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Strength Analysis of Concrete by Using Aerated Concrete Material

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Abstract- The use of AAC blocks may cut building costs by up to 25%. Because autoclave aerated concrete is lighter than traditional brick, we believe that by using this advantage, we may lower the weight of infill walls on beams, columns, and footings by replacing conventional bricks with AAC blocks while also saving reinforced steel. Because of its light weight and great deformability (low Young modulus in compression), this material tends to lessen inertia forces on the building caused by seismic activity. The masonry compressive strength of AAC, on the other hand, is very low when compared to other conventional masonry types, despite its highly restricted variability. The production method and seismic performance of autoclaved aerated concrete blocks are the subjects of this researchThe purpose of this experimental project is to develop non-autoclave concrete blocks that may be utilized in a range of applications while retaining their compressive strength and other properties. In non-autoclave aerated concrete blocks, materials such as fly ash, cement, lime, gypsum, and aluminium powder as an expansion agent are used. In this study, we examine the compressive strength of non-autoclave concrete cubes that measure 70.6 mm in size and are also 70.6 mm in height. The compressive strength of blocks was determined by varying the amounts of Aluminum powder at 0%, 0.04%, 0.08%, 0.12% and 0.16%.used in the blocks while maintaining all other parameters constant. The results of this experiment demonstrated that when the density of the blocks drops because of an increase in the concentration of aluminium powder in the blocks, the compressive strength of the blocks decreases.

Keywords- Autoclaved aerated concrete (ACC), Aluminium powder, Lightweight concrete, Strength.

I. INTRODUCTION

Since ancient Roman times, lightweight concrete (LWC) has been effectively employed, and its popularity has grown because to its reduced density and higher thermal insulation capabilities. LWC may greatly lower the dead load of structural parts when compared to normal weight concrete (NWC), which makes it particularly appealing in multi-story structures. However, the majority of LWC research has focused on "semi-lightweight" concretes, which are constructed with lightweight coarse aggregate and natural sand. Although commercially produced lightweight fine aggregate has been utilised in studies to replace natural sand in the production of "total light weight" concrete, waste materials may provide significant environmental and economic advantages if they are used to replace the fine lightweight aggregate.

When opposed to conventional concrete or standard concrete, the usage of lightweight concrete in reinforced concrete constructions offers various benefits. Because lightweight concrete has so many benefits and advantages over conventional concrete, it is not used as often as ordinary concrete. The minimal use of lightweight concrete is due to expensive aggregate costs in nations with limited lightweight aggregate supplies, a lack of expertise, and employees' lack of understanding about lightweight concrete.

- **1. Aerated Lightweight Concrete**:

With a wide range of sizes and strengths, aerated concrete may be used in a wide range of applications, including structures that are both lightweight and strong. Blocks of aerated concrete are lighter than red bricks. Aerated concrete blocks are two to three times lighter than regular concrete blocks. Aerated concrete may be classified into two varieties based on the curing method: non-autoclaved aerated concrete (NAAC). The emphasis of this study was on Non Autoclaved Aerated Concrete (NAAC), which involves water curing of blocks. Aerated concrete that is not autoclaved may be made using either a foaming agent or an air entraining agent.

- **2. Non-Autoclave Aerated Concrete blocks:**

Aerated concrete that has not been autoclaved is a lightweight block that may be utilised for load bearing and frame constructions. The strength of non-autoclave concrete blocks is comparable to that of traditional clay bricks used in brick construction. In compared to autoclaved concrete blocks, it consumes less energy. The material is utilised to address an essential requirement in the building sector, namely, to lessen the environmental implications of construction materials. Because they are huge and cover a vast area at one time, they decrease transportation costs and pollutants. They also boost building pace. These blocks offer a great thermal efficiency, decrease noise pollution, and can survive fires and earthquakes (Stefan Schnitzler, October 2006).

The idea of non-autoclaved concrete manufacture is to create a porous microstructure in the concrete mix. This may be accomplished by entraining air in the concrete with the use of a foaming agent or by adding a chemical that causes air bubbles to form. In non-autoclave concrete, there is no coarse aggregate in the mix, but there is evenly dispersed air. These non-autoclave concrete blocks provide a lightweight advantage for structural design, resulting in cost savings in the construction sector for supporting buildings and foundations.

II. HISTORY OF AUTOCLAVED AERATED CONCRETE

Autoclaved aerated concrete has been utilised in building construction since the beginning of the twentieth century. AAC is also known as Aerated Cellular Concrete, although that is the most common term for it. There have been several patents granted for autoclaved aerated concrete over the course of several decades. For his steam curing procedures, German researcher Michaelis was granted a patent in 1880. Czechoslovak inventor Czech Hoffman introduced the concept of "aerating" concrete with carbon dioxide in 1889 and established its effectiveness.

By combining aluminium powder with calcium hydroxide in 1914, American inventors Aylsworth and Dyer developed an innovative cementitious mixture for use in concrete. It was Axel Eriksson's invention in 1920 for the process of generating an air-filled mixture of limestone and crushed slate that made a substantial contribution to AAC technology progress. "Lime formula," as it is sometimes referred as.

1. Chemistry:

Because fly ash and aluminium powder, as well as a variety of other components, are mixed to form cement, the volume of the resulting mixture increases significantly. The simplified chemical processes are shown in the following diagram from beginning to conclusion:

1. $CaO + H_2O \rightarrow Ca(OH)_2 + 65{,}2\ KJ/mol$
2. $3Ca(OH)_2 + 2Al + 6H_2O \rightarrow Ca3(Al(OH)6)_2 + 3H_2$
3. $6SiO2 + 5Ca(OH)_2 \rightarrow 5CaO \cdot 6SiO_2 \cdot 5H_2O$

2. Mergers & Acquisitions:

The AAC world as we know it now was shaped significantly by the mergers and acquisitions boom in the 1990s. Between the beginning of the 1990s and the beginning of the 2000s, the ownership of technologies, manufacturing, and brand names became disjointed. Plants and technology from three different companies have been combined under the name Xella to create the new company DuroxYtongHebel. Ytong and Hebel and Durox items were manufactured under the Ytong name as a consequence of this merger. Overcapacity forced the closure of a number of factories in 2001.

The closure resulted in the loss of jobs for several AAC technology specialists. As a result of growing production costs, Hebel was forced to close its main factory in Emmering, Germany, as well as several of its other facilities. There was a confounding effect on the architectural and construction markets when well-known companies abruptly departed. Relaunched as an additional brand, the name "Hebel" replaced Ytong as the company's block brand. Additionally, not a single Durox factory has been shut down throughout the course of AAC's existence, and the material is being produced at the original Durox facilities as well as the current ones. AAC's departure led many aircrete licensees to pursue their own paths in their careers.

3. AAC Machine Builders:

Technology and processes were no longer as important as equipment and prices in the market at this time. Manufacturers of machines, initially from Europe and then from China, began to enter the vast market. Machine construction enterprises purchased Ytong technology and its multiple tilt-cake derivations and sold it as "own technology" AAC equipment. The industry's emphasis shifted away from technology and toward machine supply and after-sales service. The worldwide market for autoclaved aerated concrete developed fragmented as information sharing about production processes, product uses, and technological breakthroughs was no longer encouraged.

As a rule, machine builders lack their own AAC production facilities and must rely on their clients for all of the aforementioned AAC-related products, services, chemical processes, and more. The financial involvement of technology suppliers in their own production was not uncommon in the past. AAC manufacturers are now forced to deal with the same industry issues on their own, because to the wider gap that exists between architects, contractors, factories, and machine builders than it has ever been.

4. AAC Products Today:

Concrete manufacturing technology has improved tremendously during the last two millennia. As a result, since they are no longer associated with private knowledge, non-reinforced AAC bricks have become commodities in many markets. Producing light and heavy reinforced AAC components, particularly with tiltcake

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technology, remains a substantial difficulty for the bulk of global manufacturers. Nonetheless, the physical qualities of AAC material improved throughout time, and its use in building grew more common. AAC is now a structurally competent construction material that is also a superb thermal insulator, sound absorber, and aesthetically pleasing material. Product densities ranging from 300 to 800 kg/m3 are now feasible, with lambda values of 0.08 (thermal conductivity) at 300 kg/m3 no longer considered an oddity.

Furthermore, high-precision goods are produced as a consequence of tight EU requirements (EN 771-4 and EN 772-16). (Tolerances of the Netherlands, has significantly affected markets). AIRCRETE Europe developed its unique flat-cake process in combination with a High Speed Cutting Frame to produce AAC products with SUPER SMOOTH surfaces. This process employs double wire cutting technology, resulting in a porous product surface. As a consequence, quick and low-cost finishing alternatives like direct paint or wallpaper application are conceivable.

In Japan, where a rocking AAC panel design is used, earthquake-resistant buildings made of AAC with a Richter scale protection of up to 8 may be created. Shizukalite boards, which are aircrete panels with better sound absorption capabilities, are another important AAC advancement. Each loud setting has a soundproofing option. The use of continuous open pore structures in these AAC panels rather than discrete ones enhances the panels' acoustic absorption.

This allows for better sound absorption in places near roads, HVAC systems, and other noise sources. Because AAC panels can endure direct fire exposure for 5-6 hours, they are an excellent choice for use as firewalls both inside and outside of buildings. These new AAC products are supposed to contribute to the rising "green house" movement, which focuses on energy efficiency and eventually develops houses that do not need any energy-consuming equipment.

III. RESEARCH METHODOLOGY

Using Aluminum powder at 0%, 0.04%, 0.08%, 0.12% and 0.16%. the researchers want to determine the strength of Non-Autoclave Aerated Concrete blocks. Here, we'll go through the most basic experimental testing done on the materials used to make the cast cube samples, as well as a quick rundown of the mixing and curing procedures employed. The results of the numerous tests on the specimen are described in the conclusion.

1. Material Properties:

To cast cubes specimens and study, use cement, fly ash, lime, gypsum, aluminium powder, and water. The next sections go into the physical characteristics of various materials.

1.1 Cement: Cement is by far the most essential component in the production of concrete. It does this function by acting as a binding agent for the separate constituents. It was OPC 43 grades of cement that were employed in this Experimental Investigation (ultratech). Table 1 lists the characteristics of the cement that was utilised.

Fig 1. Cement.

Table 1. Properties of cement.

Sr. No.	Physical Property	Results
1.	SG	3.11
2.	Primary Setting time	90 minutes
3.	Last setting time	150 minutes
4.	Fineness	2 %

1.2 Fly Ash: Fly ash is a byproduct of pulverised coal burning in thermal power plants. It is collected as a fine particulate residue from the combustion gases by the dust collecting system before they are released into the environment. The range of particle sizes in any particular fly ash is mostly dictated by the dust series equipment that is employed. It was fly ash from the Parichha thermal energy plant that was employed in this experiment facility in Jhansi, Uttar Pradesh.

Fig 2. Fly ash.

Table 2. Physical properties of fly ash.

Sr. No.	Physical Property	Results
1.	SG	2.34
2.	Bulk density	1.12 gm/cc

1.3 Quick Lime (CaO): For the production of fast lime, limestone is calcined at temperatures reaching 900°C. The quicklime used in this investigation was sourced from INDUS MINERAL PRODUCTS OF INDIA, KATNI, and Madhya Pradesh. Calcium oxide is often referred to as "quick lime." Quick lime has always been a low-cost commodity due to the abundance of limestone resources available throughout the world. Lime production and use may be traced all the way back to the ancient civilizations of Rome, Greece, and Egypt. Limestone, chalk, marble, dolomite, oyster shells, stalactites, and stalagmites are all examples of rocks that include calcium carbonate and magnesium carbonate, which are the basic elements for making lime.

Limestone is burnt in kilns that are either vertical or horizontal in orientation. The kilns are surrounded by steel shells with refracting cubes. The calcination process results in the formation of calcium oxide or lime. When limestone or calcium carbonate is heated to between 1200 and 1300 degrees Celsius, it decomposes into quicklime and carbon dioxide, which is then recycled back into the process.

$$\underset{\text{lime stone}}{CaCO_3} \xrightleftharpoons{1200^{o} - 1300^{o}C} \underset{\text{lime}}{CaO} + CO_2 \uparrow$$

1.4 Gypsum: Gypsum is a mineral that may range in colour from white to grey and can be found in the earth's crust. It is known chemically as hydrous calcium sulphates (CaSO4.2H2O), and it is mined from huge veins. It takes in several shapes. In certain places, it looks like sand. Gypsum (CaSO4.2H2O) powdered form is widely available on the market.

Table 3. Properties of Gypsum

S No.	Physical property	Results
1.	Specific Gravity	2.32

1.5 Aluminium Powder: The optimum option for foaming in AAC manufacture has been demonstrated to be aluminium, which is utilized all over the globe. Hydroxide of calcium or alkali interacts with aluminium, releasing hydrogen gas (3H2) and causing bubbles to develop. The metallic powder used in this experiment has a molecular weight of 26.98 and is available on the market in a fine grey colour.

1.6 Water: The chemical interaction between cement and water is the most critical phase in the production of concrete mortar. The presence of water aids in the formation of a gel by making it simpler to combine the various components. To make your mixing water, you may use practically any natural water that is safe to drink and has no flavour or scent. Another common practice is to grow plants in bodies of water that include marine life. When it comes to combining, water that is safe to drink is often regarded as exceptional.

2. Test on materials:
There are various tests performed to complete this experimental investigation are described below:

2.1 The Ordinary Portland cement was tested for physical properties such as:
- Fineness test
- Standard consistency test
- Setting time test
- Specific gravity

2.2 The Fly ash was tested for physical properties such as:
- Fineness test
- Specific gravity test

2.3 Properties were tested on the NAAC Blocks are:
- Density variation of Cubes
- Water Absorption test
- Compressive strength test

IV. RESULTS AND DISCUSSION

This section contains the results of the compressive strength and water absorption tests, as well as a graph depicting the strength fluctuations of Non Autoclave Aerated Concrete with different levels of Aluminium Powder at 0%, 0.04, 0.08, 0.12, and 0.16 percent.

A density variation test was also carried out to see how varying aluminium percentages affected the strength qualities of non-autoclave aerated concrete.

1. Water Absorption analysis:
For 24 hours, the cubes are submerged in water. After that, the cube should be taken out of the water and wiped away any remaining water with a towel before weighing it. After that, dry the cube in the oven for 24 hours before weighing it. Permissible Maximum Water is absorbed at a rate of 40%... Table 4 shows the results of water absorption tests on NAAC blocks.

Table 4. Water Absorption Test.

Samples	Water Absorption (%)	Result
SC	6.12	Satisfied
S1	30.64	Satisfied
S2	36.84	Satisfied
S3	43.13	Unsatisfied
S4	44.68	Unsatisfied

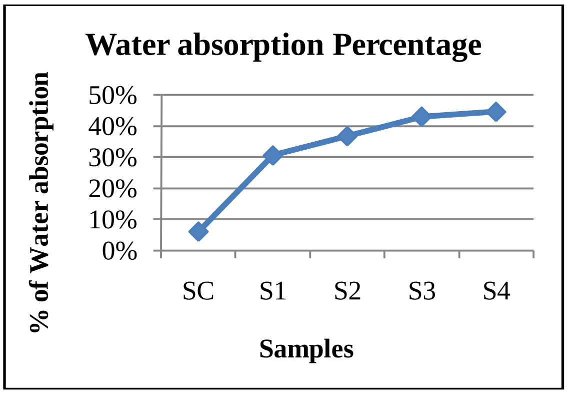

Fig 3. Variations Water Absorption.

2. Expansion in volume:

The volume of cubes is observed to have grown in comparison to the SC sample. Table 5 explains the many types of volume growth.

Table 5. Expansion in Volume.

Sample	Volume increase
S1	36.80 %
S2	41.82 %
S3	48.00 %
S4	52.04 %

3. Variation of Density:

The amount of aluminium powder in the NAAC blocks affected their density. When it dropped from 1392.45 kg/m3 at 100% to 667.81 kg/m3 at 0.16 percent, the consequences are clearly seen in Figure 4. The density of aerated concrete that has not been autoclaved decreases as the amount of aluminium powder in the mixture increases.

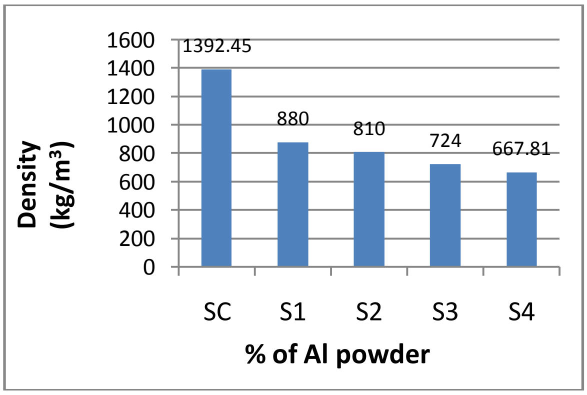

Fig 4. Density variation of blocks.

4. Compressive Strength test:

A compressive testing machine is used to conduct this test. The compressive strength of NAAC blocks was measured at three different ages: seven days, fourteen days, and twenty-one days. The compressive strength is determined using a procedure that complies with IS3495 (Part 1):1976. The cube was centred on the bottom plate of the universal testing machine. The top plate of the standard testing apparatus was then lowered down to the cube and tightened into place with no movement. The load was then applied at a consistent pace. Table 6 displays the compressive strength data. The graph depicts the fluctuation in compressive strength. The test results are shown below:

Table 6. Compressive strength of NAAC blocks.

Samples	Compressive strength in N/mm^2		
	7 days	14 days	21 days
SC	4.00	6.70	10.32
S1	1.84	2.97	4.48
S2	1.63	2.38	3.75
S3	1.10	1.86	2.90
S4	0.80	1.3	2.08

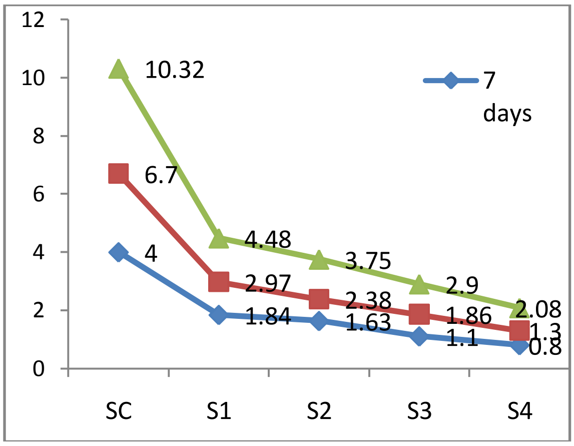

Fig 5. Compressive strength of NAAC blocks.

5. Cost Analysis:

This chapter examines the costs of non-autoclave aerated concrete cubes created using concrete and aluminium powder at various ratios.Only the cost of materials is included in the cost analysis. A NAAC block performs better than traditional clay bricks. The following table 7 shows the cost of NAAC blocks:

Table 7. Cost analysis of Concrete Bricks

S. No.	Material	Rate (Rs/Kg)	SC	S1	S2	S3	S4
1.	Cement	6	2340	1478.8 8	1361. 4	1216.8	1121
2.	Fly ash	0.4	194	123.2	113.3	101.29	93.38
3.	Lime	1.5	102	65	59.3	53.04	48.81
4.	Gypsum	1.1	32.17 5	20.306	18.7	16.73	15.55
5.	Aluminum Powder	200	0	49.29	90	121.4	149.4
6.	Water	0	0	0	0	0	0
Total (Rs)			2668. 175	1736.6 7	1642. 7	1509.2 6	1428. 14
Per Brick Cost (Rs)			4.72	3.07	2.90	2.67	2.53

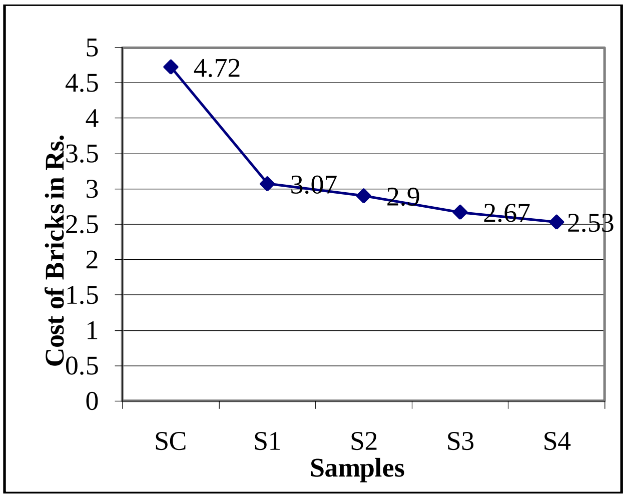

Fig 6. Cost Analysis of NAAC Blocks.

V. CONCLUSION

Construction and building industries employ traditional bricks as the most frequent building material because of its durability and low cost. Autoclaved aerated concrete blocks are a kind of building material that has become more popular in recent years. Autoclaved aerated concrete is made by combining fly ash with lime, cement, water, and an aerating agent to form a cohesive mixture (AAC). AAC is mostly produced in the form of cuboid blocks and prefabricated panels, although it may also be produced in other forms. Automatically aerated concrete is a kind of concrete that is engineered to have a high number of closed air holes.

AAC blocks provide a number of advantages, including being energy efficient, long-lasting, low-density, and lightweight. It is manufactured by mixing a foaming agent into concrete in various-sized moulds as required, then cutting blocks or panels from the resulting 'cake lump' with a wire cutter and steam-heating them until they are set. This method is referred known as autoclaving in the industry. A non-toxic construction material created from industrial waste and including non-toxic chemicals, this substance has been recognized as an ecologically acceptable building material. Understanding AAC blocks and their long-term viability in the construction industry is the emphasis of the presentation; this research gives an overview of AAC blocks.

Following conclusion are drawn from present research work:

- The water absorption of NAAC blocks rises as the amount of aluminium powder increases.
- Water absorption is less than 40% in samples S1 and S2, which is suitable for light weight concrete.
- Traditional clay bricks are heavier than NAAC blocks.
- As the amount of aluminium powder in the material increases, the density of the substance falls. From sample S1 to S4, density drops between 725 Kg/m^3 and 512 Kg/m^3.
- NAAC blocks with S1 and S2 samples have compressive strengths of 4.48 N/mm^2 and 3.75 N/mm^2, respectively, which are higher than third-class bricks (i.e. more than 3.5 N/mm2).

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