International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 05 | May 2020 www.irjet.net p-ISSN: 2395-0072

Aerated Concrete Production using Various Raw Materials: A Review

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Abstract - *Aerated Concrete (AC) has many benefits for structures such as heat insulation, sound insulation, fire and mould resistance, reduced dead weight and many more. AC products include blocks, wall panels, floor, roof panels, and lintels. Besides insulating capability, one of AC's important advantages 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. Aerated concrete is relatively homogeneous as compared to normal concrete; as it does not contain course aggregate phase that shows vast variation in its properties. The focus of this paper is to study the investigations on the properties of aerated concrete on the basis of different aerating agents and other ingredients used.*

Key Words: **Aerated concrete, Air-entraining agents, foamed concrete, foaming agents**

1. INTRODUCTION

Aerated Concrete is an important construction material for architects, engineers and builders. Aerated concrete is also well-known as a cellular concrete. It is an appropriate material with high energy efficiency, fire safety, and cost effectiveness. AC is a versatile light weight concrete and they are generally used as blocks. AC is produced by adding in a predetermined amount of aluminium powder and other additives into slurry of ground high silica sand, cement, lime powder, water. Aerated concrete (AC) is a popular building material which is used all over the world. It can be divided into two main types according to the method of production. They are foamed concrete (non-autoclaved aerated concrete (NAAC)) and autoclaved aerated concrete (AAC). i) Foamed concrete is produced by injecting preformed stable foam or by adding a special air-entraining admixture known as a foaming agent into a base mix of cement paste or mortar (cement + water or cement + sand + water). ii) The AAC is produced by adding in a predetermined amount of aluminum powder and other additives into slurry of ground high silica sand, cement or lime and water. The background of foamed concrete began much later than lightweight aggregate concrete. Since Roman times, lightweight aggregates and foaming agents have been employed to reduce the weight of concrete. However, unlike these foamed or light aggregate mixes, true aerated concrete relies on the alkaline binder (lime & cement) reacting with an acid to release gases, which remain entrained in the material.
Aerated Concrete has been around for over 80 years. The application of foamed concrete for construction works was not recognized until the late 1970s. Invented in 1923, AAC has been used extensively in Europe and Asia. It comprises over 40% of all construction in the United Kingdom and 60% in Germany. Beside the AAC began approximately 100 years ago. In 1914, the Swedes first discovered a mixture of cement, lime, water and sand that was expanded by the adding aluminum powder to generate hydrogen gas in the cement slurry. Prior to that, inventive minds had tried beaten egg whites, yeast and other unusual methods of adding air to the concrete. Foamed concrete have high flow ability, low self-weight, minimum consumption of aggregate, controlled low strength, and excellent thermal insulation properties. The density of foamed concrete has wide range (1600- 400kg/m^3), with appropriate control in the dosage of the foam, can be obtained for application to structural, partition, insulation, and filling grades.

2. CLASSIFICATION OF AERATED CONCRETE

Narayanan et al. from his study the main classifications of aerated concrete is as mentioned below:

2.1. Based on the method of pore-formation

Air-entraining method (gas concrete): Gas-forming chemicals are mixed into lime or cement mortar during the liquid or plastic stage, resulting in a mass of increased volume and when the gas escapes, leaves a porous structure. Aluminium powder, hydrogen peroxide/ bleaching powder and calcium carbide liberate hydrogen, oxygen and acetylene, respectively. Among these, aluminium powder is the most commonly used aerating agent. Efficiency of aluminium powder process is influenced by its fineness, purity and alkalinity of cement, along with the means taken to prevent the escape of gas before hardening of mortar. In the case of Portland cements with low alkalinity, addition of sodium hydroxide or lime supplement the alkali required.

Foaming method (foamed concrete): This is reported as the most economical and controllable pore-forming process as there are no chemical reactions involved. Introduction of pores is achieved through mechanical means either by pre-formed foaming (foaming agent mixed with a part of mixing water) or mix foaming (foaming agent mixed with the mortar). The various foaming agents used are detergents, resin soap, glue resins, saponin, hydrolysed proteins such as keratin etc.

Combined pore-forming method: Production of cellular concrete by combining foaming and air-entraining methods has also been adopted using aluminium powder and glue resin [1].

2.2. Based on the type of binder

Aerated concrete is classified into cement or lime based depending on the binder used. Attempts have also been made to use pozzolanic materials such as pulverised fuel ash or slate waste as partial replacement to the binder or sand [1].

2.3. Based on the method of curing

Aerated concrete can be non-autoclaved (NAAC) or autoclaved (AAC) based on the method of curing. The compressive strength, drying shrinkage, absorption properties etc. directly depend on the method and duration of curing. The strength development is rather slow for moist-cured products. Autoclaving initiates reaction between lime and silica/alumina bearing ingredients. The other variables of significance are the age and condition of the mix at the start of the curing cycle and rates of change of temperature and pressure. Autoclaving is reported to reduce the drying shrinkage significantly and is essential if aerated concrete products are required within acceptable levels of strength and shrinkage [1].

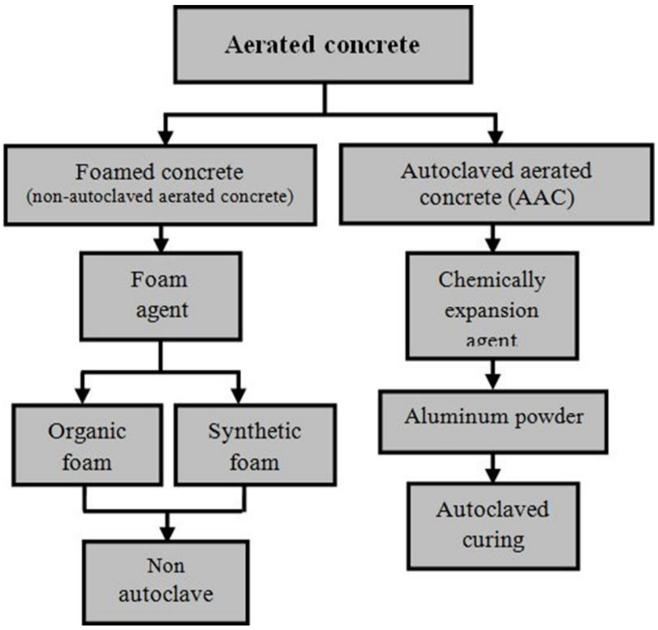

Fig -1 Classification of light weight aerated concrete [3]

3. COMMONLY USED MATERIALS

Cement (OPC): As per IS:12269 (53 grade), Ordinary Portland Cement (OPC) of 53 grade were taken in this project as it provides high strength and durability to structures because of its optimum particle size distribution, superior crystalline structure and balanced phase composition. In the construction industry, most of the cement used in the present day context is either C53 or C43 grades.

Fig-2 Cement

Sand: The quality of sand used in concrete affects more or less for both fresh and hardened properties of the concrete. In the present investigation, a good quality and well-graded natural river sand was used. The sand was sieved properly through 4.75 mm sieve to take out the pebbles or organic matter (if any). Confirming to IS 383-1970, natural sand was taken in the present project work, where silica content should not be less than 80%.

Fig -3 Sand

Lime: As per IS 712-1973, Lime is a calcium-containing inorganic mineral in which carbonates, oxides, and hydroxides predominate. In the strict sense of the term, lime is calcium oxide or calcium hydroxide. It is also the name of the natural mineral (native lime) CaO which occurs as a product of coal seam fires and in altered limestone xenoliths in volcanic ejection. It should be class 'C' lime.

Fig -4 Lime

Aluminium Powder: As per IS 438-1972, Aluminum powder is usually used to obtain aerated concrete by a chemical reaction generating a gas in fresh mortar, so that when it sets it contains a large number of gas bubbles. Aluminum is used as a foaming agent in AC production worldwide and it is widely proven as the best solution for its purpose. Aluminum powder in the AAC industry is often made from foil scrap and exists of microscopic flake-shaped aluminum particles. Aluminum powder with grain size less than 100µm and particularly with fractions less than 50µm, can easily form highly flammable aero suspensions (dust clouds) during pouring or vibration [2].

Fig -5 Aluminium powder

4. APPLICATIONS OF AERATED CONCRETE

Sethy et al. from his study there are many applications of aerated concrete. Following are some of the areas were aerated concrete is used:1) Aerated concrete blocks can be useful in various building types such as commercial, residential and educational. 2)These blocks are applicable in warehouses and buildings with industrial aim, bearing in mind their high insulation capacities, less construction time, cost effectiveness and also their light weight which reduces dead load of building, considerably makes AC an adequate material to use. 3) Aerated concrete is used in the construction of dwellings and businesses. AC can be used to quickly create kitchen surfaces. AC has the advantage that it can be shaped with saws, files and rasps. 4) AC is used preferentially in external walls because of its outstanding insulation properties. 5) AC is used in multi-storey buildings and it is quite viable for even 5-storey constructions [2].

5. CASE STUDIES

5.1 Aerated Concrete Produced Using Locally Available Raw Materials

In this study, locally available raw materials were used for the production of aerated concrete. A hybrid binder that comprised lime and gypsum was used.

Matalkah et al. in this study Different foaming agents were considered for production of aerated concrete, including saponin that is found abundantly in different plants. The binder considered in this work comprised lime: gypsum at 20:80 weight proportions with different dosages of foaming agents. Foam was generated in water by adding the foaming agent (saponin or liquid soap) to water, and stirring the solution at high speed. Several indigenous aerated concrete materials were developed successfully. One with lime-gypsum matrix and saponin foaming agent was selected for further characterization. It was found to provide a viable balance of compressive, tensile and flexural strengths, density, thermal conductivity, stability of the foam structure, elastic and shear moduli and sorptivity for use as the core in sandwich composite construction modules. The ratio of flexural-to-split tensile strength of aerated concrete (at 7 days of age) is also high when compared with normal concrete [4].

5.2 Production of Aerated Foamed Concrete with Industrial Waste from the Gems and Jewels Sector of Rio Grande do Sul-Brazil

Pedro et al. leaded the production of aerated concrete using solid waste to reduce environmental impacts through the preservation of natural resources. In this context, the possibility of using agate gemstone waste, called rolled powder, which basically consists of silica (SiO_2), in the manufacture of aerated foamed concrete blocks completely replacing the natural sand was evaluated. Preformed foam was used as the air entrained by mechanical stirring with a mixture of natural foaming agents derived from coconut. The experiments demonstrated that the best water/cement ratio was 1.28 for 18% (of total solid mass) addition of foam, which generated a sample with a density of 430 kg/m3, and a compressive strength of 1.07 MPa. The result for compressive strength is 11% smaller than the requirements of the Brazilian standard (NBR 13438) for autoclaved aerated concrete blocks, but the results are promising. From this study, it was found that rolled powder can be used as an aggregate in the manufacture of AFCB, reducing the liabilities of agate manufacturing companies and reducing environmental impacts due to the irregular disposal of this waste. Also, with the use of this residue, it is possible to reduce the consumption of natural sand, which is a finite aggregate and its extraction causes environmental damages, mainly in riverbeds and lakes [5].

5.3 Aerated Concrete Incorporating Quarry Dust

Siveji et al. In this study an investigation is done to reduce the density without significantly reduce compressive strength. Recycled aggregates such as quarry dust can be used as a replacement to sand, further reducing the cost and environmental impact. From this study the optimum percentage aluminum content at lowest percentage rate i.e.: 0.5%, 1%, 1.5% to get reasonable compressive strength with minimum density, keeping fly ash at 20 %(As per IS: 2185(Part 3)-1984 the maximum permissible limit of fly ash in cement is 20 %.), w/c at 0.45. As the percentage of aluminum powder addition increases the weight of concrete also get decreased. 1% and 1.5% cubes float on water. As the various percentage of aluminum powder for cement fly ash paste increases, the compressive strength of concrete decreases. Maximum compressive strength is at 0.5% aluminum content and its value is above 5MPa (6.7MPa) with low density (1001.72 Kg/m3). So, the optimum aluminum content suitable for light weight masonry block is 0.5% [6].

5.4 A study on properties of foamed concrete with natural and synthetic foaming agent

Varghese et al. Study focused on the production aerated concrete using natural and synthetic foaming agents. A partial replacement of binding material is done with silica fume which provides additional strength compared to foam concrete without silica fume. Preparation of natural foam is done by taking Soap nut in required amount, say 8 in number and cleaned. It was boiled in 1 liter water for 10 minute at a temperature 110^{0}C and temperature is lowered to 70^{0}C and it was maintained for 30 minutes. It was then cooled to room temperature. Comparing to synthetic foaming agents, the natural foaming agents are more easily available and are less expensive. Natural foam has lower consistency and strength. Hence for a given proportion, the density of FC with natural foaming agents higher than that of foam concrete with synthetic foaming agents. For a given proportion, the ratio of compressive strength, flexural strength and splitting tensile strength for FC with synthetic foaming agents to that of FC with natural foaming agents were obtained as 0.4,0.61 & 0.33 respectively. Compressive strength of FC, both natural and synthetic, was influenced by the substitution of silica fumes [7].

5.5 Utilization of natural zeolite in aerated concrete production

Karakurt et al. In this study, natural zeolite (clinoptilolite) was used as an aggregate and bubble-generating agent in autoclaved aerated concrete (AAC) production. The crushed and grinded samples were classified into two different particle sizes: 100lm (fine-ZF) and 0.5–1mm (coarse-ZC) before using in AAC mixtures. The optimum replacement amount was determined as 50% and at this rate the compressive strength unit weight and thermal conductivity of AAC were measured as 3.25MPa, 0.553kg/dm3 and 0.1913W/mK respectively. It was found that replacement of silica sand with zeolite decreases the unit weight of aerated concrete specimens. However, use of fine zeolite compared with a coarses ample increases the water requirement of the mixture because of the higher surface area. This has negatively affected the strength of the zeolite aerated concrete (ZAC) specimens. The ZAC produced with coarse zeolite (ZC) show better physical and mechanical properties than reference AAC specimens. Although the optimum substitution amount was found to be 50% coarse zeolite being added into the concrete formulation, relatively lower and higher amounts (25 and up to 75% ZC) can also be considered. # Results of thermal insulation analysis obtained in this study (0.1157–0.1932W/mK) show that the concretes produced can be used as a thermal insulation material in structural applications as the general thermal conductivity values given for AAC range from 0.08 to 0.19W/mK. The useable replacement amounts of natural zeolite with quartz were determined to be 50% for ZF and 75% for ZC. # It was also found that use of calcined zeolite (especially that with coarse particles),both as an aggregate and as a bubble-generating agent, produced denser and stronger ZAC specimens because of the lower aeration capacity of zeolite compared with that of aluminum powder in the composite [8].

6. CONCLUSIONS

Aerated concrete have almost all the properties similar to conventional concrete except in some mix materials and properties. Aerated lightweight concrete does not contain coarse aggregate, and it is possess many beneficial such as low density with higher strength compared with conventional concrete, enhanced in thermal and sound insulation, reduced dead load in the could result several advantages in decrease structural elements and reduce the transferred load to the foundations and bearing capacity. Aerated lightweight concrete is consider economy in materials and consumption of by-product and wastes materials. The production of aerated concrete using the above materials are moreover economical and eco-friendly. There are many more materials having engineering properties suitable for production of aerated concrete. Scope for research in this area can be extended.

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