade-43. Cement had been collected from the local market. With a specific gravity of 3.11 and a density of 1440kg/m3

Marble powder: Marble powder was taken from the local marble industry.

Rice husk ash: Rice husk ash (RHA) obtained from local sources was naturally incinerated and utilized in the experimental procedure. RHA that had been sieved through a 90-micron mesh was employed as a partial substitute for cement in NAAC.

Fine aggregates: We have conducted a sieve analysis on the fine aggregates used in this experiment. All the fine aggregates have passed through a 4.75mm sieve.

Water: Normal tap water is used for this experiment as per the specification given in IS 456:2000.

3.2. Mix Proportion

All materials are weighed properly as per the requirement of the mixed design. Materials such as Cement, rice husk ash, marble powder and Aluminium powder are properly mixed in dry form. Then water is added to the dry materials and mixed to get a consistent mixture.

Table 1 Mix the proportion of NAAC blocks (RHA)

Sample	Mix proportion	Replacement of cement with RHA (% age)	w/c ratio	Al powder (% age of total dry weight)
S	1:1.5	0%	0.60	-
S_0	1:1.5	0%	0.60	1.5%
S_1	1:1.5	3%	0.61	1.5%
S_2	1:1.5	6%	0.63	1.5%
S_3	1:1.5	9%	0.65	1.5%
S_4	1:1.5	12%	0.67	1.5%
S_5	1:1.5	15%	0.67	1.5%

Table 2 Mix proportion for RHA and marble powder

Sample	Mix proportion	%age of RHA+ Marble powder	w/c ratio	Al powder (%age of total dry material)
S_1	1:1.5	3%+0%	0.61	1.5%
$S_{1.1}$	1:1.5	3%+3%	0.61	1.5%
$S_{1.2}$	1:1.5	3%+6%	0.61	1.5%
$S_{1.3}$	1:1.5	3%+9%	0.61	1.5%
$S_{1.4}$	1:1.5	3%+12%	0.61	1.5%

3.3. Preparing of Moulds

The experimental moulds, each measuring 70.6mm x 70.6mm x 70.6mm, were meticulously prepared for the concrete work. Before assembly, each part of the mould was meticulously cleaned to ensure no residue of hardened concrete or dirt on the inner surfaces. After thorough cleaning, all the parts were assembled and securely tightened to prevent any slurry from leaking out. Furthermore, the inner surface of the mould was carefully oiled before pouring the mix, ensuring that the green cake mixture would not adhere to the surface, allowing for easy removal of the cubes once they had hardened.

Figure 2 Mixing concrete.

3.4. Casting of Specimen

To prepare the specimens, precise amounts of all the ingredients were gathered. The mixing process involved three distinct steps: dry mixing, wet mixing, and combined mixing. During the dry mixing stage, the sand, cement, and rice husk ash/marble powder were meticulously blended. Separately, the aluminium powder was mixed with water. These two mixes were then merged and thoroughly mixed to form a slurry. The slurry was mixed for 2 minutes to ensure the prevention of lumps formation.

3.5. Moulding and Demoulding

Concrete was filled in moulds up to 2/3rd ht. of mould i.e. 47mm for cubes. After 30 min. we could see the formation of bubbles in the specimen which were formed due to the presence of aluminium powder. Two hours later swelling in concrete could be seen and mould was filled. The extra portion was removed at that time only and the specimen was levelled up to the required height. Then the specimen was kept at room temperature for 24 hours. After 24hrs concrete moulds were opened carefully and cubes were removed.

Figure 3 Concrete after filling mould

3.6. Curing

After 24hrs. moulds were opened, and cubes were taken out then each specimen was marked according to its specifications. After marking specimens were dipped in a curing tank for 7 days, 14 days and 28 days of curing. The quality of water in which cubes were dipped was cleaned and free from impurities because the quality of water used for curing also affects the strength of concrete.

3.7. Testing

After curing samples were taken out from the water and kept in a dry place for 3-4 hrs. to remove extra moisture from the specimen. After that samples were ready for testing. Different tests were performed on samples such as compressive strength test, split tensile strength water absorption test etc.

4. RESULTS

4.1. Water Absorption

Water absorption must be calculated to check the percentage of moisture in NAAC blocks. For that, we had to carry out a water absorption test. Max. The permissible limit for water absorption should not be more than 20% as per IS 1077:1992. (BIS, 1992)

Table 3 Water absorption (RHA)

Samples	Water Absorption (%)	Result
S	5.12	Satisfied
S_0	12.8	Satisfied
S_1	13.6	Satisfied
S_2	15.01	Satisfied
S_3	17.2	Satisfied
S_4	19.56	Satisfied
S_5	21.72	Unsatisfied

Table 4 Water absorption (RHA and marble powder)

Samples	Water Absorption (%)	Result
S_1	13.73	Satisfied
$S_{1.1}$	14.32	Satisfied
$S_{1.2}$	15.64	Satisfied
$S_{1.3}$	17.33	Satisfied
$S_{1.4}$	19.72	Satisfied

4.2. Density

Concrete density is a crucial parameter that influences its structural performance, insulation properties, and suitability for different construction applications. The density of Non-Autoclaved Aerated Concrete (NAAC) is significantly lower than that of conventional concrete due to its porous nature, making it a lightweight alternative.

As per IS code IS 2185 (part1): 2005 concrete blocks of grade B have a density between 1100 kg/m^3 and 1500 kg/m^3(BIS:2185, 2005)

Table 5 Density of NAAC (RHA)

Sample	Replacement of cement with RHA	Density (kg/m^3)	Decrease in density (%)
S_0	0%	1961.8	-
S	0%	1443.5	26.25%
S_1	3%	1469.8	25.08%
S_2	6%	1454.4	25.87%
S_3	9%	1441.4	26.53%
S_4	12%	1430.2	27.1%
S_5	15%	1408.4	28.21%

Table 6 Density of NAAC (RHA + marble powder)

Sample	Replacement of cement with RHA+ Marble powder	Density (kg/m^3)	Decrease in density (%)
S_1	3%+0%	1469.8	25.08%
$S_{1.1}$	3%+3%	1475.61	24.8%
$S_{1.2}$	3%+6%	1480.4	24.54%
$S_{1.3}$	3%+9%	1478.2	24.66%
$S_{1.4}$	3%+12%	1475.2	24.81%

4.3. Compressive Strength

The compressive strength of the NAAC block can be determined by taking the maximum load value which is applied to the specimen at the time of testing divided by the cross-sectional area of the specimen. Three specimens of the concrete block were tested and an average of three values was taken. Compressive strength of C-class common burnt clay brick is taken as per IS code i.e. IS 1077:1976 (ANNEXURE III) (No, 1976)

Table 7 Compressive strength of NAAC (RHA)

Sample	Replacement of cement with RHA	Avg. Compressive Strength(N/mm^2)		
		7 days	14 days	28 days
S_0	0%	17.8	19.02	20.43
S	0%	6.43	6.62	8.2
S_1	3%	6.81	7.23	8.42
S_2	6%	6.43	6.91	8.13
S_3	9%	6.21	6.73	7.96
S_4	12%	6.01.	6.5	7.78
S_5	15%	5.87	6.31	7.65

Table 8 Compressive strength of NAAC (RHA+ marble powder)

Sample	Replacement of cement with RHA+ Marble powder	Avg. Compressive Strength(N/mm^2)	
		7 days	28 days
S_1	3%+0%	4.64	5.13
$S_{1.1}$	3%+3%	5.72	5.92
$S_{1.2}$	3%+6%	5.93	6.23
$S_{1.3}$	3%+9%	5.62	5.87
$S_{1.4}$	3%+12%	5.24	5.54

4.4. Split Tensile Strength

Split tensile strength for Non-Autoclaved Aerated Concrete (NAAC) with varying proportions of rice husk ash (RHA) replacing cement reveals important insights into the material's performance. The control sample (S0) exhibited the highest split tensile strength of 1.68 N/mm^2 at 28 days. The introduction of RHA as a partial cement replacement led to a reduction in split tensile strength across all tested samples. The findings suggest that while the inclusion of RHA does decrease the split tensile strength of NAAC, a 3% replacement represents an optimal balance, offering a sustainable alternative with minimal performance loss. Higher percentages of RHA lead to further reductions in tensile strength, which should be considered when designing NAAC for structural applications. These results support the potential for incorporating industrial by-products like RHA into concrete formulations to enhance sustainability in the construction industry. According to IS: 5816:1999 tensile strength is 8% to 12% of the compressive strength.

Table 9 Split tensile strength

Sample	Replacement of cement with RHA	Avg. split tensile strength (N/mm^2)	
		7 days	28 days
S_0	0%	1.53	1.68
S	0%	0.81	0.96
S_1	3%	0.86	0.98
S_2	6%	0.79	0.95
S_3	9%	0.75	0.92
S_4	12%	0.72	0.89
S_5	15%	0.70	0.86

CONCLUSION

It is concluded that as the percentage of RHA increases in NAAC, the water absorption capacity also increases. Similarly, the increase in the percentage of RHA while adding marble powder in NAAC showed only a slight variation in water absorption. The density of lightweight concrete should be between 1100 kg/m3 to 1500 kg/m3 as per IS 2185(part 1):2005, and the results showed that the density of NAAC blocks is within this range. The dry density obtained for NAAC blocks is lower than that of bricks, with the lowest density obtained for sample S4. The optimum value of compressive strength of NAAC with RHA is found for sample S1, which is 8.42N/mm2 (5% Replacement of cement with RHA). The optimum value of compressive strength of NAAC (RHA+ marble powder) is obtained for S1.2, which is 6.93 N/mm2 and lies between the compressive strength of C-class bricks. Lastly, 3% replacement of cement with RHA gave the optimum value of split tensile strength, which is 0.98 N/mm2.

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