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Properties of Autoclaved Aerated Concrete in Different Curing Conditions: A Review

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Abstract: Autoclaved aerated concrete (AAC) has many benefits for structures, such as heat insulation, sound insulation, fire resistance, reduced dead weight, and many more. AAC products include blocks, wall panels, floor and roof panels, and lintels. Besides its insulating capability, one of AAC's advantage in construction is its quick and easy installation since the material can be routed, sanded, and cut to size on-site using standard carbon steel band saws, hand saws, and drills. Although AAC has been produced for many years, there are still some points that need to be clarified. One of these points is the effect of humidity intrusion on AAC members in areas with high relative humidity levels, like Mediterranean climates. Therefore, various tests associated with the mechanical and physical properties of AAC concrete should be carried out, particularly Compressive Strength test in order to assess the strength of AAC blocks. The current project intends to analyse the physical and mechanical properties of autoclaved aerated concrete blocks at three different curing conditions using an accelerated curing tank to compare the effects of curing on the properties of AAC.
Keywords: Aerated Concrete, Foam Concrete Pozzolanic Materials, Filler Materials, Compressive Strength

I. INTRODUCTION

One of the most important directions in modern building material science is the development and introduction of new effective heat-insulating materials, which is mainly due to the growth of the electricity rate and the cost of energy needed for heating buildings. As for the energy efficiency of buildings, increasingly stringent requirements for the thermal resistance of enclosing structures and controlled environment improvements in buildings are worth mentioning [1]. Lightweight concrete with a low density is an example of a material with efficient thermal characteristics and sound insulation for the structure. Lightweight materials can enhance the seizure capability of a building. The following are the different types of lightweight concrete: (a) Lightweight Aggregate Concrete; (b) Aerated, Cellular, Foamed, or Gas Concrete, which can be manufactured by creating bubble voids within the concrete or mortar mass using suitable air-entraining agents and provides greater homogeneity and distribution of the voids within the concrete; and (c) No-Fines Concrete, which can be manufactured by removing the fine aggregates from the mix, resulting in no segregation of the fine. It can be classified as (a) Structural Lightweight Concrete, (b) Masonry Concrete, or (c) Both shown in Figure.1 [2]. The Thermal Coefficient of the insulating concrete should be less than approximately 0.3 J/m^2 s °C/m.Different types of pozzolanic materials can be used as a replacement for the binder in concrete to reduce CO_2 emissions caused by OPC. GGBFS, fly ash, and silica have been used in place of OPC and were accounted to achieve better physical properties. In the presence of moisture, pozzolanic materials form calcium silicate hydrates after a chemical reaction withcalcium hydroxide.

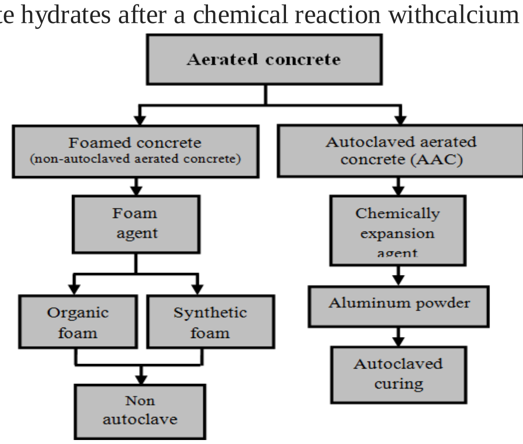

Fig.1. Classification of Lightweight AeratedConcrete

Sustainable waste can be used to partially replace aggregate in concrete. The accumulation of waste can have a negative impact on the environment. It can also be viewed as an effective way to recycle waste. Reusing or recovering waste has two main advantages. It moderates the use of ordinary resources and protects the use of landfills for non-reusable materials. Certain pre-treatment methods can be applied to improve the bond between the concrete matrix and the waste. Thus, an increase in strength was observed with the addition of the surface-modified waste. Concrete mixed with cement and pozzolanic materials are stronger than concrete mixed with cement alone. Concrete containing silica fume was tested with different proportions of rubber granules. The combination of crumb rubber and silica fume is stronger than the combination of crumb rubber and cement [3].

A. *Aerated Concrete*

Aerated Concrete is a new lightweight, highly insulating and durable building material available in a variety of sizes and thicknesses. Compared to red brick, aerated concrete blocks are lightweight. Aerated concrete blocks are two to three times lighter than regular concrete blocks. Aerated concrete can be divided into two grades based on the curing process. Autoclaved Aerated Concrete (AAC) and Non-Autoclaved Aerated Concrete (NAAC) [4]. Several studies have been conducted to investigate the effects of mixing ratio, thermal inertia properties, water-to-solid ratio, vapor pressure, and curing time on the properties of Autoclaved Cellular Concrete [5]. The amount of aluminium powder added affects the density of aerated concrete. Aluminium powder is the most commonly used air entrainment material. Hydrogen peroxide, bleaching powder, and calcium carbide can also be used, but release hydrogen, oxygen, and acetylene accordingly [6]. To obtain accurate physical properties of concrete, the porosity of AAC must be determined. Hydration reactions can be enhanced by high-pressure steam conditions. High-pressure steam also improves the properties of concrete. Microstructural studies of AAC show that hydration products fill the pores of concrete [7]. AAC blocks are approximately 85% lighter than red bricks, which can reduce structural weight. In other words, AAC blocks are inexpensive and have reasonable compressive strength [8].

AAC density is reduced by fly ash and GGBFS [16]. GGBFS initiates pozzolanic reactions to form CSH gels when mixed with cement. This makes GGBFS a suitable partial replacement for cement. In GGBFS, a pozzolanic reaction occurs after a certain age. Compressive strength values increase as the amount of GGBFS increases to 30% [9]. Replacing cement with GGBFS and fly ash helps aerated concrete reaches a strength of 25 MPa. Studies have been carried out on aerated concrete with various fillers. Rubber dust can also be used as a filler in aerated concrete. The exchange gives a less dense mixture. The optimal dosage of rubber powder was found to be 5% [3]. The addition of fillers also affects the workability of concrete. Induction furnace slag can be used as a semi-substitute for fines. However, workability shows a decrease in concrete with over 40% replacement of fine aggregate due to its angular nature [10]. Workability also depends on the addition of various mineral admixtures. Workability increases initially with the addition of mineral admixtures but decreases with higher cement replacement rates [11]. Superplasticizer dosage should be optimized based on admixture- cement compatibility and admixture-admixture compatibility. The workability of concrete is reduced by the addition of a liquefier [12].

Recently, a study was organized investigating the use of quarry dust as a substitute for natural aggregates. Experiments are conducted using conventional concrete pouring methods. Quarry dust, which is generated in large quantities both onsite and offsite, is a by-product of stone cutting, grinding, screening, and crushing and poses several environmental concerns. This reduces energy consumption and greenhouse gas emissions. About 30% of the total stone waste comes from quarries. This vast amount ends up in landfills [10]. A trade publication has investigated the use of waste as filler in aerated concrete, which is harmful to the environment and human well-being. Replacing granite powder has a positive effect on workability, strength and durability. Marble powder fills the pores created by aluminium powder and increases the strength of aerated concrete. Energy efficiency is improved by using rubber and rubber products instead of fly ash. In this way, the use of waste reduces disposal costs and land area [13]. A better concept is to incorporate the benefits of lightweight concrete into the fabrication of masonry structures. The production of concrete for casting masonry blocks is different from the different types of concrete for lightweight building blocks. To reduce costs and shrinkage, less cement should be used [14]. Conventional concrete blocks are typically cast with very little water and minimal slump.

B. *Foam Concrete*

Foamed concrete is produced either by the pre- foaming method or mixed foaming method Pre-foaming method involves the separate production of??base??mix??cement, slurry (cement paste or mortar) and a stabilized aqueous (water-based foam agent), and then the thorough blending of foam into a base mix [18]. In mixed foaming, the surface-active agent is mixed with the base mixture. During the process of mixing, the addition of ingredients helps to form a foam-producing cellular structures in concrete as shown in Fig. 2.

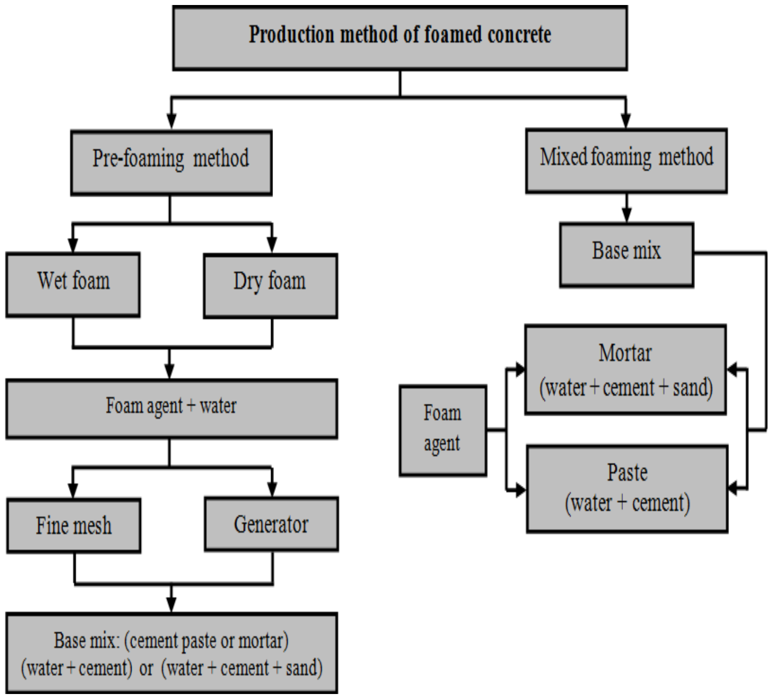

Fig. 2. Classification of Foamed Concrete

The preformed foam can be either wet or dry. The wet foam is produced by spraying a solution of the foaming agent over a fine mesh, has a bubble size of 2 to 5 mm, and is relatively less stable. Dry foam is produced by forcing the foaming agent solution through a series of high-density restrictions and forcing compressed air simultaneously into the mixing chamber. Foaming agents are used to obtain foamed concrete. It's called an air entrainer [19]. Foaming agents have the greatest impact on foamed concrete. When blowing agents are added to the mixing water, they create individual bubble cavities that are incorporated into the cement paste. The properties of foam concrete are highly dependent on the quality of the foam. Air voids are limited from 10% to 70% in aerated concrete created by air pockets. These air pockets can be generated by protein or synthetic-based propellants. Various methods can be used to create these air pockets [20]. A volume fraction of preformed foam can be incorporated into the cement paste by a method known as the physical foaming process. Air entrainment agents such as H2O2, fine aluminium or zinc powder can be used to entrain air into the cement paste through a chemical reaction. This process is known as Chemical Aeration Technology [21]. These two materials have different air entrainment mechanisms. Protein-based foam concentrates generate air bubbles through protein breakdown. They generate stable gas bubbles through the formation of hydrogen bonds between molecular groups [21,22]. Synthetic builders are hydrophilic, so they dissolve easily in water and generate air bubbles. Drainage, coalescence, and disproportional can affect foam stability. Therefore, different blowing agents produce foamed concrete with different performance [20]. The type of blowing agent used has a significant effect on the fluidity, compressive strength, water absorption, drying shrinkage and frost resistance of freshly foamed concrete [23,31]. It also affects the thermal resistance and adsorption coefficient of foam concrete [24].

Supplementary Cementitious Materials (SCMs) are the by-product of industrial production processes which can be used to improve the strength and durability of foam concrete due to its pozzolanic action. Silica fume, metakaolin, fly ash, and GGBFS are some of the important SCMs. These SCMs can be used either individually or as a partial replacement for cement [26]. Even though they do not contribute much to the early strength development, considerable increase in later strength is obtained considering the effect of filler type (fly ash) on foam concrete. A locally available foaming agent, 53-grade Portland cement, coarse river sand and class F fly ash were used for the experiment. Mixes which were prepared with fly ash as filler showed a better consistency value, increased strength due to increase in fineness, higher flow characteristics and an improved strength-to-density ratio [28,32]. However, with rise in density, water absorption decreased Very few studies have been made by incorporating GGBFS in foam concrete. GGBFS is a by-product of iron manufacturing which when added to concrete enhances its properties like workability, strength and durability [29,30].

II. PRODUCTION OF AUTOCLAVED AERATED CONCRETE

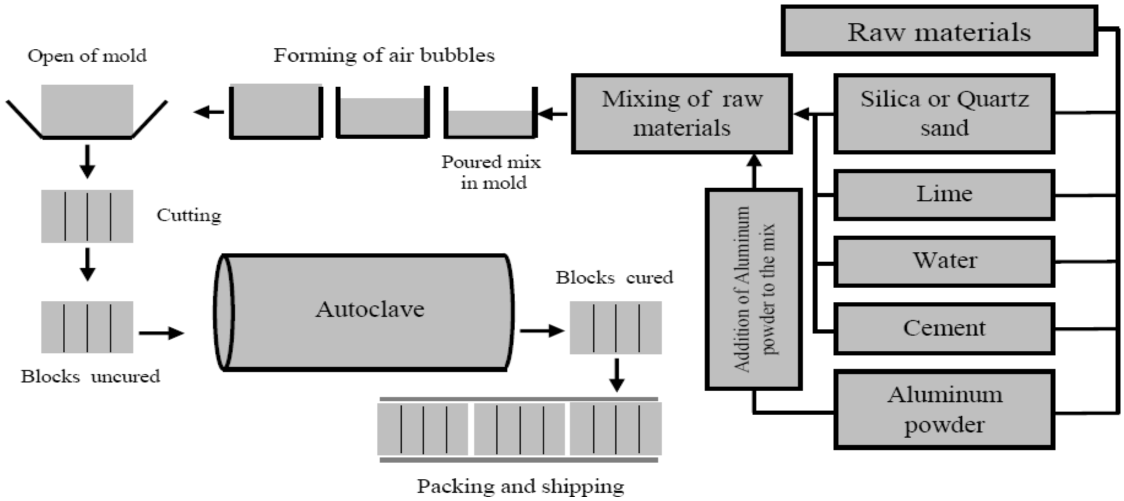

Fig. 3. Process Phases of AAC Production

A mixture of finely ground sand, cement, quicklime (quicklime), anhydrite or gypsum, and aluminium powder or paste (foaming agent) is mixed with water to form a slurry [6]. The slurry is then poured into steel moulds to about two-thirds the volume of the mould. A reaction then takes place between aluminium and water in an alkaline environment to produce hydrogen gas (H_2). Small air bubbles are generated and as the slurry hardens, the expanding air bubbles create a cake-like product that fills the volume of the mould. In the manufacture of reinforcing elements such as floor, wall and roof panels, corrosion-resistant steel reinforcements are placed in the mould either before or immediately after the casting.

During the so-called rising process, the cake generates heat due to the dissipative reaction of the burned lime. This accelerates the hardening reaction of the cement and the "cake" develops sufficient green strength for handling after about 2-4 hours. The cake is then cut horizontally and vertically into blocks or slabs using cutting equipment such as high-pressure wires and forming knives. The cut cake is then transferred to an autoclave where hot saturated steam initiates the curing process of the AAC material. The typical pressure range is 1.1-1.3MPa (160-190 psi) and temperature range is 190-205°C (380-400°F).

In the hardening process, finely ground sand reacts with lime and water to form a specific hydrated calcium silicate crystal structure known as tobermorite ($C_5S_6H_5$). This is a natural mineral. After about 12 hours the finished building material is ready for packing, shipping and assembly. The material hardensfurther after autoclaving process [7,18].

III. CHARACTERISTICS OF AERATED CONCRETE

A. Workability

Workability is measured using a flow chart. The workability of cement paste or mortar is based on fluidity. Flowability or processability increases as the ratio of water to solids increases. Hard-paste is not suitable for the production of aerated concrete [33].

B. Density

The water-to-cement ratio is a factor that affects the aeration rate and thus the density of the concrete. If made of pozzolanic material, consider the water-to-solids ratio, not the water- to-cement ratio. The water-to-cement ratio should not be too low due to poor aeration and should not be too high due to cavity eruption. Therefore, the water-cement ratio is assumed based on the consistency of concrete and there is no point in choosing a given one.

C. Water Absorption

As the density of concrete increases, the water absorption decreases. According to the water absorption at constant density decreased with increasing curing temperature. The comparative density of with the lowest water absorption is at a temperature of 90 °C [34].

D. Micro Structure

Micro structural properties of the aerated concrete is the 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. Thevariation 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, AAC possesses good strength compared to others. 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 [6].

IV. CONCLUSIONS

Aerated lightweight concrete is unlike conventional concrete in some of its materials and properties. Aerated lightweight concrete does not contain coarse aggregate and has many advantages, including low density with higher strength when compared to conventional concrete, improved thermal and sound insulation, and reduced dead load, which could result from several advantages, such as decreased structural elements and reduced transferred the load to the foundations and bearing capacity. Foamed concrete is different at the end of the process of forming air voids as compared with autoclaved aerated concrete. The air voids in foamed concrete are formed by foam agents; this operation is physical processing. The air voids in autoclaved aerated concrete are formed by adding the aluminium powder to the other materials and the action between them; this operation is chemical processing. The air voids are homogenously distributed within aerated lightweight concrete. The compressive strength of foamed concrete can be developed to reach structural strength compared with autoclaved aerated concrete. Aerated lightweight concrete is considered the most economical in terms of materials,consumption by-products, and waste materials such as fly ash and GGBS.

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