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Review

Properties and applications of foamed concrete; a review

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HIGHLIGHTS

- Stability of fresh foamed concrete is controlled by type and volume of foam agent added.
- The compressive strength is a primary function of the desirable density design.
- Foamed concrete has potential characteristics to produce structural applications.
- Foamed concrete is superior fire resistance compared to normal concrete.

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ABSTRACT

Foamed concrete possesses characteristics such as high strength-to-weight ratio and low density. Using foamed concrete reduces dead loads on the structure and foundation, contributes to energy conservation, and lowers the labor cost during construction. It also reduces the cost of production and transportation of building components compared to normal concrete and has the potential of being used as a structural material. This paper provides a review of foamed concrete constituents, fabrication techniques, and properties of foamed concrete. This literature review also aims to provide a comprehensive insight into possible applications of foamed concrete in the construction industry today.

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1. Introduction

Foamed concrete is defined as a light cellular concrete which can be classified as a lightweight concrete (density of 400–1850 kg/m^3) 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 [1–3], and excellent thermal insulation [4]. Furthermore, the foamed concrete is considered as an economical solution in fabrication of large scale lightweight construction materials and components such as structural members, partitions, filling grades, and road embankment infills due to its easy production process from manufacturing plants to final position of the applications [2,5–7]. In practice, foamed concrete has been commonly used in construction applications in different countries such as Germany, UK, Philippines, Turkey, and Thailand [8,9].

Historically, the Romans first realized that by adding animal blood into a mix of small gravel and coarse sand with hot lime and water and agitating it, small air bubbles were formed making the mix more workable and durable [10,11]. However, the first Portland cement based foamed concrete was patented in 1923 by Axel Eriksson [12]. Further, the initial comprehensive review was conducted by Valore on cellular concrete [1,12]. Over the past 20 years, substantial improvements in production equipment and better superplasticizers, foam agents have permitted the use of foamed concrete in a larger scale and many efforts have been made to study the characteristics and behavior of foamed concrete comprehensively in order to simplify its usage in structural applications. So far, some researchers [2,13–16] reported that the foamed concrete possesses superior properties such as low density which helps to reduce structural dead loads, foundation size, labor, 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 material 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. Table 1 compares typical parameters between foamed concrete and other types of concrete in terms of raw material, method of production, compressive strength, insulation performance, and environmental relationship.

2. Constituent materials and preparation methods

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 supplementary materials are fly ash, plasticizers, and fibers. All the above mentioned materials will be described in detail in sub-sections below.

2.1. Binder

Cement is the most dominant binder in foamed concrete. The types of cement used in the foamed concrete are namely ordinary Portland cement, rapid hardening Portland cement, calcium sulfoaluminate cement, and high alumina cement, which can be used in ranges between 25% and 100% of the binder content [3,17–19]. However, other supplementary materials such as silica fume, fly ash, lime, incinerator bottom ash and Lytag can also be replaced with a percentage of cement ranging between 10% and 75% [14,20–22]. The supplementary materials are used to improve mix design consistency, long term strength and to reduce costs [23]. Each supplementary material may contribute to properties of foamed concrete in different fashions. For instance, the purpose of using silica fume is to strengthen the foamed concrete in a short time due to their filler characteristics and pozzolanic behavior [3,24–26], while fly ash needs a longer time to reach the maximum strength comparing to cement [17]. Therefore, the supplementary materials should be used as partial replacements according to desirable foamed concrete properties.

2.2. Foam agent

Foam agents control the concrete density through a rate of air bubbles created in the cement paste mixture. Foam bubbles are defined as enclosed air-voids formed due to the addition of foam agent. The foam agents are commonly synthetic, protein-based, detergents, glue resins, hydrolyzed protein, resin soap, and saponin, [19,27,28]. The most common foam agents are synthetic and protein based. The protein based foam agents result in a stronger and a more closed-cell bubble structure which permits the inclusion of greater amounts of air and also provides a more stable air void network while the synthetic ones yield greater expansion and thus lower density [7,10,29]. The content of the foam agent has a considerable effect on properties of both fresh and the hardened concrete [11,30]. It is reported that the excessive foam volume results in a drop in flow [26,31]. However, the flow is significantly affected by mixing time. As reported, the greater the mixing time, the more the entrained air, albeit, prolonged mixing may cause the loss of entrained air by dropping the air content [10,12]. Moreover, water-reducing chemical admixtures are likely to cause instability in the foam and subsequently are not usually used. The stability of foam agent should be confirmed based on ASTM C 869-91 and ASTM