A Review on Fiber Reinforced Foam Concrete

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Abstract

Foamed concrete is defined as a light cellular concrete which can be classified as a lightweight concrete (density of 400–1850 kg/m³) with random air-voids created from the mixture of foam agents in mortar. Foamed concrete is recognized for its high flowability, low cement content, low aggregate usage, and excellent thermal insulation. Furthermore, the foamed concrete is considered as an economical solution in fabrication of large scale lightweight construction materials but due to its low compressive strength it cannot be used as structural members. The paper provides a review to develop structural foamed concretes by using cement, sand and steel fibers. This review paper mainly tends to evaluate the structural properties of foamed concrete and then it is expanded to elaborate the improvements in foamed concrete design proportions and selection of constituent materials in order to enrich its performance at fresh and hardened states.

Keywords: Foamed concrete, Light weight, Flowability, Design proportions, Structural properties

I. INTRODUCTION

About two thousand years ago, the Romans made concrete with small gravel and coarse sand mixed together with hot lime and water. They realized that by adding animal blood into the mix and agitating it, small air bubbles could be formed making the mix more workable and durable and led to manufacture of highly air entrained cement based materials. (V Bindiganavile and M Hoseini)

Aerated concrete is a lightweight concrete in which aeration can be done with the help of air entraining agents like aluminium powder in which air is entrapped in the mortar matrix.

Light weight concrete is an important and versatile material in modern construction. It has many and varied applications including multistorey building frames and floors, bridges, offshore oil platforms, and prestressed or precast elements of all types. Many architects, engineers, and contractors recognize the inherent economies and advantages offered by this material, as evidenced by the many impressive lightweight concrete structures found today throughout the world. Structural light weight concrete solves weight and durability problems in buildings and exposed structures. Light weight concrete has strengths comparable to normal weight concrete, yet is typically 25% to 35% lighter. Structural lightweight concrete offers design flexibility and substantial cost savings by providing: less dead load, improved seismic structural response, longer spans, better fire ratings, thinner sections, decreased storey height, smaller size structural members, less reinforcing steel, and lower foundation costs. Lightweight concrete precast elements offer reduced transportation and placement costs. Light weight concrete has density less than conventional concrete that is less than 2000Kg/m³.

Foamed concrete possesses superior properties such as low density which helps to reduce structural dead loads, foundation size, labour, transportation and operating costs. Besides, it enhances the fire resistance, thermal conductivity and sound absorbance due to its textural surface and micro-structural cells. This review paper mainly tends to evaluate the structural properties of foamed concrete and then it is expanded to elaborate the improvements in foamed concrete design proportions and selection of constituent materials in order to enrich its performance at fresh and hardened states (Amran and Ali 2015).

The primary independent variables were the types and volume fraction of fibers, and the amount of air in the concrete. Steel fibers were investigated at 0, 0.25%, 0.5%, 0.75% and 1% volume ratios. Aluminium powder is also added to introduce air into the concrete. This paper reviews basic information regarding the mechanical properties of Fiber reinforced foamed concrete and compares it with foamed concrete.

II. LITERATURE REVIEW

A. Review Paper 1

Ramarurthy et al.(2009) Studied classification of literatures on foam concrete related to its constituent materials, mix proportioning, production and fresh state & hardened properties. By proper control in dosage of foam, a wide range of densities (1600– 400 kg/m³) of foamed concrete can be obtained for application to structural, partition, insulation and filling grades.

This paper identified and presents the following review needs: (i) developing affordable foaming agent and foam generator, (ii) investigation on compatibility between foaming agent and chemical admixtures, use of lightweight coarse aggregate and
reinforcement including fibers, (iii) durability studies, and (iv) factors influencing foam concrete production viz., mixing, transporting and pumping.

There is need to investigate compatibility between foaming agent and reinforcement including fibers, for enhancing the potential of foam concrete as a structural material.

The production of stable foam concrete mix depends on many factors viz., selection of foaming agent, method of foam preparation and addition for uniform air-voids distribution, material section and mixture design strategies, production of foam concrete, and performance with respect to fresh and hardened state are of greater significance. With the above aspects in view, this paper classifies the studies on foam concrete related to its constituent materials, mix proportioning, production and fresh state and hardened properties.

B. Review Paper 2

Kim et al. (2010) studied the mechanical properties and stress – strain behavior of fiber aerated light weight concrete. Fiber reinforced aerated lightweight concrete (FALC) was developed to reduce concrete’s density and to improve its fire resistance, thermal conductivity, and energy absorption. Compression tests were performed to determine basic properties of FALC. The primary independent variables were the types and volume fraction of fibers, and the amount of air in the concrete. Polypropylene and carbon fibers were investigated at 0, 1, 2, 3, and 4% agent was used to reduce the water-cement ratio and keep good workability. A surfactant was also added to introduce air into the concrete. This study provides basic information regarding the mechanical properties of FALC and compares FALC with fiber reinforced lightweight concrete.

Fiber aerated lightweight concrete (FALC) has a promising future for precast concrete panels that can be used in both small and tall building structures because it combines the comfort of AACL, the adaptability of lightweight aggregate concrete, and the reliability of FRC. The properties investigated include the unit weight, uniaxial compressive strength, modulus of elasticity, and toughness index. Also, a new modulus of elasticity equation is presented, and the effects of fibers on strength and toughness are evaluated. Based on the properties, a stress-strain prediction model was proposed. It was demonstrated that the proposed model accurately predicts the stress-strain behavior of FALC.

The disadvantage of Polypropylene fibers are that they are sensitive to fire, sunlight and oxygen, they have low modulus of elasticity, and they bond poorly with the concrete mix whereas steel fibers can be used as it has better bonding with matrix and also are less sensitive to fire, sunlight.

To perform this experiment, lightweight concrete mix designs with various densities, air volume, chopped fiber volume and types were used. To improve compressive strength and ductility, as well as the performances for wall panel, expanded clay coarse, fine aggregate, and surfactant to control the density, two different kinds of chopped fibers and self-compaction admixture were used for laboratory experiment. Also, preliminary test results included not only a complete stress-strain curve, but also a measure of ductility, such as energy to failure per unit strength, or ratio of failure strain to yield strain to find constitutive model. In this work, the surfactant contents were 0 and 0.1%, and the fiber volume fractions were 0, 1, 2, 3, and 4%.

C. Review paper 3

Bing et al. (2012) studied the development of structural foamed concretes by using silica fume, fly ash and polypropylene fibers. The study presents the use of fly ash for fully replacing sand to produce foamed concrete. Fine silica fume and polypropylene (PP) fiber were used to improve properties of foamed concrete. Lightweight foamed concretes with a wide range of concrete densities (800–1500 kg/m3) were studied mainly for compressive strength, splitting tensile strength, and drying shrinkage. The results indicate that foamed concrete with a density of 800–1500 kg/m3 and compressive strength of 10–50 MPa can be made by using silica fume and PP fiber. Fine silica fume and PP fiber greatly improved the compressive strength of foamed concrete. In addition, adding PP fiber significantly improved the splitting tensile strength and drying shrinkage resistance.

Bing et al. discussed two different methods for manufacturing foam concrete. Method A consists of mixing a preformed foam (surfactant) or mix-foaming agents into the cement and water slurry. As the concrete hardens, the bubbles disintegrate, leaving air voids of similar sizes. Method B, known as autoclaved aerated concrete (AAC), consists of a mix of lime, sand (or fly ash), cement, water, and an expansion agent (aluminum powder) that is poured into a mold. The reaction between the aluminum powder and cement causes microscopic hydrogen bubbles to form, expanding the concrete to about five times its original volume. After evaporation of the hydrogen, the highly closed-cell, aerated concrete is cut to size and steam-cured in a pressurized chamber.

This paper reports on an effort to develop structural foamed concretes of 800–1500 kg/m3 with corresponding strengths of about 10–50 MPa. Foamed concretes containing silica fume as a cement replacement to improve the paste strength were investigated. The effects of foam volume and polypropylene (PP) fiber on the compressive strength, splitting tensile strength, and shrinkage were also investigated.

D. Review paper 4

Ramanamurthy et al. (2015) studied the influence of fineness of aluminum powder by evaluation of variation in the workability of the mix, rate of aeration and fresh density with time, dry density, compressive strength and water absorption of aerated cement paste and mortar. In order to enhance the performance of aerated concrete, several additives were tried. The dosage of aluminum powder required to achieve a desired density reduces with an increase in its fineness. Inconsistent with the dosage of aluminum...
powder required, for a given dry density or compressive strength of aerated cement paste or mortar, the water absorption increases with fineness of aluminium powder. The compressive strength is reported to be influenced by the shape, size and method of pore formation, age of the sample, direction of loading, characteristics of ingredients used and method of curing. This paper mainly focuses on evaluating the variation in workability of the mix with time, rate of aeration, fresh and hardened density, compressive strength and water absorption of aerated concrete, both using paste and mortar studies, while studying the influence of fineness and dosage of aluminium powder.

E. Review Paper 5
Yang et al. (2015) developed high-performance aerated concrete to replace AAC block. The objective of this study was to develop high-performance aerated concrete without the high-pressure steam curing process to replace currently constructed AAC blocks. A total of 16 aerated concrete mixes were produced using a cementitious paste and foaming agent to generate air voids entrapped in the matrix. Considering the most influential factors with regard to the strength of aerated concrete foaming volume rate (Vf) of preformed foam, water-to-binder ratio (W/B), and unit binder content (B) were selected as main experimental parameters. To achieve high strength gains, especially at an early age, for aerated concrete under an air curing environment, the binder and chemical agent were specially designed as follows: 3% anhydrous gypsum was added to ordinary Portland cement (OPC), of which the loss on ignition was controlled to be less than 1.5%; and the content of polyethylene glycol alkylether in a polycarboxylate-based water reducing agent was modified to 28%. The quality and availability of the mixed aerated concrete were examined, wherever possible, through comparisons with the minimum requirements. In addition, empirical models to predict the various properties of the high-performance aerated concrete, which included dry density, stress–strain curves, and thermal conductivity, were established based on the regression analysis of the test data.

All concrete mixes investigated displayed enhanced workability and defoaming resistance, achieving self-compactability performance. Furthermore, the measured mechanical properties prove that the developed high-performance aerated concrete has considerable potential for practical application.

F. Review paper 6
Hilal et al. (2015) studied on void structure and strength of foamed concrete made without/additives. Study has been undertaken to investigate the effect of different additives on the strength of foamed concrete by characterizing air-void size and shape parameters and identifying the influence of these parameters and changes to cement paste microstructure on strength. Nine different mixes, made using preformed foam, were investigated with varying density (nominally 1300, 1600 and 1900 kg/m³) without/with additives (silica fume, fly ash and super plasticizer) used either individually or together. Optical microscopy and scanning electron microscopy were used in this investigation. Compared to the conventional mixes, inclusion of additives (individually or in combination) helped to improve both the cement paste microstructure and air-void structure of foamed concrete. For a given density, although the additives in combination led to increased void numbers, higher strength was achieved due to reduced void size and connectivity, by preventing their merging and producing a narrow void size distribution. Furthermore, super plasticizer has the most beneficial influence on voids when used alone and it further improves void structure (smaller and number voids) when used in combination with other additives. Not only enhancement of void structure but also improved cement paste microstructure both contribute to the strength of the foamed concrete.

Superplasticizer has the most beneficial influence on voids when used alone and it further improves void structure when used in combination with other additives, but in foam concrete the cells created inside makes the concrete more workable, so plasticizers are not added initially. They can be added if the workability of foam concrete is affected with the addition of fibers.

G. Review paper 7
Huang et al. (2015) studied on proportioning and characterization of Portland cement-based ultra-lightweight foam concrete. Due to desirable thermal insulation properties, superior fire-resistant and higher durability, ultra-lightweight foam concretes are recommended to achieve energy efficiency in buildings. Generally, aluminate cement, sulphoaluminate cement and other quick hardening cementitious materials are used to control the stability of air-voids in foam concretes. These special cementitious materials are relatively expensive and not universally available, retarding the application and popularization of foam concrete. In the present study, the proportioning and properties of Portland cement based ultra-lightweight foam concrete were investigated. The results show that ultra-lightweight foam concretes with apparent density of 100–300 kg/m³ can be prepared using Portland cement, fly ash, hydrogen peroxide and chemical admixtures. Factors influencing the properties of ultra-lightweight foam concrete were investigated, and the relationships between compressive strength, thermal conductivity and apparent density of foam concretes were evaluated. Collapse and air-voids escape can be avoided by adding thickening agent and foam stabilizing emulsion into foam concrete. Most of pores in ultra-lightweight foam concrete were non-connected pores with size of 2.0–4.0 mm, resulting in a lower thermal conductivity, desirable compressive and tensile strengths.

Ultra-lightweight foam concretes with apparent density of 100–300 kg/m³ were successfully prepared using Portland cement, fly ash, hydrogen peroxide and chemical admixtures. In this thesis work Aluminum powder can be used as foam agent as it has less reaction with other constituent materials.
H. Review Paper 8

Amran et al. studied the properties and applications of foamed concrete, which includes a review of foamed concrete constituents, fabrication techniques, and properties of foamed concrete. Foamed concrete consists of basic and supplementary components. The basic components are cement, sand, and water for mortar, plus aggregates to produce concrete, whilst the secondary materials are fly ash, plasticizers, and fibers. This paper provides a review of foamed concrete constituents, fabrication techniques, and properties of foamed concrete. It also aims to provide a comprehensive insight into possible applications of foamed concrete in the construction industry today.

The compressive strength is considered as the primary function of the desirable density design, as a main consideration for this lightweight concrete, which can finally be used to fabricate structural, non or semi-structural components. Meanwhile, durability is another property of foamed concrete that needs to be at a level which can effectively allow it to resist the aggressive environments. This can be achieved by selecting the most suitable type of foam agent added. Foam agents produce a uniformed distribution of pores, where they decrease the segregation problem in an early state, prevent the ingress of chloride, prohibit sulphate attack and increase the time range during fire while enhancing its fire resistance. Stable foamed concrete production depends on many factors such as type of foam agent, method of preparation of foam agent to initiate a uniform or homogeneous distribution of air voids (bubbles), design calculation accuracy of the mixture, and foamed concrete production, hence the enhancement of performance in fresh and hardened states are significantly elaborated. In order to produce foamed concrete with high consistency and stability, it is recommended to reduce the volume of foam agent, using partial replacement of cement by either fly ash or silica fume which reduces the process of heat of hydration.

The above review mainly intended to evaluate the current material properties of foamed concrete. In order to clarify the mechanisms of foamed concrete it is necessary to compare with conventional concrete.

III. Conclusions

Foam concrete can be effectively applied in construction industry due to its desirable properties. Fiber aerated lightweight concrete (FALC) has a promising future for precast concrete panels that can be used in both small and tall building structures because it combines the comfort of AACL, the adaptability of lightweight aggregate concrete, and the reliability of FRC. High-performance aerated concrete has considerable potential for practical application.

Mechanical properties of foamed concrete depends on the foam volume, type and volume of fiber and the compressive strength is influenced by the shape, size and method of pore formation, age of the sample, direction of loading, characteristics of ingredients used and method of curing.

Fine silica fume and PP fiber effectively improve the compressive strength of foamed concrete. In addition, adding PP fiber significantly improved the splitting tensile strength and drying shrinkage resistance.

Stable foam concrete mix depends on foaming agents, foam preparation methods, air-voids distribution, materials, mixture design strategies & production methods. The primary variables are types, volume fraction of fibers, amount of air in the concrete. Collapse and air-void escape can be avoided by adding thickening agent & stabilizing emulsion. Compared to the conventional mixes, inclusion of additives helped to improve both the cement paste microstructure and air-void structure of foamed concrete.

Acknowledgement

I wish to extend my gratitude and, indebtedness to Asst. prof. Praveen Mathew Department of Civil Engineering, who is also my thesis guide, for his generosity and willingness to share his valuable time and expertise with me. I would also like to express my sincere gratitude to all my friends and classmates for their help and support.

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