Global NEST Journal, Vol 26, No 2, 05432

Utilization of cement power plant beds for aerated concrete thermal blocks

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Received: 10/10/2023, Accepted: 10/12/2023, Available online: 13/01/2024
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https://doi.org/10.30955/gnj.005432

Graphical abstract

Abstract

Nowadays cement industry power plant bed wastes can be used to create aerated concrete blocks for widespread usage in the construction sector instead of sand. The optimum materials for building enclosures for a variety of uses include aerated concretes. To enhance the physical and mechanical qualities of Non-Autoclaved Aerated Concrete (NAAC) blocks, bed material is introduced in this study as a superior alternative material. The non-autoclaved concrete blocks in this study are made with cement, bed materials, fly ash, gypsum, and a consistent amount of 0.65 grams of aluminium powder. The mix preparation and method employed for manufacturing NAAC blocks, the composition of mix specimens and the dosing and mixing processes have been expounded upon, shedding light on the critical steps in the production. According to the suggested method in IS 2185 (Part III) of 1984, the proportion of bed materials was taken by volume of compacted dry material for NAAC of Size 22cm x 10.5cm x 7cm. Experiments into the NAAC block's compressive strength plus water absorption of the bed materials were followed by comparisons of these characteristics with clay and fly ash bricks sold in the market. As a result, NAAC blocks met the 6 MPa strength criteria specified by Indian Standard code IS2185 (Part III): 1984. However, the strength of the aforementioned NAAC brick at 28 days was 7.28 MPa for Sample T5. A more in-depth presentation of the testing methods, focusing on the compressive strength tests was conducted at various intervals (7, 14, 21, and 28 days). The density values and water absorption rates for each test sample (T1 to T5) are now presented with additional insights into the observed trends. According to the research, blocks manufactured with NAAC bed materials tend to be stronger and lighter than those made with conventional clay bricks. They also produce non-autoclaved concrete blocks. Therefore, the creation of such inexpensive blocks can be employed for extensive production.

Keywords: Non-autoclaved aerated concrete, bed material wastes, lightweight concrete, clay brick, cement clinker dust, cement bypass dust and fly ash brick.

1. Introduction

Following the power generation and transportation sectors, the global cement manufacturing sector ranks among the top emitters of greenhouse gases, accounting for 10% of all emissions (Pavlíková *et al.* 2019). The release of a significant proportion of carbon dioxide into the atmosphere, which has been kept in minerals and rock forms of varied origins for billions of years, has an impact on the troposphere's ecological state (Tolstoy *et al.* 2020). Additionally, clinker dust accumulates on industrial building roofs where it hydrates and forms buildups that can cause structures to collapse. Filters catch some of this dust (aspiration), which needs to be disposed of further. Consequently, it is necessary to reduce cement use while utilizing it in the development of building materials. There is a need to entirely recycle the waste from the cement business in addition to reducing cement consumption because cement manufacturing is known to be hazardous to the environment. The goals for reaching this goal were to thoroughly examine the physical and structural features of Non-Autoclaved Aerated Concrete and to assess cement power plant bed material wastes as a unique binder. Wastes from plant beds are characterized by coarse volumetric particles with noticeable cleavage, and it is evident that minerals are present, which ensures good binding capabilities.

The by-products of the cement industry, including carbon dioxide (CO_2), Cement Clinker Dust (CKD), and Cement Bypass Dust (CBPD), can have a severe influence on the environment. The method employed greatly affects how much dust is produced during the manufacturing of cement clinker. A typical cement plant is susceptible to generating 1000 tons of CBPD each day, and it usually varies from 0 to 25% by mass of the clinker. The dust is still maintained in piles even though it has practical uses in many different industries, such as soil stabilization, the construction of concrete mixtures, chemical processing, or the production of ceramics and bricks. This is a problem for the environment; hence efforts are being made to find innovative ways to manage pollution. In this study, CBPD and CKD are used as binder substitutes in non-autoclaved byproducts because CBPD contains a substantial amount of free lime—more than 30%—compared to other binder types. An extremely fine by-product of the manufacturing process of Portland clinker is cement kiln by-pass dust. CBPD is utilized to create binders owing to its high alkali concentration, where it could serve as an activator of elements with latent binding capabilities. For geotechnical soil stabilization, binders made of CBPD, cement, and mineral additives such as limestone granulated blast furnace slag, or fly ash are utilized (Yoobanpot *et al.* 2017; Buczyn´ski and Iwan´ski 2017). It is well-known in the literature that CBPD is employed in the so-called "geopolymers" that produce alkali-activated binders, where the existence of alkali-metal silicate and the heavy concentration of water-soluble acid both aid in the binding process of alumina silicates (Sultan et al. 2018; Heikal et al. 2020). Numerous studies have partially replaced the cement binder in concrete compositions using waste dust (Wojtacha-Rychter *et al.* 2022; Kejkar *et al.* 2020).

Due to its lightweight, Non-Autoclaved Aerated Concrete (NAAC) is commonly utilized as a porous building material for walls, roofs, lower floor walls, and low load-bearing wall structures. NAAC is a lightweight concrete that contains a significant amount of air voids. Approximately 70 percent to 80 percent of air gaps are present in NAAC blocks, which are also easier to drill, nail, cut, and save than lumber (Ulykbanov *et al.* 2019). Contrarily, the NAAC lacks any coarse material, making it highly lightweight and portable between units (Sukmana *et al.* 2019). A mix consisting of cement, quicklime, sand, H_2O, and expansion agents including AL powder is typically used to create NAAC, a low-density, and poor-strength material (Kalpana *et al.* 2020). NAAC possesses several advantageous qualities, including low heat conductivity, fire resistance, strong sound insulation, and water absorption (Chen *et al.* 2017). In general, the main distinction between AAC and NAAC depends on their curing methods (Chica *et al.* 2019), when compared is that non-autoclave-aerated concrete is efficiently produced and there is no requirement for curing using elevated pressure and steam; it will rapidly cure below 80 to 110°C for an interval of 3 to 6 hours, resulting in lower utilization of energy and reduces the enormous costs for manufacturing & is also more advantageous to the economies of the nations which have energy crisis or issues. This research aims to use waste from cement plants' beds to make non-autoclave aerated concrete, which is frequently used in place of siliceous materials like quartz sand since it is readily available in large quantities. However, enhancing economic affordability and environmental sensitivity Reduced use of the primary siliceous raw material sand during processing lowers production costs, and improves the ecological status of the environment.

2. Literature review

The impact of CBPD on mix preparation as a part of the substitution of cement mainly the Portland (PC) for other materials in the production of concrete was examined by (Al-Harthy *et al.* 2003) The findings showed that as bypass dust concentration increased in the tested materials, the total compressive strength dropped in comparison to the control mixture. (Udoeyo *et al.* 2002) validated the considerable reduction of concrete's compressive strength containing CBPD in comparison with the control mix. However, it was noticed from the investigation that a little reduction in compressive strength resulted when 20 percent of PC was substituted with CBPD. According to (Bernal and Provis 2014), a larger supply of raw materials is required to produce geopolymers, which will boost their endurance. Studies on the usage of waste using the cement manufacturing sector as a starting point to produce alkali-activated compounds are few (Kadhim, *et al.* 2020; Abid *et al.* 2021). Based on their investigation, (Aydin *et al.* 2019) determined that a potential alternate driver of CaO for the production of ceramic mural tiles may be cement kiln dust. Clay bricks were effectively coated with CKD dust (Mahrous and Yang 2011). To create pressed construction brick, Abdul Kareem and Eyada employed two varieties of CKD with both cement and sand (Abdulkareem and Eyada 2018). To create unfired construction bricks, (Abdel-Gawwad *et al.* 2021) used CKD with red clay brick waste and silica fume as the primary materials. The addition of CKD as well as CBPD, consequently, has a favorable impact on the qualities of wall materials, as may be inferred from the above. Additionally, as cement by-product dust mostly consists of calcium oxide (CaO), this makes it extremely likely that it may be utilized as an alternative for lime binding agents in materials where lime is one of the primary constituents.

Sand-lime compositions comprising 92 percent quartz sand along with 8 percent lime plus water and autoclaved aerated concrete are two examples of lime-based wall materials (Qu and Zhao 2017) According to (Danish *et al.* 2020) using cement waste to create materials with various forms of hardening can offer a certain degree of self-healing characteristics in use. Chemical reactions that occur within the components of various mixes throughout hydrothermal processing in an autoclave give the finished goods their physical and mechanical characteristics. Crystalline silica, which is generated from quartz sand, interacts with lime in sand-lime products that require a temperature of 170-180°C and an exertion of ten barring to produce energized Ca_2SiO_4, including the fuzzy C-S-H gel formulation and the clear crystals tobermorite (Li *et al.* 2020). As stated by (Vojvodikova *et al.* 2021a; Vojvodikova *et al.* 2021b), The adoption of a quicklime substitute in autoclaved products might result in financial gains throughout every stage of production and have a positive impact on the environment. Investigations for utilizing the least quantities of CBPD containing free CaO contents of less than 10% for the manufacturing of autoclaved materials were done by (Tkaczewska 2019). These mortars had strength measurements of 63.93 MPa and 68.97 MPa, respectively, after 28 days of autoclaving. The surge in compressive strength of the mortar's mixture following autoclaving is the result of the hydrothermal conditioning process, resulting in the development of the C-S-H with a more significant percentage of crystallizing in the structure of fully developed spikes and permitting the cement mortar to attain higher strength.

According to (Danish 2020), clinker dust should be studied and used more thoroughly, along with other manufacturing byproducts such as cenospheres. As a result, efforts are currently being made to adopt alkali-activated composites at two different industrial and experimental levels. These efforts are being undertaken with the aid of mineral fine powders that have the same chemical makeup as clinker dust with artificial origins, and they are still in progress. As a result, there is great potential in the investigation of the structural creation of Alkali-activated products using waste from the manufacture of cement as a base material. The usage of CBPD is restricted according to the patent EP 3 705 462 A1 to an extent of 6-59% of single or multiple quick lime sources. (Temmermans *et al.* 2020). However, no research has been done to definitively determine if CBPD dust can replace lime binders. Additionally, there isn't much data that shows waste dust being used in lime-silica products. Less than 30% of the cement dust utilized up to this point has free CaO in them. According to Deepak Khanal (Deepak Khanal *et al.* 2020), it is difficult to meet the growing demand for construction since many new building materials are discovered to be used in various ways. When compared to brick, which has an average compressive strength of 3.402 N/mm^2 and a density of 1685.8 kg/m^3, the compressive strength of the AAC block was estimated to be 4.324 N/mm^2, despite its low density of 617.6 kg/m^3. The AAC blocks' water absorption, however, was shown to be greater than that of clay bricks. According to (Thakkar and Hardiya, 2020) the majority of studies concentrated on conducting tests on AAC blocks for static as well as dynamic loads, compression results, physical characteristics, framework on plain ground, thermal efficiency, and block with an opening; yet, only a small number of researchers concentrated on the impact of seismic loading with filled AAC blocks and brick infill buildings.

In this study, we have scrutinized the waste generated by the cement industry, and the presented findings underscore the substantial quantities of waste available. These quantities present a viable opportunity for the practical utilization of electrostatic precipitator dust, offering a pragmatic solution to various challenges, encompassing economic considerations and eco-friendly technological hurdles.

The primary objective of this paper is to conduct a comprehensive exploration into the construction of Non-Autoclaved Aerated Concrete (NAAC) using components derived from cement power plant beds, such as cement clinker dust and cement bypass dust. This undertaking necessitated a meticulous characterization of the waste generated during cement manufacturing, positioning it as an innovative binder. Furthermore, an in-depth analysis of the mechanical and physical characteristics of the material was carried out to contribute valuable insights to the field.

3. Materials and methods

3.1. Materials used

Cement, Fly Ash, gypsum, aluminium powder, and water are the primary ingredients employed in this research project to prepare non-autoclaved aerated concrete. Given the cost and economic considerations, we are using fly ash and waste cement plant bed materials as filler agents instead of river sand in the manufacturing process for Non-Autoclaved Aerated Concrete blocks. Other raw materials used in this experimental study included gypsum, aluminium powder, and water.

3.1.1. Ordinary portland cement (OPC)

The most popular cement used in a normal concrete building is called Ordinary Portland Cement (OPC). The definition of cement as a bonding substance with cohesive and adhesive qualities that enable it to bind various building components and create a compacted structure is defined by codal provision IS 269:1989 and IS 383:1970, which is white in color with a density of 1440 kg/m^3 and a compressive strength of 53 MPa as in Figure 1.

Figure 1. Ordinary portland cement (OPC)

3.1.2. Fly ash

One of the naturally formed byproducts of the burning of coal is fly ash, which is almost identical to volcanic ash in composition. In today's cutting-edge power-generating facilities, combustion temperatures for coal exceed over 2800°F. Bottom ash as well as Fly Ash are naturally produced by coal combustion and are composed of noncombustible materials. Fly ash has a density that ranges from 400 to 1800 kg/m^3. It offers sound absorption, thermal insulation, and fire protection. Refer to Figure 2 for powdery Fly Ash. The kind of Fly Ash utilized is Class C, which includes 20% lime and has a maximum loss of ignition of 6%.

3.1.3. Bed materials: Cement bypass dust and cement clinker dust

Cement Bypass Dust (CBPD) was acquired via the Alangulam cement company plant in Virudhunagar District.

Cement bypass dust is an extremely fine powder that ranges in color from off-white to fawn or simply light brown. According to ASTM D854, it possesses a specific gravity of around 2.54. According to research, free lime is the primary ingredient in CBPD, as seen in Figure 3. Since free CaO is so strongly reactive, it interacts with water very quickly. Belite, the clinker phase that forms at the lowest temperature, is the second-largest component (Kurdowski 2014). The potassium chloride is a condensed version of the chlorides found in the CBPD. Calcite and quartz are secondary phases that are formed from basic materials that have not been treated.

Figure 2. Class C fly ash

Figure 3. Cement bypass dust (CBPD)

The physical properties and conventional chemical components of CBPD are shown in Tables 1 and 2. In general, elevated CaO, K_2O, Na_2O, and Cl^- concentrations are indicative of CBPD. Portland cement and CBPD share a lot of the same constituent elements.

Table 1. Physical properties of the cement bypass dust

Physical properties	Range
Grain size [μm]	0.20–15 μm
Specific surface area [cm^2/g]	5480
Density [kg/m^3]	3010

The use of regular Portland cement would pose the same environmental risks as the use of CBPD if any such risks were to exist. In actuality, CBPD would be encapsulated and solidified as a filler substance! The usage of CBPD in such a scenario should not be expected to provide any environmental hazards due to excessive heavy metal concentrations in leachates within the asphalt concrete matrix.

Depending on the location inside the dust collecting system, the kind of execution, the collected dust facility, and the kind of fuel utilized, sections of Cement Kiln Dust (CKD), a fine, powdery substance, may include some reactive calcium oxide. Unreacted raw feed, feed and clinker dust that has partially been calcined, free lime, enhanced concentrations of alkali Sulfates and halides in specific and other volatile chemicals, and free lime are the four main components of CKD. Dark grey and rather abrasive clinker dust comprises a fine powder. The physical appearance of the cement kiln dust is shown in Figure 4. A 23% residue was found after utilizing a No. 008 sieve to measure the degree of grinding. Aspiration dust has a fineness of 18% and is a pale brownish dust that is extra widely dispersed compared to clinker powder. The dust's physical characteristics and chemical makeup are listed in Tables 3 and 4.

Table 2. The chemical composition of the cement bypass dust

Compound	Percentage
Silicon dioxide (SiO_2)	15.84
Calcium oxide (CaO)	63.76
Ferric oxide (Fe_2O_3)	2.76
Potassium oxide (K_2O)	2.99
Titanium dioxide (TiO_2)	0.48
Sulfur trioxide (SO_3)	1.65
Aluminum Oxide (Al_2O_3)	3.57
Sodium oxide (Na_2O)	0.33
Magnesium oxide (MgO)	1.93
Chloride ion (Cl^-)	1.09
Manganese (III) oxide (Mn_2O_3)	0.07
Loss-on-ignition	5.38

Figure 4. Cement Kiln Dust (CKD)

Table 3. Physical properties of the CKD

Physical properties	Range
Actual Density, kg/m^3	3.12
Specific Surface Area, m^2/kg	210
Bulk Density, kg/m^3	1.24

Table 4. Chemical composition of the Cement kiln dust

Compound	Percentage
CaO	71.64
SiO_2	16.89
Al_2O_3	4.11
Fe_2O_3	4.30
K_2O	4.30
MgO	1.49

3.1.4. Aluminium powder

Aluminium acts as an expansion agent. As shown in Figure 5, when the raw material combines via Aluminium powder, air bubbles are generated as a result of a process involving calcium hydroxide, Aluminium, and water.

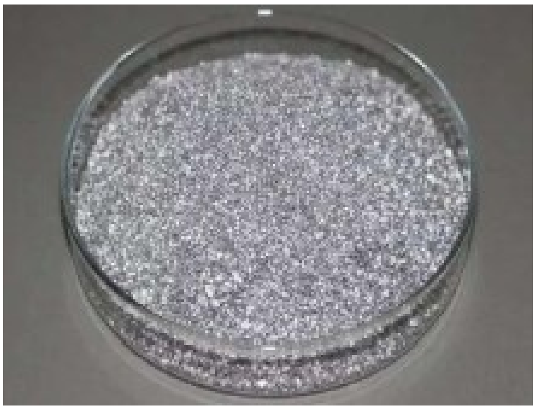


Figure 5. Aluminium powder

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

3.1.5. Gypsum

Gypsum (CaSO42H2O), which is readily accessible on the market, is utilized as a powder.

3.2. Mix preparation and method

Initially, bed materials were taken in accordance with the recommended method employed in IS 2185 (Part III) 1984 by volume, while aluminum powder was weighted with a consistent quantity of 0.65 grams. The raw materials comprised of cement, fly ash, and gypsum are next weighed with an accuracy of +1g. Then, weighted dry materials were added to a bucket and thoroughly mixed.

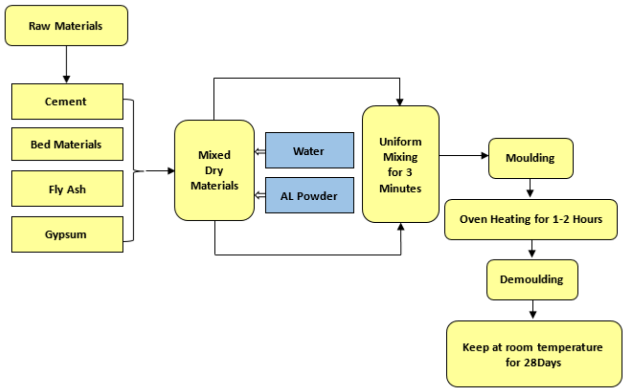


Figure 6. Flow Diagram of the Experimental process

Warm water heated to 60 degrees Celsius was then added, and the mixture was stirred for 2 minutes before the addition of aluminum powder. The final paste was then poured into NAAC molds measuring 22 cm by 10.5 cm by 7 cm, and the molds were lubricated with a hand brush before being filled. After being held at 60 to 70 degrees Celsius for one to two hours in the oven, the samples were taken out and demoulded before being stored at a constant temperature upto 28 days to achieve maximum strength. The flow diagram of the evaluation stages is given in Figure 6.

Table 5. Composition of the mix Specimens (in Percentage)

Test Samples	Portland Cement	Bed Material Wastes	Fly Ash	Gypsum	AL Powder	W/R
T1	25	12	60	3	0.07	0.60
T 2	25	24	48	3	0.07	0.60
T 3	25	36	36	3	0.07	0.60
T 4	25	48	24	3	0.07	0.60
T 5	25	60	12	3	0.07	0.60

Table 5 displays the arrangement of mixed-designed samples. The proportions of cement, gypsum, and aluminum powder remained constant throughout this experiment, however, the ratios of waste bed material and fly ash varied. At room temperature, all tests were carried out. Throughout the experiment, the water ratio (W/R) remained at 0.60.

3.2.1. Dosing and mixing

Following the preparation of the raw materials, addition of dosage and mix preparation are the following stages in the manufacture of NAAC blocks. The final product's quality is determined by the dosing and mixing processes. Keeping the proportions of each ingredient the same: Cement: Bed material waste: Gypsum: Fly Ash = 25:60:12:3, having a water ratio of between 0.60 and 0.65, and aluminum powder making up roughly 0.07% of the mixture's total dry components.

It typically requires up to 5 – 5.5 minutes to mix and pour. The absolute or proportionate mix is created using dosing along with a mixing device to create NAAC blocks. Pumping of fly ash into a container. Once the necessary mass has been put in, the pumping stops. Corresponding to that, individual containers containing gypsum, cement, and Fly Ash are poured using bearers or conveyors. Once the necessary quantity of every single ingredient was successfully put into its corresponding containers, a controller transfers all ingredients into the mixing drum as shown in Figure 7. Additionally, attached as a component of the mixing unit is a smaller bowl-shaped device used for feeding aluminum powder. The slurry is ready to be put into molds using a dosing device once it is thoroughly churned for the required amount of time. This mixture is dispensed into molds by the dosing equipment in predetermined amounts. Continuous dosing and mixing are used because, if there is a pause amid charging and discharging chemicals, the leftover mixture might start to solidify and clog the entire system. The whole dosing and mixing process for the manufacture of NAAC blocks is fully automated and requires very little human involvement.

3.2.2. Casting and curing of mix

When the raw material mix for casting is prepared, it is put into the molds. Molds are available in various sizes based on installed capacity, such as the 22 cm x 10.5 cm x 7 cm mold depicted in Figure 8. Prior to casting, a thin coating of oil is lined up to the molds to refrain the mix from attaching to them. Aluminum combines with calcium oxide and water to produce hydrogen gas when the slurry is blended and put into greased molds. The slurry mix grows as a result of the tiny cells that are created. A threefold increase in volume may result from such expansion. A bubble can be anywhere from 2.5 and 4.5 mm in size. Thus, this clarifies the reason NAAC blocks are light and insulating. Once the process of raising concludes, the mixture is then permitted to set and cure. Normally, the forming and pre-curing procedure takes 60 to 240 minutes. Rising is also impacted by weather patterns and the nature of the raw resources. Pre-curing is hence often referred to as "heating chamber pre-curing." Pre-curing is completed when the mix is sufficiently firm. Concrete that has not been autoclaved is cured in a large pressure vessel referred to as an autoclave. An autoclave usually consists of a steel tube that is three meters in diameter and 45 meters long. Around 180°C of high-pressure steam is fed into the autoclave, and pressures typically vary from 801 to 1200 KPa. Following which blocks are then taken in preparation for the demolding.

(a)

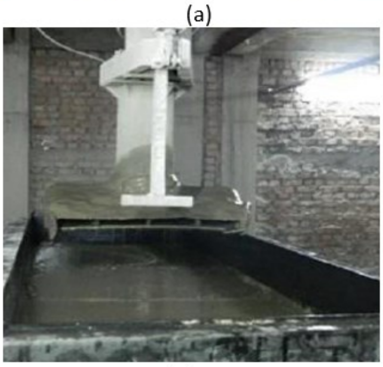
op (b)

Figure 7. (a) System for mix proportion control; and (b) Machine for raw materials mixing

3.2.3. Demoulding

Demoulding is possible only once the mix concrete has reached cutting strength. A mold is moved for the demoulding procedure once it has left the pre-curing room. The demoulding process varies greatly depending on the technology supplier, but all earlier operations, such as required raw material for mix preparation, dosage and mixing, and casting, are essentially the identical procedure throughout every technology. Different mold types required by various technology providers are evidence of differences in demoulding as in Figure 9.

(a)



(b)

Figure 8. (a) Specimen in moulds; and (b) Pouring device

Figure 9. Demoulding

In accordance with IS 2185 (Part III) 1984, bed materials were measured by volume, and aluminum powder was added. Cement, fly ash, and gypsum were then mixed and combined with warm water. After stirring and adding aluminum powder, the resulting paste was poured into lubricated NAAC molds. The molds underwent a curing process in the oven, followed by demolding and storage at a constant temperature for up to 28 days to achieve optimal strength.

4. Testing methods

The article uses waste cement plant bed material to analyze the physical and mechanical characteristics of samples. These tests are required to confirm that the CKD and CBPD dust used in extra binder products is suitable for producing concrete bricks used to construct walls. In accordance with IS 516: 1959, Five blocks of concrete specimens having dimensions of 22 cm x 10.5 cm x 7 cm were evaluated for compressive strength 28 days after curing. For the test, concrete cube samples were utilized, and they were submerged entirely in water. The density and weight of H_2O in the container were calculated, and the specimens were subsequently let to dry at 102°C to a persistent weight. Samples have been weighed in water, with measurement findings recorded to the closest 0.01 g. The resultant dried specimens were weighed after cooling, and the experimental outcome was noted. Equation (1) was utilized to conclude the computations.

$$\rho = \frac{m_d}{V_0} Kg / m^3 \tag{1}$$

Where, m_d is the dry sample weight; V_0 is the sample's volume including pores which is calculated as per Equation (2).

$$V_0 = \frac{m_1 - m_2}{\rho_\omega} \tag{2}$$

Where, m_1 represents the saturated sample weight that is weighed in air per gram; m_2 denotes the saturated sample weight that is weighed in water per gram; ρ_ω is the water density in g/cm^3.

In compliance with the Indian standard IS 1124 (1974), water absorption was determined. Five samples were tested in the experiment. Equation (3) was utilized to determine the water absorption.

$$w = \frac{(m_1 - m_d)}{m_d} \times 100\% \tag{3}$$

Where m_d is the sample's weight after drying, m_1 is the sample's weight after soaking.

5. Results and discussions

5.1. Compression strength test

After 7, 14, 21, and 28 days, respectively, the compressive strength of the finished porous materials was tested by Indian Standard code IS2185 (Part III): 1984, as shown in Figure 10. Following Indian Standard code IS2185 (Part III): 1984, the final sample T5 met the strength requirement of 6 MPa as a result, and after 28 days revealed the maximum compressive strength of 7.28 MPa; in contrast, samples T4 which contained 48% bed material waste and 24% fly ash exhibit the compressive strength of 5.4 MPa. On the other hand, sample T1, which included 60% Fly Ash and 12% bed material waste, had the lowest density of 861.23 kg/cm3 and the lowest compressive strength of 1.8 MPa. According to the data, the compressive strength reaches its peak after 28 days, as demonstrated in Table 6 and shown in Figure 11.

Table 6. Evaluations of the test specimens

Test Samples	Compression Strengths				Density (Kg/m3)
	After 7 Days (MPa)	After 14 Days (MPa)	After 21 Days (MPa)	28 Days (MPa)	
T1	1.8	1.9	2	2.2	861.23
T 2	2.9	3	3.2	3.8	873.97
T 3	4.3	4.6	4.9	5.1	881.79
T 4	5.4	5.6	5.7	5.9	911.39
T 5	6	6.5	7	7.28	915.37

Figure 10. Experimental Setup for Compression Strength Test

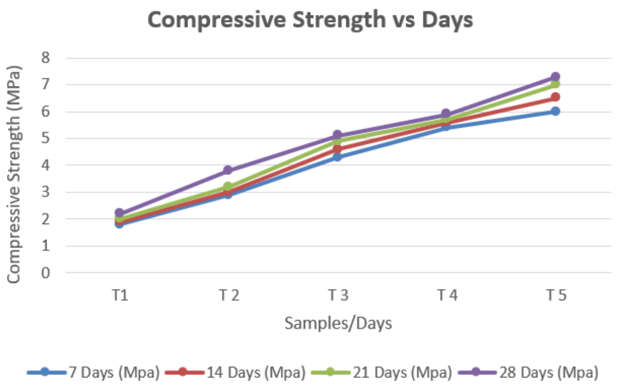


Figure 11. Compression Strength (MPa) vs Samples on 7, 14, 21 and 28 Days

5.2. Impact of compressive strength over density

According to the data, compressive strength and density are inversely related. Sample T5 exhibits the highest density of 915.37 Kg/m^3 and maximum compressive strength, whereas Sample T1 exhibits the lowest density of 861.23 Kg/m^3 and least compressive strength as shown in Figure 12.

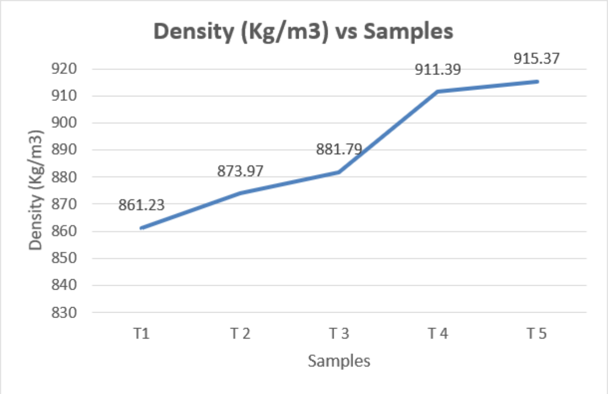


Figure 12. Compression strength vs. density

5.3. Water absorption test

According to Indian standards, IS 2185-3 (1984), the final porous components of the Non-Autoclaved Aerated Concrete blocks were examined for water absorption.

Figure 13 depicts the experimental procedure used to measure water absorption, and Figure 14 displays the water absorption value. Sample T1 exhibits a relatively high-water absorption measurement of 25.6% due to its relatively low density and abundance of air voids, in contrast to sample T5, which displays a water absorption measurement of 18.2%.

Figure 13. Water absorption test

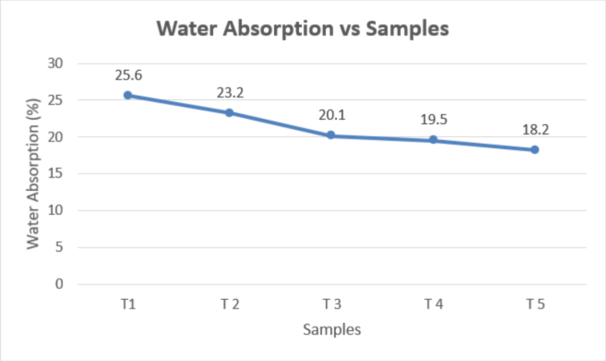


Figure 14. Water absorption of samples

6. Comparison of clay, fly ash, and NAAC concrete bricks

NAAC will have less of an impact on the environment than conventional clay bricks as well as Fly Ash bricks, which will aid in reducing global warming. NAAC is a sustainable construction product with a composition that is similar to foam blocks. Fly ash, a byproduct from power plants is used to make NAAC blocks, a durable, ecologically friendly, and green building material. NAAC blocks may recycle the waste they produce. Red brick production uses raw materials like sand and clay, which affects the environment and depletes resources. The topsoil is removed during the process of making red bricks, wasting the natural clay raw material. NAAC blocks don't contain any topsoil. On the contrary, NAAC blocks are constructed of fly ash, a byproduct of power plants. Concerning the autoclaving recycling process, which lowers CO2 emissions, AAC blocks use less energy. The use of NAAC blocks significantly lowers the cost of transportation. It is cheaper and easier to carry because it is significantly lighter than conventional bricks. The overall dead weight of a building is significantly reduced when NAAC blocks are used, allowing for the establishment of taller buildings. Considering it is extremely lightweight, it reduces a construction's overall bulk. Table 7 provides a thorough market comparison of clay brick, fly ash brick, and NAAC brick.

Table 7. Comparison of clay, fly ash and NAAC bricks

Parameters	Clay Brick	Fly Ash Brick	NAAC Brick
Structural cost	No savings	Minimal savings	Steel savings up to 15%
Breakage or Wastage	More Wastage	Average 11-12%	Less than 5%
Manufacturing speed	Comparatively slow	May delay the time of the set	Speedy construction
Availability	Shortage in Monsoon	On-demand	Anytime
Energy Savings	No savings	10-15% savings	30% reduction
Accuracy as per dimension	90%	95%	99%
Price or Cost	-	Additional cost of chemicals	30% cheaper than red bricks

Our compression strength tests revealed that the composition of Non-Autoclaved Aerated Concrete (NAAC) blocks significantly influences their mechanical properties. Sample T5, with 7% bed material waste and 48% fly ash, displayed the highest compressive strength of 7.28 MPa after 28 days, meeting the required standard. Conversely, Sample T1, with 60% fly ash and 12% bed material waste, exhibited the lowest compressive strength of 1.8 MPa and the lowest density. Water absorption tests further emphasized the impact of composition on NAAC characteristics. The comparison with clay and fly ash bricks highlighted NAAC's environmental benefits, showcasing reduced structural cost, breakage, manufacturing speed, and energy savings. In conclusion, the practical implications of our findings suggest the importance of material selection for enhancing NAAC's mechanical properties and sustainability in construction practices.

7. Conclusion

This paper has elucidated the feasibility of employing fly ash and cement power plant bed material wastes in the production of ultralight Non-Autoclaved Aerated Concrete (NAAC) bricks. NAAC exhibits promising practical applications, particularly in masonry and basic roofing, as demonstrated by the optimal performance of Sample T5, comprising 60% bed material waste and 12% fly ash. Despite falling short of meeting load-bearing structure requirements, NAAC blocks, incorporating bed materials, offer a viable alternative to conventional clay bricks, showcasing superior strength and reduced weight for potential large-scale production. Non-Autoclaved Aerated Concrete (NAAC) blocks have several advantages over conventional Autoclaved Aerated Concrete (AAC), including promoting and lowering the cost of goods. This environmentally conscious approach not only contributes to energy conservation but also holds the potential for substantial environmental benefits. According to the research, blocks manufactured from NAAC bed materials are both stronger and lighter than those formed with conventional clay bricks. Therefore, the manufacture of such inexpensive blocks may be done on a big scale. The utilization of bed material waste in conjunction with fly ash presents a positive stride towards sustainable construction practices, aligning with the broader goal of reducing environmental impact. Overall, our research underscores the significance of adopting NAAC blocks, emphasizing both their practical applications and the environmentally sustainable aspects, thus contributing to advancements in the construction industry.

Acknowledgment

The authors with a deep sense of gratitude would thank the supervisor for his guidance and constant support rendered during this research.

Funding statement

The authors received no specific funding for this study.

Conflicts of interest

The authors declare that they have no conflicts of interest to report regarding the present study.

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