# STUDY ON AERATED CONCRETE BLOCKS

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**Abstract -** *This paper summarises the current knowledge in the usage of light weight concrete masonry blocks. The paper comprises of masonry performance of such a construction material, different materials used for constructing light weight masonry blocks, and different tests to evaluate the performance of the masonry structures.*

***Key Words***: Aerated concrete, Pozzolanic materials, Aerating agent, Aluminium powder, Aerated concrete blocks, Masonry wall …

## 1. INTRODUCTION

Lightweight concrete is an important construction material nowadays, as it increases thermal insulation properties and also decreases the thermal load coming on the building [1]. Light weight concrete is widely using all over the world due to its light weight, high strength, low thermal conductivity, low shrinkage, low absorption, high heat resistance and which possess sharp edges and corners [2].

Mainly, the light weight concrete has three classifications: (i) no-fines concrete, (ii) lightweight aggregate concrete and (iii) aerated concrete. The aerated or foam concrete is produced under CLC technology. Cellular light weight concrete has good mechanical properties, transport properties, thermal insulation and sound insulation. Cellular light weight concretes are produced by mixing the ingredients like cement, fly ash, foam and water in the required proportions in the mixer. The foam is the aerating agent which pumped to the concrete through a specialised equipment that adds fixed volume of air voids at constant pressure [3]. Barleena Thomas et al. (2019) optimized the foam volume based on density and compressive strength. Various percentages of foam by wt of cement (2.5%,5%,7.5%,10%,15%,20%) were taken. Low density and required strength was obtained at 5% and 7.5 % of foam [4].

Aerated concrete is not concrete, a cement or lime mortar, in which air-voids are entangled in the mortar matrix by incorporating an appropriate aerating agent. Aerated concrete can be again grouped dependent on the technique for pore development, such as (i) air-entraining method or gas concrete (ii) foaming method or foamed concrete and (iii) combined pore forming method. Another classification based on curing method (i) non autoclaved aerated concrete and (ii) autoclaved aerated concrete.

Air entraining method in which the air entraining chemicals are added into the mortar in the liquid stage or plastic stage, when this gas escapes, a porous structure will be created. Aluminium powder, hydrogen peroxide or bleaching powder and calcium carbide are different aerating agents and liberate gases like hydrogen, acetylene and oxygen respectively. Most commonly using aerating agent is Al powder due to its efficiency.

Foaming method is the most economical method and which involves a controlled pore forming technique. Here no chemical reactions are involved and the pore development is accomplished through mechanical methods. That is, a foaming agent mixed with water or mortar. The different foaming agents utilized are: detergents, glue resins, resin soap, hydrolysed proteins such as keratin, Saponin etc.

In combine pore forming method both foaming an air entraining methods are combined together. It uses both Aluminium powder and the glue resin [5].

E. Muthukumar et al. (2017) studied the effect of dosage of Aluminium powder and fineness on the properties of moist-cured aerated concrete such as workability, rate of aeration, fresh and dry density, Compressive strength, water absorption etc. The variations of workability are determined by Marsh cone test and flow table test. The workability of aerated concrete decreases with increment in the rate of aeration. For a desired density, the dosage of Aluminium powder decreases with the increment of fineness and for a constant Al powder dosage and W/C ratio, the dry density decreases with the increment of fineness of Aluminium powder. And the compressive strength will be highest will be at lowest fineness [6].

The density of light weight concrete ranges between 320-1920 kg/m3. According to the range of bulk density, the light weight concrete has another classification: low-density concretes (300-800 kg/m3), moderate-strength concretes (800-1500 kg/m3), and structural concretes (1350-1920 kg/m3). The compressive strength of the above concretes varies in the range of 0.7-2.0 MPa, 7-14 MPa, 17-63 MPa respectively [7].

Many pozzolanic materials were used as the binders instead of cement binder or partially replaces the cement content to get higher strength and well packed structural system.

Indu Susan Raj et al. (2019) evaluated the replacement of cement by flyash in aerated concrete. The optimum strength and density were obtained at the 20% replacement of cement at the Al powder dosage of 0.25% by wt of cement [8]. Studies similar to test the effectiveness of cement replacement by fly ash also conducted by Susan Indu Raj et al. (2018). In that study, she obtained the optimum replacement is 20% by wt of cement. And the optimum Al powder dosage was observed at 0.25% an 0.5% by wt of cement [9].

Sabarinath R et al. (2016) studied the influence of mineral admixtures (GGBFS and fly ash) in aerated concrete. He found that when the mineral admixtures replace the cement, density decreases due to the reduction in specific gravity. And the optimum strength and low density was obtained at 25% replacement of GGBFS a fly ash. Here, the optimum Al powder dosage was 0.5% by wt of cement [10].

Aneesa Mol.U.M et al. (2017) conducted studies on foam concrete. And the replacement of mineral admixture fly ash to cement has optimized as 20% [11]

Merin K Abraham et al. (2014) studied the influence of a normal cementitious system containing fly ash. Strength and workability was greater at the replacement of cement by15% [12].

Ramesh Babu T.S et al. investigated the effect of compressive strength for the as the partial replacement of cement by class F fly ash at different percentages. The increase in FA replacement from 25% to 55%, the compressive strength is found to be decrease. The mixes containing fly ash, attains higher strength at later stages of curing due to the pozzolanic reaction of fly ash. After 56 days or 112 days, a significant reduction of strength observed after 35% of cement replacement by fly ash. So the optimum results will be at 35% FA replacement [13]

Ghasem Pachideh et al (2019) studied the effect of various pozzolanic materials on the mechanical properties and water absorption of autoclaved aerated concrete. Pozzolanic materials such as silica fume, GGBFS and zeolite were added to the concrete at 7, 14 and 21% by cement weight. And he observed that the compressive strength was improved by 72% at 21% of replacement. And also the tensile strength was improved by 25% at 7% replacement and satisfactory tensile strength at 21%. Therefore 21%of cement replacement by GGBFS is optimum here. And also the GGBFS reduces water absorption by 13, 24 and 35% at 10,30 and 90 minutes respectively [14]

P. Dinakar etal. (2013) studied the effect of cement replacements with fly ash in SCC. It is observed that replacement of cement with fly ash around 30-50% of the total cement will be the optimum for developing SCC when we are using the binder as Portland pozzolanic cement. When PPC is used, higher percentage replacement of fly ash, i.e.; more than 50% is not suitable. And higher compressive strength of 100 MPa was observed at 30% replacement. At this percentage, durability of concrete will be high also. It possesses high chloride penetration resistance [15]

Kasim Mermerdas (2017) conducted a study on using Fly ash or GGBFS as binder materials to produce light weight geopolymer mortar. And the study concludes that as the binder content increases, strength of LWGM increases. But the increment is not proportional. Here the aggregate used are light weight fine aggregates. Due to the very high porosity,6 the whole density is less but when the LWFA is more the compressive strength will be less [16]

Kamal Nepune etal. (2016) studied the effect of Fly ash and GGBFS as Activated geopolymer binders as an option in contrast to the Portland cement binder. The use of these binders helped to reduce the water content. And also those have comparable workability with respect to the OPC concrete. Geopolymer concrete showed better workability retention up to 2 hours than OPC concrete of same grade. Normal strength concrete with the partial replacement of OPC by 20-40% of GGBFS or FA gives the same strength as that of geopolymer concrete which uses GGBFS or FA as the binder material [17]

To incorporate the light weight in concrete can be done by mainly by the partial replacement of the fine aggregate by lightweight materials.

Properties of fresh and hardened lightweight aggregate concretes are studied by Kou et al. (2009) by partially replacing the fine aggregates by PVC plastic granules. The natural Sand is partially replaced by waste PVC plastic granules at various percentages such as 5% to 45% by volume of fine aggregate. Two major discoveries are obtained. The positive side of the study shows that the partial replacement of PVC granules in concrete cubes results lower density, having lower drying shrinkage, more ductile and higher resistance to Cl- ion penetration. The negative side reveals that the compressive strength, tensile splitting strength and workability of the concretes were reduced. The results thus obtained shows the role of plastic granules in aerated concrete blocks [18].

Sarika R et al. (2017) studied the effect of aerated concrete in which fine aggregate is partally substituted with rubber powder and cement is replaced with fly ash. She has found the fractional substitution of fine aggregate with rubber decreases the density. The optimum percentage of replacement of rubber was found as 5% by wt of sand. The workability of aerated concrete decreases with increment in percentage of replacement of fine aggregate by rubber [19]. Tom Damion et al. (2018) investigated the influence of aerated concrete incorporated with flyash and PVC granules. In which optimum dosage of Al powder was 0.5% by wt of cement. PVC content varied by 25-100%. For required strength and low density, 50% substitution of fine aggregate by PVC is considered as optimum [20].

Siveji et al. (2018) added quarry dust keeping binder level constant with no M sand to make aerated concrete masonry block. As per the required strength and density, the ratio of quarry dust to the binder is optimized as 1:0.5 [21].

Geethu Kallunkal et al. (2016) conducted studies on foam masonry blocks in which fine aggregate is partially replaced with quarry dust. The result was optimized at 30% replacement [22]. A similar study was conducted by Paul Ben Pulliattu et al. (2017) on aerated concrete and got the optimum quarry dust replacement as 50% [23].

L K Lohani etal.(2012) studied the effect of the replacement of fine aggregate partially by quarry dust. This study aims at exploring the possibilities of quarry dust being used as such a substitute. Design mix of concrete with 28 days compressive strength 20MPa were cast with 0% 20%, 30%, 40%, and 50% replacement of sand with quarry dust. Various laboratory tests including fresh and hardened concrete tests were conducted on mixes and results were compared with standards. This eliminates large scale mining problem [24]

Ansu John et al. (2013) investigated the effect of partial replacement of fine aggregate by furnace slag. 30% replacement gives higher strength and slump value compared to the control mix [25].

Hameed et al. studied the effect of replacement of FA by marble sludge waste and quarry dust. Use of industrial wastes as partial replacement for fine aggregate, which decreases the utilization of natural assets, vitality and contamination of earth makes the concrete green and competent for sustainable development. Marble sludge powder when used as filler material reduces the total voids content in concrete. Quarry rock contains very small sized particles with no silt or organic impurities which results in the improvement of concrete strength. Addition of quarry rock dust and the powdered marble sludge chemically reacts with concrete admixture and results improvement in pozzolanic reaction, concrete durability and micro-aggregate filling. Compressive, split tensile strength and durability for concrete made of quarry rock dust shows 1.14 times higher than the normal concrete. Comparatively sulphate attack resistances also increased. To reduce environment pollution and to improve durability of concrete can be attained by the application of green concrete [26].

Pooja et al (2018) investigated the behaviour of concrete with partial replacement of fine aggregate with waste plastics. The fine aggregate is replaced by the plastic waste of small grain size range ranges of 15-30%. Slump test, compressive strength tests, water absorption test and water permeability test were conducted to understand the properties of concrete. The compressive strength of the concrete blocks incorporated with waste plastic was higher compared to the strength of conventional concrete blocks. Strength is maximum at 15% [27].

Aboobacker Sidheeqe M S et al. (2019) reviewed many journals and studied the utilization of waste materials as filler in aerated concrete. Granite powder replacement positively affects on workability, strength and durability properties. Marble powder occupies the pores created by Aluminium powder and thereby increases strength of aerated concrete. Replacement of FA by quarry and rubber increases the energy efficiency. So the usage of waste materials decreases the cost and land space for disposal [28]. Incorporating the merits of the light weight concrete in the production of masonry structures is a better concept. The concrete production for the casting of masonry units will be different for other concretes compared to the light weight blocks. To minimize the cost and shrinkage, the quantity of cement taken to be minimized. Generally, the conventional concrete blocks are cast with very less amount of water with minimum slump. Those things are entirely different to the lightweight concretes. The factors such as grading of aggregates, Mix proportions, mechanical resistance of the aggregates, the particles shapes, the type of block machine and the curing process are very important to the light weight concrete blocks manufacturing. Generally, in [29].

## 1.1 Characteristics of Aerated Concrete

(i) Workability

Workability is measured using flow table. Workability of the cement paste or mortar is based on the flow. When the water to the solid ratio increases, flow or workability increases. Stiff pastes are not suitable for aerated concrete production [30].

(ii) Density

Water cement ratio is a factor that affects on the amount of aeration and thus the density of concrete. If it consists of pozzolanic materials, Water solid ratio is to be considered instead of water cement ratio. The water cement ratio should not be much lower due to the insufficient aeration and should not be not much higher due to the rupture of voids. Thus the water cement ratio is taken on the basis of the consistency of the concrete, there is no any relevance to the selection of pre-determined one.

(iii) Water absorption

Water absorption reduces with increase in the density of concrete. As per the study conducted by Muthukumar etal.(2017), For a constant density, the water absorption has reduced for the increase in curing temperature. A comparative density with minimum water absorption is obtained at a temperature of 90ºc [6].

(iv) Micro structure

N. Narayanan et al. investigated the micro structural properties of the aerated concrete. The aerated concrete in which large number of voids are uniformly distributed to reduce the density. This study reports the investigations conducted on the structure of cement-based autoclaved aerated concrete (AAC) and non-AAC with sand or fly ash as the filler. The variation of the compressive strength, flexural strength etc. are explained based on the micro structure and the analysis was based on SEM and XRD. Micro structure of the aerated concrete may be altered due to the curing conditions, compositional variation of filler materials etc. The hydration process in the cement based autoclaved aerated concrete will be faster than the aerated concrete containing sand and fly ash as filler. Because, the fly ash will be surrounded by the hydration products formed by cement and slow down the hydration process. The rate of hydration also affects the micro structure. So that, the micro structure of cement based AAC will be stable with time. The reaction products in the AAC will be better crystalline and in non AAC, it will be poorly crystalline. So that, AAC possesses good strength compared to other. An inter transition zone is present at the void-paste interface. The voids act as aggregates of zero density. The transition zone will be less porous and unlimited space is available for hydration and move out the bleed water [7].

## 2. AERATED MASONRY BLOCKS

Light weight concrete blocks are usually produced from Portland cement, water, and sand or any lightweight aggregates. The prime consideration of using the aerated concrete masonry blocks is to reduce the density of masonry units [31]. Light weight concrete masonry blocks can be made by adding light weight aggregates or constructing the blocks as hollow. Light weight aggregates can be prepared by the processes such as expanding, palletizing, or sintering processes. The aggregates also can be prepared by processing natural or local materials, and aggregates consisting of the end products of coal or coke combustion. The aggregates are mainly composed of lightweight cellular and granular inorganic materials. [32].

Light weight block increases productivity even at the same labour price, and workers are typically more efficient because the lighter block is less intensive. The self-weight of Light weight block is much lesser than the normal concrete masonry blocks. As block weight is reduced, installed cost is also get reduced [33].

Indu Susan Raj et al. (2014) studied the properties of air entrained masonry blocks. The optimum percentage of Al powder should not be more than 2% for masonry blocks. And she found that the compressive strength of aerated blocks is higher than that of commercially available light weight cement blocks [34].

The thermal insulation of the masonry walls also can be improved using these light weight blocks without using any additional insulating material. That is, thermal comfort can be improved for a masonry wall, either increase the thickness of the wall, or use cavity walls or using some additional insulating material. The light weight block permits higher thermal comfort with single leaf wall structure, that is only single layer of the blocks is required. And its construction is different from cavity wall construction, which consists of two layers of masonry with a cavity between them. Another solution to improve the thermal insulation to construct cavity walls. This alternative solution to cavity walls can be a very interesting solution under economic and technologic point of view, because can be more economic, more quick to build and less subjected to workmanship quality. The use of light weight concrete blocks in the masonry system also increases the water tightness.

IS 2185 Part 1 suggesting that Light-weight Concrete Blocks can be Solid or hollow concrete blocks, Size of concrete masonry blocks are taken according to the requirements. The cement replacement by the Fly ash can be done up to 20% by volume of cement in masonry blocks [35].

Autoclaved aerated concrete is a class of lightweight concrete that is made by first creating gas bubbles in the fresh concrete and then cured in high-pressure steam is known as autoclaved. The autoclaved aerated method is used in the production of AAC masonry blocks. This is because the aerated concrete produced from this method has a uniformly generated cellular structure of air voids in the range of 0.1-1 mm forming in the cement paste or mortars. It possesses one-sixth to one-third of weight of the conventional concrete blocks and high thermal and heat resistance. It is highly porous with 60-70% of air. Size of AAC blocks is 610mm length, 200mm height, 50-375 mm thickness. AAC is made of quartz-rich sand, lime, cement and aluminium powder. Aluminium power is used as the aerating agent in the concrete [36]. M. Kalpana et al. reviewed many studies about autoclaved aerated concrete. The AAC has many advantages over conventional concrete. It has advanced strength to weight ratio, lower coefficient of thermal expansion, and good sound insulation as a result of air voids within aerated concrete. The AAC blocks can provide better stability in inside the building. The AAC blocks are highly resistant to earthquake. It's safer and reliable for the building subjected to earthquake loading. And these blocks can afford very high levels of electricity. These are all the ways by which the AAC blocks ensure stability to the structure and also it is stable in its shape [37]. Autoclaved aerated concrete masonry blocks are shown in figure 1.

Figure 1: Autoclaved aerated concrete masonry block

Keun-Hyeok Yang (2015) Conducted a study to develop high performance aerated blocks as an alternative to the autoclaved aerated concrete blocks without using the high pressure steam curing process. For getting high-strength at an early age, for aerated concrete under an air curing environment, the ordinary Portland cement was controlled to 1.5% and 3% anhydrous gypsum was then added; and a chemical polyethylene glycol alkyl ether in a poly carboxylate-based water-reducing agent was added at various percentages and modified to 28%. And also a foaming agent based on a protein-hydrolization with enzymatic active components, which helped to produce very close pores. Various prediction models were designed to support the determination of the mixture proportions to obtain required values for dry density, compressive strength, and thermal conductivity of aerated concrete and those values to be comparable with AAC blocks. For the required air volume and compressive strength, the optimum value for the foaming volume rate and water binder ratio are 1250% and 25% respectively. At the same value of dry density, the compressive strength after 28 days of curing is higher than the strength of the conventional concrete blocks [38].

Major application of these aerated concrete blocks is to construct masonry walls. As per IS 6042-1969, Light-weight concrete blocks shall be embedded with cement or lime mortar. A proportion of 1: 2: 9 cement, lime, sand mortar may generally use for normal masonry work, If the load is too much high and severe exposure condition, then a proportion of 1:1:6 mortar shall be used. If a good quality lime is not available, 1: 6 proportion of cement and sand mortar may be used [39].

If the blocks are hollow, then a grout must be given to fill that holes, if not, the load transfer will not be satisfactory. Grout is a fluid mixture of cement, aggregates, and water, which is used to fill vertical and horizontal voids in the blocks, in order to increase the strength and stiffness of the masonry wall, reinforcing steel bars are embed with grout. Grout is more important material when the masonry walls are reinforced. The compressive strength of the walls increases when the grout strength increases [40].

Individual block units will be tested for compressive strength, Water absorption, Thermal conductivity, Drying shrinkage etc. All the tests were conducted according to the IS 2185(Part 1): 2005 [41]. Compressive strength, flexural strength and thermal conductivity of autoclaved concrete block made using bottom ash as cement replacement materials

Watcharapong Wongkeo (2012) tested the Compressive strength, flexural strength and thermal conductivity of autoclaved concrete block made using bottom ash as cement replacement materials [42]. The thermal conductivity test was carry out in accordance with ASTM D 5930-01[43]. Three samples of 40 x 40 x 160 mm prisms were tested for flexural strength inaccordance with ASTM C 348-97 [44].

## 2.1 Testconucted on Masonry Walls

The mechanical properties of masonry walls evaluated by testing a small portion of wall that represents the entire system. Masonry walls are tested for compressive strength test, Flexural strength and Shear strength. Mainly the compressive strength. Because, the major load on the masonry wall is compressive or vertical loads [45].

The performance of masonry walls is evaluated by using masonry prisms or masonry wallets. conducted a study on the masonry prisms and wallets. Masonry prisms are the arrangement of masonry blocks with less than 3 courses. Masonry wallets are arrangement with 5 courses or more. He concludes that the prisms are a better representation of the actual masonry construction. An also determined that 3-course prism better represents masonry properties of the walls when compared to 2-course prisms [46].

After the masonry prism test, the strength calculated must be multiplied with a correction factor. The correction factor is determined according to the ratio of prism height to least lateral dimension of prism. Minimum length of the prism shall be 100mm. The load is applied perpendicular to the bed joints. These are specified under ASTMC 1314 or IS 1905:1987 [47,48].

Željka Radovanović etal. (2015) evaluated the mechanical performance of the walls with different masonry units. Masonry wallets with clay brick block and concrete blocks are tested for compressive strength. The testing of compressive strength and elasticity modulus have been performed by the conditions defined in the European standard EN 1052-1[41]. Comp strength of clay brick block is higher than concrete blocks. Elastic modulus is higher for concrete blocks Due to the brittle nature of clay brick block, the masonry wall does not have higher strength [34]. Masonry prisms can be arranged in different configurations. But as a representative of the whole wall, we are generally arranging the blocks in the way that is given in the figure 2: [49].

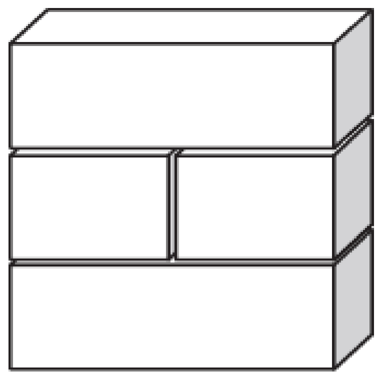

Figure 2: Masonry prism configuration

Masonry prisms with different configurations are used for testing compressive strength, Flexural test, Shear test etc. The dimensions of the compressive prism were 390mmx190mmx190mm. shear prism were 590 mm x 390 mm x 190 mm. masonry specimens in sections perpendicular to the bed joints for the flexural strength test were in stretcher bond with dimensions of 1390 mm x 790 mm x 190 mm [50].

Jamshid Zohreh Heydariha et al. (2017) studied how the strength of masonry is dependent on factors such as block size, block strength, grout strength etc. As the block strength and size increases, strength of masonry increases, due to the less number of joints. Load carrying capacity increases with increase of grout strength [51].

Fernao etal.(2019) conducted a study on compressive strength of high strength concrete grouted masonry prisms. Two types of prisms are there. Hollow prism and Grouted prism. The efficiency of grouted masonry depends on many factors like construction procedures, compaction of the grout, shrinkage characteristics of the grout, block geometry, and bond between grout and block. When the high strength grout is used, the shrinkage will be less and there is no significant difference in between 14 days and 28 days' compressive strengths [52].

## 3. SUMMARY

Masonry is the oldest structural system which mainly resists the compressive loads. A major need of the masonry walls to reduce the self-weight of the structure and increase the productivity. When the basic units of the masonry possessing lighter weight, then those can be easily laid. So that the labour cost and installation cost also can be reduced. Use of light weight masonry blocks as the basic units of masonry system instead of the normal or conventional masonry blocks can improve all these requirements. The properties such as thermal insulation, water tightness etc. are higher for the light weight block. The light weight can be achieved by many techniques, mainly aeration. Various types of aeration techniques are there. And also to many materials are replaced the aggregate to gain lighter weight. Along with aeration, to improve strength, either pozzolanic materials partially replaces the cement content or use of the pozzolanic materials as binders instead of using OPC.

Many tests are conducted on individual light weight blocks. Such as for compressive strength, flexural strength, Water absorption, Thermal conductivity, Drying shrinkage etc. When these blocks are applied to the masonry wall construction, then testing is required to the whole wall. It is difficult to test the whole wall, instead of that, we can use masonry prisms, a small portion of wall represents the entire system. Masonry prisms are tested to study the compressive, flexural and shear behaviours of the masonry wall. Among that, the compressive strength test is more important because the masonry wall is mainly subjected to the compressive or vertical loads.

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