



Experimental Investigation On Autoclaved Aerated Concrete By Adding Aluminium Powder

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ABSTRACT

Autoclaved Aerated Concrete (AAC) is an ultra-light weight concrete. It can weigh as little as 1/5 as much as ordinary concrete due to its distinct cellular structure featuring more tiny pockets of trapped air by the formation of hydrogen air bubbles. This cellular structure gives AAC a number of exceptional physical characteristics. AAC consists of basic materials that are widely available. These include cement, lime, fly ash, gypsum and aluminum powder as forming agent with different proportion. Fly ash, the raw material used in the greatest volume in AAC, is one of the world's most abundant natural resources. The finished product is up to five times the volume of the raw materials used with a forming agent. Due to this increase in volume, AAC is very resource efficient. It is one of the materials which can produce light weight, energy efficiency, strength and environmentally friendly concrete compared to conventional concrete. But the increase in aluminum powder content caused a decrease in the compressive strength and density of aerated concrete. The use of AAC block also reduce the requirement of material like cement, fine aggregate and coarse aggregate. This experimental study deals with the increase in compressive strength by changing the mix proportion and the density is decreased as compared to the conventional concrete.

KEYWORDS: Aluminum Powder, Porosity, Lightweight Concrete, Sustainable Construction, Compressive Strength and Cementitious Composites.

1. INTRODUCTION

Autoclaved aerated concrete is a pre-cast construction material. At roughly one fifth of the weight of normal concrete, it is an incredibly light weight building material. It provides excellent thermal and acoustic resistance and also protects against house hold hazards as termites and fire. LWC is commonly referred to as autoclaved cellular concrete because hydrogen bubbles form during the production process, resulting in small pockets of air within the concrete that substantially increase the volume of the final concrete product. Though the precise composition of light weight concrete may vary, it is generally made up of lime, gypsum, fly ash, cement and water or some other building component and aluminium powder. The aluminium powder reacts with the cement and forms hydrogen bubbles to form within the mix, thereby increasing the volume-to-weight ratio of the concrete mix. After the mix is cast into the desired form and the volume-increasing chemical reactions occur, the concrete mix, which is still soft, is autoclaved.

Lightweight concrete is either a cement or lime mortar, classified as aerated concrete, in which air voids are entrapped in the mortar mix by means of a suitable aerating agent. Broadly speaking aerated concrete falls into the group of cellular concrete. The prominent advantage of aerated concrete is its lightweight, which economies the design of supporting structures including the foundation and walls of lower floors.

It provides a high degree of thermal insulation and considerable savings in material due to the porous structure. By appropriate method of production, aerated concrete with a wide range of densities ($300\pm 1800\text{ kg/m}^3$) can be obtained thereby offering flexibility in manufacturing products for specific applications (structural, partition and insulation grades).

Lightweight concrete is relatively homogeneous when compared to normal concrete, the properties of aerated concrete depend on its microstructure system and composition, which are influenced by the type of binder used, methods of pore-formation and curing. Although aerated concrete was initially envisaged as a good insulation material, there has been renewed interest in its structural characteristics in view of its lighter weight. It is a lightweight, precast building material that simultaneously provides structure insulation in fire and mold resistance. LWC products include blocks, wall panels, floor, roof panels and lintels.

2. OBJECTIVE

The main objectives of this investigation are to examine the properties of density, weight and compressive strength of the concrete which is produced by adding aluminium powder.

3. SCOPE

The current study is aimed to compare the weight and density of the Autoclaved Aerated Concrete to the conventional concrete by adding aluminium powder in which different proportions of aluminium powder is used to make nano air bubbles in concrete. The study of different parameters like compressive strength, density, weight and also overall material consumption.

4. REVIEW OF LITERATURE

A. Just & B. Middendorf - Lightweight (or) Foamed concrete year 2004, They proposed that light weight concrete is AAC. By adding air entraining agent aluminium powder to the slurry of concrete, it reacts with water & cement it form a hydrogen gas. The hydrogen evaporates with atmosphere and leaves from concrete the air occupies the space in concrete. He concludes due to light weight property LWC has many advantages compared to the normal conventional concrete and it is only applicable in lintels, floors and roofs etc.,

Er. Dhawal Desai - Development of light weight concrete year 2013, He proposed that development of light weight concrete (or) AAC by the use of aluminium powder. It is lighter than the conventional concrete with a dry density of 300 kg/m^3 up to 1840 kg/m^3 . LWC is a pre-cast construction material. Aluminium powder is used at a rate of 0.05% to 0.08% by volume of cement. It can carry loads up to 1200 psi. He suggests that decreasing of water-cement ratio in concrete increase the strength of concrete.

Stefan Schnizler - Lightweight concrete as a green building material year 2006, He proposed that LWC is a “green” (or) “Eco friendly”. Lightweight concrete avoids toxic emissions. The manufacturing of LWC also results in a product that is light weight, strong, nontoxic. LWC has high thermal efficiency and has good sound insulation property. LWC withstands in fires & earthquakes. It has excellent durability, energy efficiency and ability to recycle.

N. Narayanan, K. Ramamurthy - Structure and properties of aerated concrete year 2000, Aerated concrete is relatively homogeneous when compared to normal concrete, as it does not contain coarse aggregate phase, yet shows vast variation in its properties. The properties of aerated concrete depend on its microstructure (void-paste system) and composition, which are influenced by the type of binder used, methods of pore-formation and curing. Although aerated concrete was initially envisaged as a good insulation material, there has been renewed interest in its structural characteristics in view of its lighter weight, savings in material and potential for large scale utilization of wastes like pulverized fuel ash. The focus of this paper is to classify the investigations on the properties of aerated concrete in terms of physical (microstructure, density), chemical, mechanical (compressive and tensile strengths, modulus of elasticity,

drying shrinkage) and functional (thermal insulation, moisture transport, durability, fire resistance and acoustic insulation) characteristics.

Hebel - Assessment of light weight concrete year – 1998, LWC is a lightweight, structural, precast building material of the uniform cellular structure. It is formed by combining sand, lime, cement, gypsum, water and an expanding agent, which forms a porous, micro structure in the concrete. At one-fifth the weight of concrete, the most solid units are easily placed and secured with a thin-bed mortar. With wood-like behavior, blocks shape easily and fasten using common woodworking tools and fasteners. The masonry-like units and reinforced panels are a part of a complete range of products that enable a structure to be built entirely of LWC. The entire structural shell including, basements, walls, stairs, floors and roofs are all made from precast autoclaved aerated concrete products. LWC was used to build a seven-story hotel in Atlanta in preparation for the 1996 Olympic Games. LWC is manufactured from sand, cement, lime, gypsum, water and an expanding agent. Unlike lumber, all of these materials are readily available and are abundant natural resources. Since the finished product is nearly five times the volume of the raw materials used in manufacturing, this product uses resources very efficient.

5. SPECIFICATION OF MATERIALS

CEMENT - Cement is main component to making the concrete. In this investigation the Ordinary Portland cement was used. The 53 grades of the cement were used in the present investigation.

FINE AGGREGATE - Fine aggregate can be natural or crushed. The specifications required that it should consists of hard, dense, durable, uncoated rock fragments and shall be free from injurious amounts of dusts, clay, silt, mica, organic matter, soft and flaky particles. The sand particle should also pack to give minimum water. The present study the sand used, conforms to zone II (as per IS (383-1970)). The Specific gravity of sand is 2.60.

COARSE AGGREGATE - The coarse aggregate is the strongest and least porous component of concrete. Presence of coarse aggregate reduces the drying shrinkage and other dimensional change occurring on account of movement of moisture. Coarse aggregate contributes impermeability of concrete, provided that it is properly graded and is suitably designed. Coarse aggregate is conventional concrete contributes to the heterogeneity of the cement concrete and there is weak interface between cement matrix and aggregate surface in conventional concrete. These two factors result in low strength of conventional concrete. For a given aggregate, the permeability decreases with higher cement content and for given cement content, the permeability decreases with the fineness modulus of sand. To get water tight concrete the aggregate must contain a large proportion of very fine particles.

WATER - Water is an important ingredient of concrete as its activity participates in the chemical reactions with cement. The strength of cement comes mainly from the binding action of the hydrated cement gel. The requirement of water should be reduced to that required for chemical reaction of hydrated cement as the excess water would end up in only formation of undesirable voids in the hardened cement paste concrete paste concrete. It is generally started that the water fit for drinking is fit for making concrete. In the present investigation drinking water was used both mixing and curing of concrete specimens.

ALUMINIUM POWDER - Aluminium Powder to be collected in kalishwari Metal Powders Private Limited, Sivakasi. Aluminium powder in the AAC industry is often made from foil scrap and exists of microscopic flake-shaped aluminium particles. It is used as a forming agent in AAC production. Aluminium is usually used to obtain AAC by a chemical reaction generating a gas in fresh concrete and forms a gas bubbles. It's finess modulus is up to 92%.

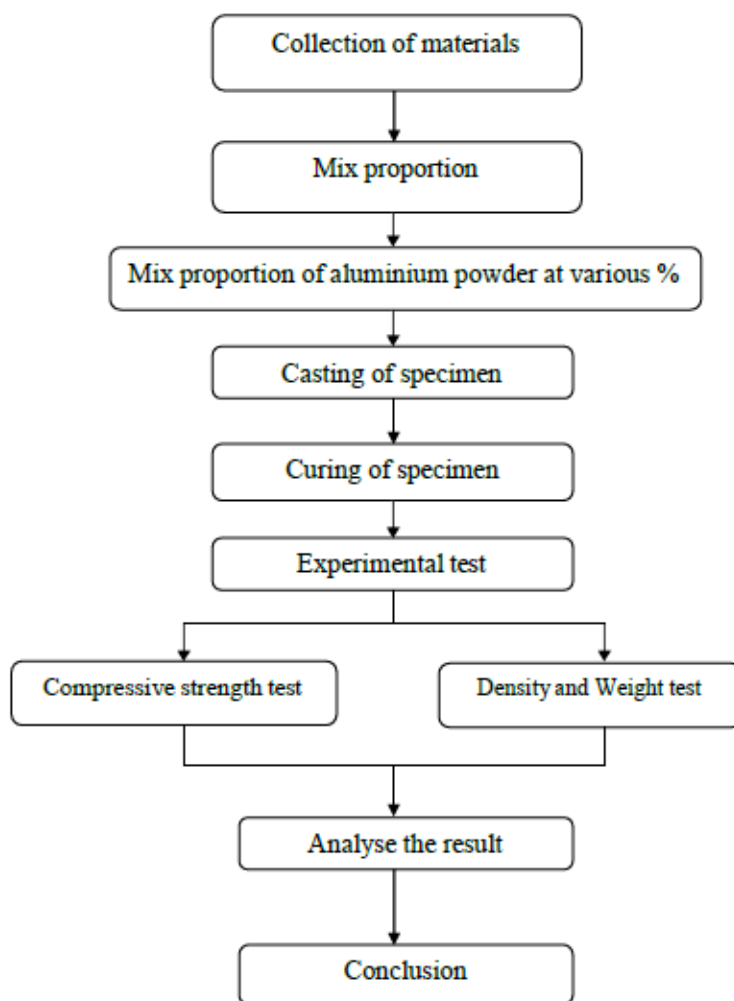
LIME - It is the main constituent which contributes to the strength. Its proportion has to be popularly maintained as to make the cement sound and strong. Excess of lime makes the cement unsound and causes the cement to expand and disintegrate. On the other hand, if lime is deficient, the strength of the cement is reduced and the cement sets quickly. Lime conforming to class C lime specified as per IS 712-

1984.

GYPSUM - The main purpose of adding gypsum in the cement is to slow down the hydration process of cement once it is mixed with water. When gypsum is added into the cement and water is added to it, reaction with C3A particles takes place to form ettringite. This ettringite is initially formed as very fine-grained crystals, which form a coating on the surface of the C3A particles. These crystals are too small to bridge the gaps between the particles of cement. The cement mix therefore remains plastic and workable.

FLY ASH Fly ash is a finely divided residue resulting from the combustion of powdered coal and transported by the fuel gases and collected by electrostatic precipitator. It is also called as pulverized fuel ash (PFA). This is particularly used for making high strength and high-performance concrete.

6. METHODOLOGY



7. MIX DESIGN

Mix design is the process of selecting suitable ingredient of concrete and determines their relative proportions with the objective of certain minimum strength and durability as economically as possible. The objective of the concrete mix design as follows

The first objective is to achieve stipulated minimum strength.

The second objective is to make the concrete in the most economical manner.

Cost wise all concrete depend primarily on two factors, namely cost of materials and cost of materials and cost of labor. Labour cost by way of form works, batching, mixing, transporting and curing is namely same for good concrete.

Therefore, attention is mainly directed to the cost of cement is sought for by designing the mix.

7.1 MIX DESIGN AS PER IS 10262-1982 FOR CONVENTIONAL CONCRETE

Design stipulation

Test data for materials

Target mean strength

Selection of water cement ratio

Selection of section

Calculation of cement and fly ash

Proportion of volume of coarse aggregate and fine aggregate content

Mix calculation

7.2 MIX DESIGN AS PER IS 2185 (Part 3) 2005 FOR AUTOCLAVED AERATED CONCRETE

Stipulation for proportioning

Test data for materials

Calculation of cement and mineral admixture

Trial

8. EXPERIMENTAL WORK

8.1 CASTING AND CURING OF TEST SPECIMENS

Concrete specimen is made on site to check that the strength of the concrete is the above minimum strength which has been specified. Making, curing and testing specimens should be carried out in the correct manner. Even small deviations from the standard procedures will usually lead to compressive strength results which are lower than the standard procedures will usually lead to compressive strength results which are lower than the true strength results which are lower the true strength of the concrete.

PREPARATION OF MATERIALS - All materials shall be brought to room temperature. The cement samples at the laboratory shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material care is being taken to avoid the intrusion of foreign matter. The cement shall then be stored in a dry place, preferably in air tight metal containers. Samples of fly ash, gypsum, lime and aluminium powder for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. In general, the forming agent and admixtures shall be separated and recombined for each concrete batch.

PROPORTIONING - The proportions of the materials including water in concrete mixes used for determining the suitability of the materials available shall be similar in all respects to those to be employed in the work. Where the proportions of the ingredients of the concrete as used on the site are to be specified by volume, they shall be calculated from the proportions by weight used in the cubes and the unit weights of the materials.



Fig. 1: Proportioning of materials

WEIGHING - The quantities of cement, each size of aggregate, aluminium powder and water for each batch shall be determined by weight to accuracy of 0.1 percent of the total weight of the batch.

8.2 Curing of concrete specimens

Normally membrane curing is used. The test specimens shall be stored on the site at a place free from vibration, under damp matting, sacks or other similar material for 24hrs $\pm$ 1/2hr from the time of adding the water to the other ingredients. Immediately after curing the specimens should be covered with damp matting or other suitable damp material and then with polythene or similar impervious sheeting and stored in a place where the temperature can be kept for approximately 16 to 24 hrs.



Fig. 2: Curing of specimen

8.3 TESTING OF CONCRETE

8.3.1 FRESH CONCRETE TESTS

8.3.1.1 SLUMP CONE TEST

Slump test is used to determine the workability of fresh concrete. Slump test as per IS:1199-1959 is followed. The apparatus used for doing slump test are slump cone.

The internal surface of the Mould is thoroughly cleaned and applied with a light coat of oil.

The mould is placed on a smooth, horizontal, rigid and non-absorbent surface.

The mould is then filled in four layers with freshly mixed concrete each approximately to one-fourth of the height of the mould.

Each layer is damped 25 times by the rounded end of the damping rod.

After the top layer is rodded, the concrete is struck off the level with a trowel.

The mould is removed from the concrete immediately by raising it slowly in the vertical direction.

The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured.

This difference in height in mm is the slump of the concrete.

Slump in cm	Workability	Uses
2-4	Very low	Concrete used for road construction
4-5	Low	Concrete of piers, slabs, walls
5-10	Medium	Concrete for normal RCC work

Table 1: Recommended slumps

Workability value for concrete is obtained by carrying out slump cone test. The variation in the slump arises due to the adding of cement with Aluminium Powder. The table shows the variation in the slump value with adding of Aluminium Powder. As the proportion of ash increases the water value as that of conventional concrete is less.

Workability	Medium	Medium	Medium	Medium
Aluminium powder in concrete (%)	0	0.05	0.06	0.07
Slump (cm)	5.3	5.3	5.4	5.2

Table.2: Workability of concrete

8.3.2 HARDENED CONCRETE TESTS

The following tests are as conducted.

Compressive Strength test

Density test

8.3.2.1 COMPRESSIVE STRENGTH TEST

The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural application concrete is used primarily to resist compressive stress. In those cases where strength in tension in shear is primarily the compressive strength is frequently used as a measure of these properties. Compressive strength is also used as a qualitative for other properties of hardened concrete. No exact quantities relationship between compressive strength and split tensile strength, modulus of elasticity wearing resistance, free resistance has been established nor are they likely to be. And these give much useful information to the engineers. For practically their compressive strength increases as the specimen size decreases. At least three cubes of 15cm×15cm×15cm are cast for each age usually 14 and 28 days. The specimens are cured for one day and in water for test of the days. The specimens are tested in saturated conditions. Cubes are placed in such a manner testing machine that the line of loading is perpendicular to the direction it was cast. Constant load of 140 kg/cm²/min is applied till failure. Compressive strength = Ultimate load/Bearing area.

PLACING THE SPECIMEN IN THE TESTING MACHINE:

The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the specimen which are to be in contact with the compression platens. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast that is not to the top and bottom.

The axis of the specimen shall be carefully aligned with the center of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine. As the spherically seated block is brought to bear on the specimen the movable portion shall be rotated gently by hand so that uniform seating may be obtained. The load shall be applied without shock and increased continuously at a rate of approximately

140kg/cm²/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall be recorded and the appearance of the concrete and any unusual features in the type of failure.



Fig. 3: Compressive strength test

8.3.2.2 DENSITY TEST ON HARDENED CONCRETE

After 28 days curing, one set of concrete specimens were taken out from storage for density test according to ASTM C 642, for testing at particular day. These specimens were turned to SSD (Saturated Surface Dry) condition by removing water from the surfaces. Then SSD weight of samples in air (C) was measured. Next the specimens were placed in oven at a temperature of 100 to

110⁰C for 24 h. After that weight of the specimen was measured. This is oven dry weight of samples in air (A). After that, the specimens were placed under water in a bucket and weight under water (D) was obtained. Temperature of water at test day (T) was also recorded and water density (ρ) was calculated for that temperature. Then from density of concrete was calculated. From this test results, it can easily be said that density increases with days. But rate of density change is low. Concrete with SC shows more density values than concrete with BC.

$$\text{Dry density (bulk density), } g_1 = A\rho/(C-D)$$

9. RESULT AND DISCUSSIONS

In the present investigation compression strength test, Density and weight test are carried out for Conventional Concrete and Autoclaved Aerated Concrete (AAC). Compression strength, weight and density test for Autoclaved Aerated Concrete of mix m₁, m₂, m₃ for 28 days are shown in below tables.

9.1 COMPRESSIVE STRENGTH RESULTS

S.NO.	Design Mix	Aluminium powder added (%)	Compressive strength (N/mm ²)
1	M ₁	0.05	2.90
		0.06	2.45
		0.07	1.45
2	M ₂	0.05	5.20
		0.06	3.87
		0.07	2.98
3	M ₃	0.05	7.50
		0.06	6.83
		0.07	5.28

Table 3: Compressive Strength of Autoclaved aerated concrete in 28 days

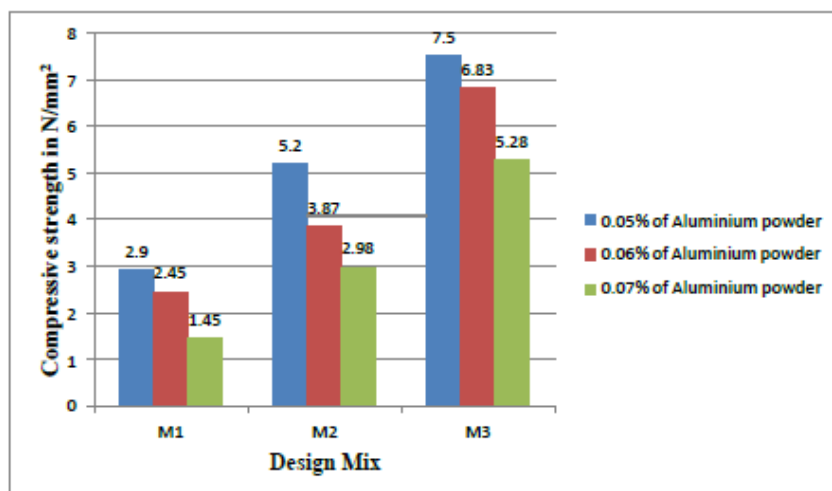


Fig.4 Compressive strength of AAC in 28 days

9.2 WEIGHT AND DENSITY RESULTS

S.NO.	Design Mix	Weight of the concrete (kg)	Density of concrete (kg/m ³)
1	Conventional concrete	8.62	2554.9
2	M ₁	1.86	550
3	M ₂	2.19	650
4	M ₃	2.57	760

Table 4: Weight and Density of Concrete Specimen at 28 days

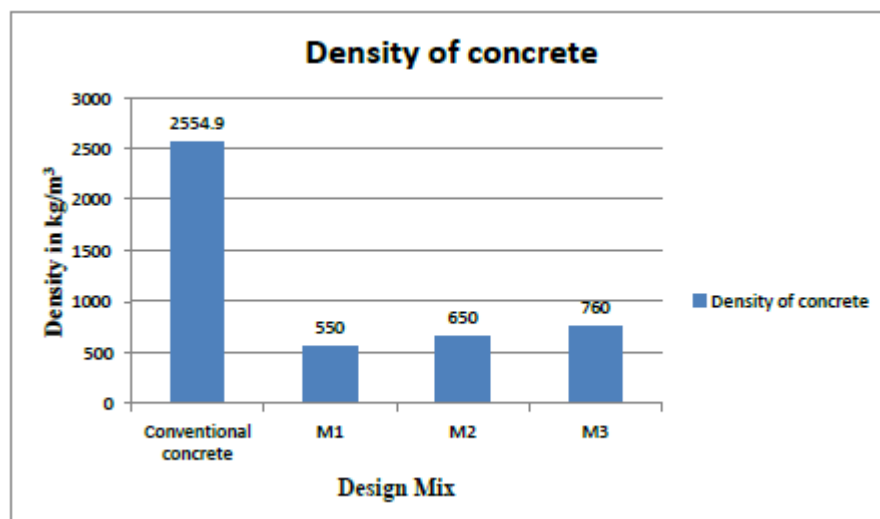


Fig.5 Density of concrete specimen at 28 days

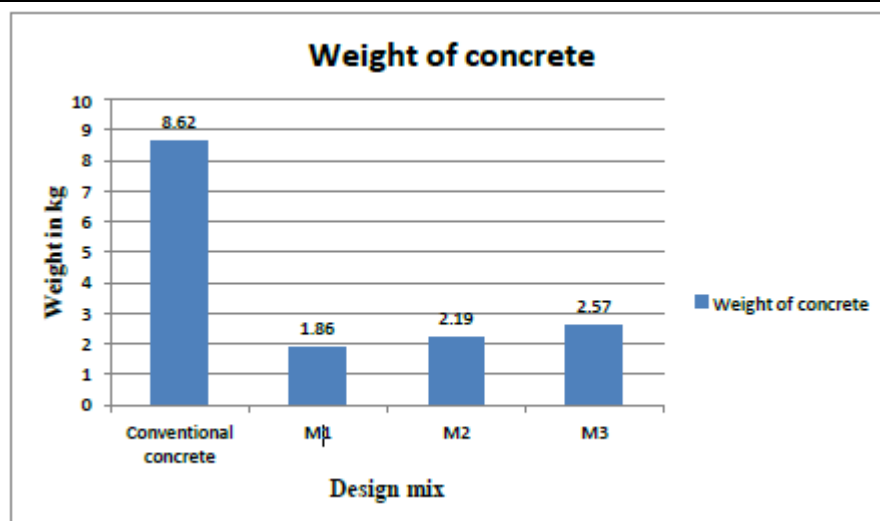


Fig.6 Weight of concrete specimen at 28 days

Comparing with normal concrete autoclaved aerated concrete has less weight and density but it has less compressive strength adding additional admixtures with different proportion the strength of the concrete increased. Comparing with normal concrete for the same design mix the light weight concrete has less weight and higher compressive strength than other proportions of aluminium powder added.

10. CONCLUSION

Based on limited experimental investigation of the Autoclaved Aerated Concrete is much lighter than Conventional Concrete. It is composed of cement, lime, gypsum, fly ash, high water-cement ratio and aluminium powder. Just as we mix the aluminium powder in the cement slurry the hydrogen bubbles are formed. It consists of many pores and it can withstand upto G+4. It is a good insulator of heat and sound thus can be used in place of conventional concrete blocks or at the place of conventional bricks. AAC block has 55.92% lesser density than conventional concrete.

The mix proportion of aluminium powder is added up to 0.05% to 0.07%. By increasing quantity of aluminium powder gradually to cement slurry the compressive strength decreases. Adding additional admixtures like fly ash, lime, gypsum strength of the concrete increased. The advantages of autoclaved aerated concrete are to reduce the mass or dead load, thermal resistance, faster construction, easy workability and design flexibility, energy efficiency, good sound insulation properties of the concrete structures, etc, while maintaining adequate strength. Autoclaved aerated concrete (AAC) has a desirable strength it is used in structures such as floors, roofs, lintels and it is also used for the buildings up to G+4. The disadvantages of autoclaved aerated concrete are skilled labours are required, contractor are less familiar with the product, projects far from manufacturing facilities will suffer from higher initial cost.

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