International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Analysis and Design of Light Weight Aerated Concrete using Fly Ash and Gypsum

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ABSTRACT

In this experimental research work, the focus is on developing the non-autoclave concrete blocks without autoclaving and keeping the compressive strength of non-autoclave blocks adoptable to various uses. Non autoclave aerated concrete blocks consists of fly ash, cement, lime, gypsum and aluminium powder as an expansion agent. Compressive strength test is carried on 70.6 mm × 70.6 mm ×70.6 mm cubes of non-autoclave concrete. Compressive strength of blocks are tested at different percentage of aluminium powder while keeping constant percentage of all other ingredients. This experiment led us to know that as the density of blocks decreases due to increase in content of aluminium powder, the compressive strength decreases.

Keywords: Aluminium powder, NAAC, Density, Water absorption, Compressive Strength.

1.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.

1.1 Aerated Lightweight Concrete:

Aerated Concrete is a lightweight, load-bearing, highly insulating, and long-lasting novel construction material available in a variety of sizes and strengths. When compared to red bricks, aerated concrete blocks are lighter. 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: autoclaved aerated concrete (AAC) and non-autoclaved aerated concrete (NAAC) (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.

1.2 Non Autoclave Aerated Concrete blocks

Non autoclave aerated concrete is a lightweight blocks which can be used for load bearing structures and frame structures. Non autoclave concrete blocks gives same strength as conventional clay bricks which is used for brick masonry. It reduces the energy consumption in comparison to autoclaved concrete blocks. The material is used to deal with the urgent need of construction industry i.e. to reduce the environmental impacts of the materials used in construction. It reduces the transportation cost and related pollution with it, and increase the speed of construction as they are of large size and covered large area in one time. These blocks have high thermal efficiency, reduces noise pollution and are well suited for withstand fire and earthquakes disasters (Stefan Schnitzler, October 2006).

The concept in manufacturing of non autoclaved concrete is to induce the pores microstructure in the concrete mix. This can be achieved by entraining the air in the concrete with the help of foaming agent or with the addition of chemical which creates air bubbles in the concrete. Non autoclave concrete does not contain any coarse aggregate in mixture but contains the air which is uniformly distributed. These non autoclave concrete blocks have an lightweight advantage for structural design, leads to savings in supporting structures and foundation in construction industry.

2.Related work

Since the beginning of the twentieth century, autoclaved aerated concrete has been used as a construction material. AAC, also known as Aerated Cellular Concrete or Aircrete, is an autoclaved aerated concrete. A number of method patents may be found in the early history of autoclaved aerated concrete. Michaelis, a German researcher, was given a patent for his steam curing procedures in 1880.

- **Mergers & Acquisitions**

  The 1990s mergers and acquisitions boom had a significant influence on the world of AAC as we know it today. Ownership of technology, factories, and brand names got jumbled between the early 1990s and the early 2000s. Plants, patents, technology, and patents from Durox, Ytong, and Hebel all ended up in the same business, dubbed Xella. All three brand names were merged under the name Ytong at one time, and Hebel and Durox items were manufactured under the name Ytong. A number of plants were shut down in 2001 due to overcapacity. Many AAC technology professionals lost their employment as a result of the shutdown. Hebel was the most impacted, with its main facility in Emmering, Germany, closing and certain Hebel plants being liquidated due to rising manufacturing costs. The departure of well-known brands baffled the market of architects, builders, and, most importantly, end customers. Following this, the name "Hebel" was reintroduced as a reinforced product brand, while Ytong remained a block brand. Furthermore, during the history of AAC, not a single Durox plant has been shuttered, and AAC is being manufactured in the existing plants as well as the initial Durox-based plants. In the AAC world, there was an outflow of know-how at this time, and many licensees had to forge their own path in the aircrete industry.

- **AAC Machine Builders**

  Market dynamics shifted dramatically at this time, moving the emphasis away from technology and procedures and toward machines and price. Machine builders, first from Europe and subsequently China, stepped into the market's wide area. Machine construction businesses bought Ytong technology and its many tilt-cake derivations and offered it as "own technology" AAC equipment. The industry's emphasis shifted from technology supply and support to machine supply and after-sales support. The global market for autoclaved aerated concrete grew fragmented as information exchange concerning manufacturing techniques, product applications, and new advancements was no longer encouraged. Machine builders, on the whole, do not have their own AAC manufacturing facilities and depend on their customers for AAC product, application, chemical processes, and so on. In the past, technology providers' financial engagement in their own manufacturing was not unusual. As a result, today's divide between architects, contractors, factories, and machine builders is bigger than it always was, pushing each AAC manufacturer to address the same industry difficulties on their own.

- **AAC Products Today**

  Over the previous two millennia, aircrete manufacturing technology has advanced dramatically. Ordinary non-reinforced AAC blocks are no longer related to any proprietary know-how, and as a consequence, AAC blocks have become a commodity in many markets. Manufacturing light and heavy reinforced AAC parts, particularly using tiltcake technology, remains a serious difficulty for the bulk of global manufacturers. Nonetheless, the physical qualities of AAC material improved throughout time, and its use grew more widespread from a building standpoint. AAC is now a structurally sound construction material, a good thermal insulator, a good sound absorber, and a decorative substance. Certain technical experts can now generate product densities ranging from 300 to 800 kg/m3, with lambda values of 0.08 (thermal conductivity) at a density of 300 kg/m3 no longer being an exception. Furthermore, tight EU requirements (EN 771-4 and EN 772-16) result in high-precision goods (tolerances of the Netherlands, has significantly affected markets). Thanks to its unique flat-cake technology with a High Speed Cutting Frame, AIRCRETE Europe has further developed that technology by providing SUPER SMOOTH surfaces to AAC products. The technique employs double wiring cutting technology, which results in a porous product surface. As a consequence, quick and cost-effective finishing, such as direct application of paint or wallpaper, is conceivable.

  AAC also provides a solution for earthquake-safe construction in seismically active areas, such as Japan, where a rocking AAC panel design provides structures with a Richter-scale protection of up to 8. Another significant AAC advancement is aircrete panels with improved sound absorption capabilities, also known as Shizukalite boards, a soundproofing option for any sort of sound sensitive setting. In contrast to traditional AAC panels with discrete pore structures, these AAC panels contain continuous open pore structures, allowing for optimal acoustic absorption near roadways, HVACs, offices, and other noise sources. The use of AAC panels as firewall solutions (both internal and exterior) adds to aircrete's worldwide image as a construction material, since AAC can resist up to 5-6 hours of direct fire exposure. With these new products, AAC, as a highly insulating and environmentally friendly material, may contribute to the increasingly popular "green housing" trend of focusing on energy efficiency and eventually creating houses without the need of energy appliances.

Review on Light weight Concrete used in previous studies

The literature review entails looking at what others have written in the realm of light weight tangible knowledge. The literature study provided insight and background information that was utilised to add something new to the topic.

Nitin Kumar et. al. [2017] AAC blocks have been researched for usage in residential constructions. AAC blocks are compact and lightweight, with excellent workability, flexibility, and durability. Sand, water, quicklime, and cement make up its makeup. AAC provides excellent opportunities to improve building quality while lowering development expenses. AAC is made from quartz sand, as well as pounded fly slag (PFA), lime, concrete, gypsum, water, and aluminium, and is consolidated in autoclaves by steam. AAC is used in a variety of construction projects, including residential residences, commercial and industrial constructions, schools, healthcare facilities, motels, and a variety of other uses.

Khandve P. V. [2016] They researched and developed on novel AAC product applications in the building sector in order to maximise the benefits of AAC. Different AAC manufacturing sectors should take the lead in popularising these new uses in order to enhance the proportion of AAC in the building industry, as well as contribute to green initiatives for the nation's long-term growth. There is a rising global demand for integrated construction solutions in the current AAC commodity market of blocks. It is well recognised that using AAC panels in construction may lower the total cost of ownership for the end user. Buildings composed entirely of prefabricated AAC pieces are quick and simple to construct, with no trash generated on-site.

Mallampalli.Ch. G. et. al. [2016] Aerated autoclaved concrete blocks were the subject of their research. AAC is one of the materials that may make up for a lack of construction resources by producing a light, energy-efficient, and ecologically friendly concrete. The purpose of this research is to provide an overview of the autoclaved aerated concrete process and its benefits over traditional concrete. Because of its unique cellular structure, which contains millions of microscopic pockets of entrapped air, it weighs as little as 1/5 the weight of typical concrete. AAC is made up of readily accessible basic materials. Sand, cement, lime, fly ash, gypsum, aluminium powder paste, water, and an expansion agent are among them.

M. Gunasekaran et. al. [2016] In autoclaved aerated concrete, the use of fly ash instead of natural sand is being studied. Use a 1:3 mix ratio and a 0.6 water-cement ratio to design an AAC mix. In these cases, fly ash is used as a substitute for sand and lime is used as a substitute for cement. Gypsum is the only material used in the specimens. When using aluminium powder, 0.25gm, 0.5gm, 0.75gm, and 1 of the total concrete weight are used in the mix. The 24-hour steam curing was used to measure the mortar's density, water absorption, and compressive strength.

Parth Desani et. al. [2016] The use of fly ash in place of natural sand in autoclaved aerated concrete is now being investigated in depth. Create an AAC mix with a 1:3 mix proportion and a 0.6 water cement ratio by using the formula below. In these cases, the sand is partially replaced by fly ash, and the cement is partially replaced by lime in both the with and without lime versions. The gypsum used in the specimens is always the same. Aluminum powder is used in proportions of 0.25gm, 0.5gm, 0.75gm, and 1 of the total weight of the concrete mix. The density, water absorption, and compressive strength of the mortar were measured after it had been subjected to 24-hour steam curing.

V. Prasanna et. al. [2016] They compared and contrasted several strategies in the building business. When planning a construction project, the contractor wants to complete the job on time; if the work is not done on time, the project's cost will rise, and the contractor will be penalised. In order to solve these issues, quick building approaches are necessary. Thus, a comparison of numerous quick methods such as Aluminum Formwork Technology, Precast Technology, and Autoclaved Aerated Concrete Blocks with the traditional approach highlights the benefits and drawbacks of each technology and aids in the implementation of the most successful one.

Shweta O. R. et. al. [2015] They investigated the possibility of replacing red bricks with environmentally friendly AAC blocks. The use of AAC blocks saves construction costs by up to 20% since the dead weight of the wall on the beam is reduced, resulting in lighter parts. The usage of AAC blocks also decreases the need for materials like cement and sand by up to half.

Ali J. Hamad [2014] They investigated the properties and applications of aerated light weight concrete. In this study, aerated lightweight concrete is divided into two categories: foamed concrete and autoclaved concrete. The raw materials, types of agents, characteristics, and applications of aerated concrete are all on exhibit. The production procedure may be classified based on whether the concrete is autoclaved or foamed. The literature study on aerated lightweight properties focuses on porosity, permeability, compressive strength, and splitting strength.

Dauzhanov Nabi et. al. [2014] Non-Autoclaved Aerated Concrete Production Parameters Using Complex Ash and Gypsum-Containing Wastes was the focus of their research. If you're looking for concrete that's strong and freeze resistant, you'll find it in non-autoclaved aerated concrete that's exactly what you're looking for, according to regulatory guidelines. Small wall blocks constructed of non-autoclaved aerated concrete based on fly ash and natural gypsum had a manufacturing prime cost of 36 percent lower than manufacturing-represented blocks of non-autoclaved aerated concrete with cement and sand, but ash and phosphogypsum had a manufacturing prime cost of 40 percent lower than manufacturing-represented blocks.

Farhana M. S. et. al. [2014] Their investigation was focused on the building industry's usage of aerated concrete blocks. There is an abundance of silica sand, which is the basic material used in AAC, across the globe. The completed product has an air content of 70 to 80 percent, which is up to five times the volume of the raw components (depending on the required strength and density.) AAC is very resource-efficient because of this massive increase in volume. The construction industry's over use of raw resources has resulted in a long-term lack of building materials and environmental harm. A number of studies have been conducted in recent years by the construction industry on the use of readily accessible raw materials in building.

3.MATERIALS AND METHODOLOGY

Concrete blocks with variation of Aluminum powder at 0%, 0.04%, 0.08%, 0.12% and 0.16%. This chapter explains the fundamental experimental testing performed on materials used for casting cubes samples, as well as a short overview of the materials mixing and curing procedures employed. The numerous tests done on the material are mentioned at the end.

Material Properties

Cement, Fly ash, Lime, Gypsum, Aluminum Powder, and water to cast cubes specimen and investigate. The physical properties of these materials are discussed in the following sections.

- **Cemen**t

  Cement is by far the most important element of concrete. In that, it works as the binding agent for the discrete ingredients.. The cement used in this Experimental Investigation was OPC 43 grades (ultratech). The properties of cement used are given in Table 1.

Table 1: Properties of cement

Sr. No.	**Physical Property**	**Results**
1.	Specific gravity	3.11
2.	Initial setting time	90 minutes
3.	Final setting time	150 minutes
4.	Fineness	2 %

- **Fly Ash**

  Fly ash is a waste material of the combustion of pulverized coal in thermal power plants. It is removed by the dust collection system as a fine particulate residue from the combustion gases before they are discharged into the atmosphere. The variety of particle sizes in any given fly ash is basically determined with the support of the sort of dust series equipment used.

Table 2: Physical properties of fly ash

Sr. No.	**Physical Property**	**Results**
1.	Specific gravity	2.34
2.	Bulk density	1.12 gm/cc

- **Quick Lime (CaO)**

Quick lime are obtained by calcining limestone at temperatures above 900°C.Quicklime taken for this research is taken from INDUS MINERAL PRODUCTS OF INDIA. Calcium oxide is commonly called Quick Lime. Quick lime has always been a cheap commodity because limestone deposits are readily available. Lime manufacturing and application dates back to the Roman, Greek and Egyptian civilizations. Raw Materials of lime are Calcium carbonate and magnesium carbonate obtained from deposits of limestone, chalk, marble, dolomite, oyster shells, stalactites and stalagmites. Vertical or horizontal kilns are used to burn limestone. The kilns have steel shells line with refracting cubes. Calcium oxide or lime is prepared by the calcinations process. Limestone or calcium carbonate is heated to a temperature between 1200ºC and 1300ºC in Kilns and it decomposes to quicklime and carbon dioxide.

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

- **GYPSUM:**

The earth's crust contains gypsum, a white to grey mineral. In chemistry, the mineral known as hydrous calcium sulphates (CaSO4.2H2O) is found in huge veins that are mined out. It takes on a variety of shapes. In certain places, it is mistaken for sand. Gypsum (CaSO4.2H2O) is readily accessible on the market and may be utilised in powdered form if required.

Table 3: Properties of Gypsum

S No.	Physical property	Results
1.	Specific Gravity	2.32

- **ALUMINIUM POWDER**

Aluminium is used as a foaming agent in AAC production worldwide and it is widely proven as the best solution for its purpose. When Aluminium is added to the mixing ingredients, it reacts with hydroxide of calcium or alkali which liberates hydrogen gas ($3H_2$) and forms bubbles. A fine grey colour, uniform, smooth metallic powder available in market is used in this experimental process, having a molecular weight 26.98.

➢ ***Preparation of Materials***

All of the ingredients are weighed to the correct proportions for the mix design. For the chemical interaction of aluminium powder with other materials, water is heated to 700 degrees Celsius to bring the mixing temperature to 400 degrees Celsius. The weight of dry material is used to determine the amount of water needed. To begin, fly ash and water are mixed in a container for 3-4 minutes. Cement, Lime, Gypsum, and Aluminum powder, on the other hand, are suitably blended in dry form. After that, the slurry and the dry material are combined and stirred for two to three minutes. The mix proportion chosen for this Experimental Investigations are given in Table 4.

Table 4: Quantities of materials in Kg by weight

Sample Designation	**Cement**	**Fly Ash**	**Quicklime**	**Gypsum**	**Al. powder**
SC	390	487	68	29.25	0
S1	246.48	308	42.97	18.46	0.246
S2	226.90	283.3	29.56	17.01	0.45
S3	202.8	253.29	35.36	15.71	0.607
S4	186.96	233.46	32.54	14.14	0.747

Results and Discussion

This section consists final values of compressive strength test and water absorption test with graph that shows the strength variations of Non Autoclave Aerated Concrete with variations of Aluminium Powder at 0%, 0.04%, 0.08%, 0.12% and 0.16%. Density variation test also performed to carry out effect of Non Autoclave Aerated Concrete with different aluminium percentages on strength properties.

Water Absorption analysis: For 24 hours, the cubes are submerged in water. Remove the cube from the water and dry it with a towel before weighing it. The cube should then be dried for 24 hours in an oven before being weighed. Max. Permitted A whopping 40% of the water is absorbed. Table 5 displays the results of water absorption tests performed on NAAC blocks.

Table 5: 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

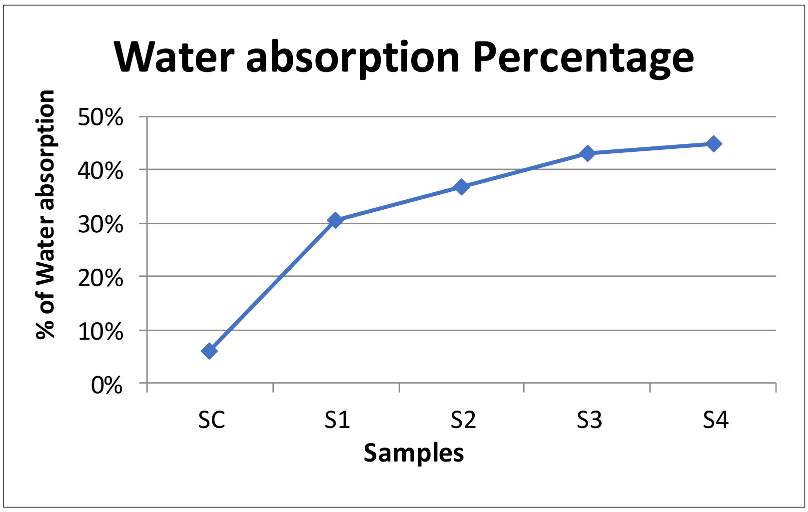

Figure 1: Variations Water Absorption

4.3. Expansion in volume: The volume of the cubes expands in relation to the SC sample. Table 6 explains the differences in volume growth.

Table 6: Expansion in Volume

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

4.4. Variation of Density: The density of the NAAC blocks varied with aluminium powder content. It decreased significantly from 1392.45 kg/m3 at 0% to 667.81 kg/m^3 at 0.16% and these results are shown in Fig1. With increasing aluminium powder content, the density of the non autoclaved aerated concrete gradually decreases due to increase in pores formed.

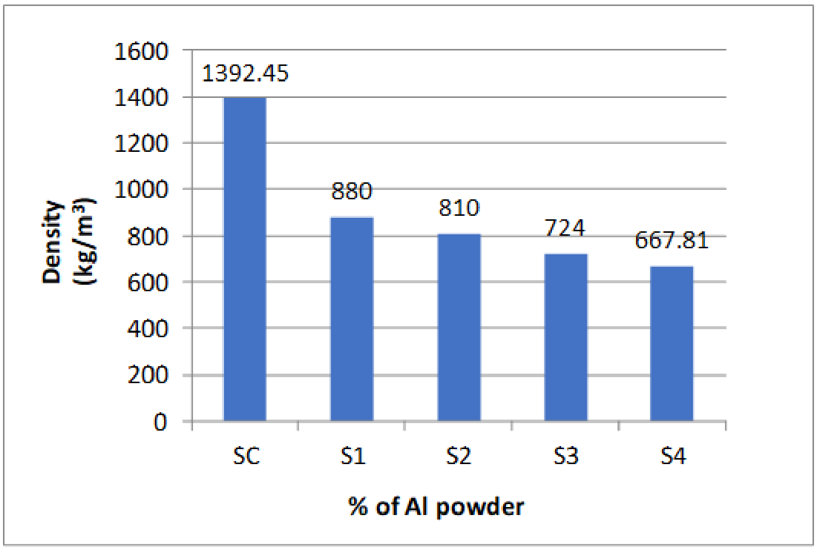

Figure 2: Density variation of blocks

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 technique 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 7 displays the compressive strength data. The graph depicts the fluctuation in compressive strength. The results of the tests are shown below:

Table 7: 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

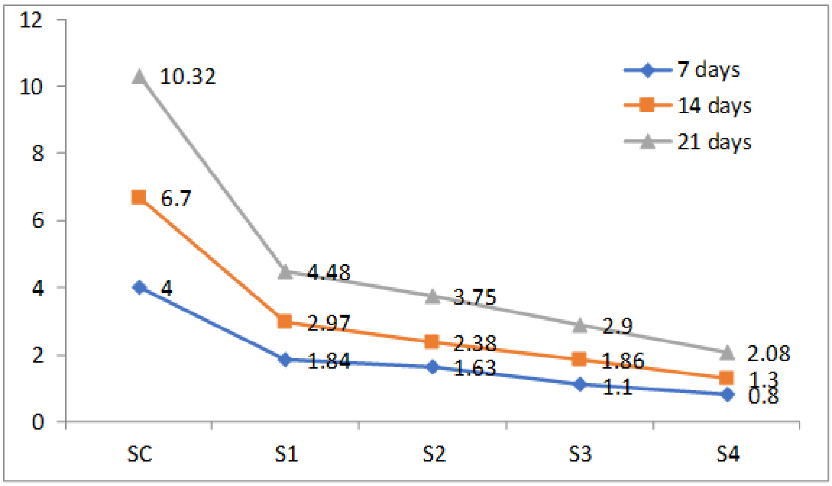

Figure 3: Compressive strength of NAAC blocks

Cost Analysis

This chapter consist of cost analysis of Non Autoclave Aerated Concrete cubes made with concrete material by using Aluminum Powder at different percentages.

Cost analysis is done by considering the cost of materials only. A NAAC block gives better results than conventional clay bricks**.** The cost of NAAC blocks are shown in following table 8:

Table 8: Cost analysis of Concrete Bricks

S. No.	**Material**	**Rate (Rs/Kg)**	**SC**	**S1**	**S2**	**S3**	**S4**
1.	Cement	6	2340	1478.88	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	32.175	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	1736.67	1642.7	1509.26	1428.14
Per Brick Cost (Rs)			4.72	3.07	2.90	2.67	2.53

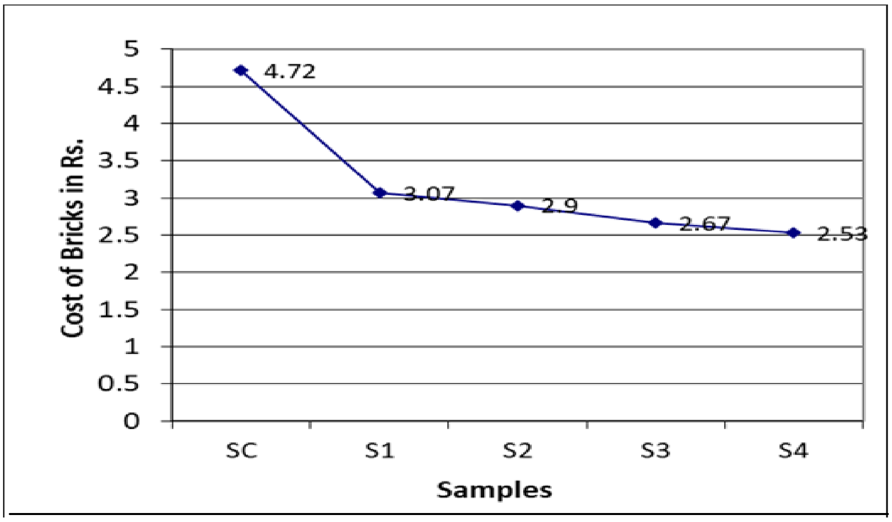

Figure 4: Cost Analysis of NAAC Blocks

Conclusions

Following conclusion are drawn from present research work:

- Water absorption of NAAC blocks increases with the increase in aluminum powder.
- Samples S1 and S2gives water absorption less than 40%, which is acceptable for light weight concrete.
- NAAC blocks are lighter than conventional clay bricks.
- The density of material decreases with increase in quantity of aluminium powder. Density decreases between the range of 725 Kg/m^3 to 512 Kg/m^3 from sample S1 to S4.
- S1 and S2 samples of NAAC blocks have a compressive strength 4.48 N/mm^2 and 3.75 N/mm^2 respectively, which comparatively shows a higher result than a third-class brick (i.e. higher than 3.5 N/mm^2).

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