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Mechanical and thermal properties of lightweight concretes with vermiculite and EPS using air-entraining agent

Adilson Schackow [a,b,*], Carmeane Effting [a], Marilena V. Folgueras [b], Saulo Güths [c], Gabriela A. Mendes [a]

[a] Department of Civil Engineering, Center of Technological Sciences, State University of Santa Catarina, Joinville, Santa Catarina, Brazil
[b] Materials Science and Engineering Postgraduate Program, Center of Technological Sciences, State University of Santa Catarina, Joinville, Santa Catarina, Brazil
[c] Laboratory of Thermophysical Properties, Campus Trindade, Federal University of Santa Catarina, Florianopolis, Santa Catarina, Brazil

HIGHLIGHTS

- We compare mechanical properties of lightweight concrete with vermiculite and EPS.
- Lower amount of lightweight aggregate and air-entraining provides higher strength.
- Vermiculite lightweight concrete has lower thermal conductivity than with EPS.
- EPS lightweight concrete has higher strength and is lighter than with vermiculite.

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ABSTRACT

This study aimed to compare mechanical and thermal properties of lightweight aggregate concrete with two kinds of lightweight aggregates, vermiculite and Expanded Polystyrene (EPS) and using air-entraining agent and superplasticizer admixture. For better reliability, a statistical analysis of the results compressive strength and density was used. The factors of the 2^2 full factorial design were: amount of lightweight aggregate (55% and 65%) and quantity of air-entraining agent (0.5% and 1.0%). The results showed that the addition of air-entraining agent left the lightweight concretes even lighter, but less resistant. EPS lightweight concrete has higher strength and is lighter than with vermiculite. Vermiculite lightweight concrete had lower thermal conductivity than with EPS. The better lightweight aggregate content was 55%.

1. Introduction

The construction industry is one of the largest consumers of raw materials today. For a sustainable future, is needed a drastic reduction in the use of raw materials. For this it is important to think about recycling of materials and reduction of waste during the construction of buildings and during its life, and also in the recycling of demolition materials [1–4].

One way of reusing is the use of EPS – expanded polystyrene, that can replace the gravel in the production of lightweight concrete [5]. EPS is widely used, for example, in electronic products packaging, and could be reused.

Lightweight concrete is normally done by incorporating lightweight aggregates such as pumice, perlite, expanded clay or vermiculite, or by air-entraining in the concrete mix [6]. Aggregates that weigh less than 1120 kg/m^3 are generally considered lightweight, and find application in the production of various types of lightweight concretes. Actually, there is a whole spectrum of lightweight aggregates weighing from 80 to 900 kg/m^3 [7].

In comparison with conventional concrete, lightweight concrete shows some excellent features, such as low density and thermal insulation [8,9].

The suitability of a lightweight concrete is governed by the desired properties: density, cost, resistance and thermal conductivity. The low thermal conductivity of lightweight aggregate is clearly more advantageous for applications requiring good isolation [10,11]. For Madandoust et al. [12], the increase in the content of EPS in lightweight concrete results in a significant reduction in the compressive strength.

The demand for lightweight concrete applications in modern buildings is increasing due to its lower density, which results in a reduction of cross sections of structural elements [13].

* Corresponding author at: Department of Civil Engineering, Center of Technological Sciences, State University of Santa Catarina, Joinville, Santa Catarina, Brazil. Tel.: +55 4740097802.
E-mail address: adilson.schackow@udesc.br (A. Schackow).

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Lightweight concrete can be more advantageous than conventional concrete due to several improved properties. The most prevalent benefit of structural lightweight concrete is the lowest deadweight [14]. Lightweight concrete refers to concrete with density less than 1950 kg/m^3 [15]. For Metha et al. [7], the term lightweight concrete is used for the concrete which weighs less than 1800 kg/m^3.

Lightweight concrete is destined to become a dominant building material in the new millennium because of its low density, unique sound insulation and thermal properties [10]. A lightweight aggregate that contribute for the thermal insulated is the vermiculite.

Vermiculite is found in America and Africa. It is a material with platey structure, somewhat similar to that of mica. When heated to temperatures of 650–1000 °C for several expanded vermiculite, or as many as 30 times its original volume by exfoliation of its thin plates. As a result, the bulk density of vermiculite is only 60 than 130 kg/m^3. And concrete made with it is very low resistance, and high shrinkage displays but it is an excellent thermal insulator [10,16].

Vermiculite is formed through the disintegration of mica, which liberates lime and takes up water. When vermiculite is heated to 800–1100 °C, it divides into thin strips. These release water, curl up like snakes and swell to become a light porous mass, which can be used as an independent loose insulation or as an aggregate in a lightweight concrete, e.g. in the proportions 6:1 vermiculite to Portland cement [1].

Vermiculite is a naturally occurring mineral. The chemical composition consists of a complex hydrated aluminum and magnesium silicate. The expanded or exfoliated vermiculite has low bulk density, high refractoriness and low thermal conductivity. Chemical inertness makes vermiculite satisfactory for many types of thermal and acoustic insulations [17]. The chemical formula of vermiculite is $(Mg,Ca)_{0.3-0.45}{\cdot}(H_2O)_n\{(Mg,Fe,Al)_3(Al,Si)_4O_{10}(OH)_2\}$ [18].

The lightweight concrete (non-structural) in civil engineering is generally used to fill the regularization of floors and slabs, especially when there is little traffic. Thus, this study can be a contribution in the verification of the effectiveness of the inclusion these two materials (vermiculite and EPS) in concrete, comparing their mechanical and thermal properties. There are several studies on mechanical properties of lightweight concrete with vermiculite or EPS [19–21]; however, this study differs by using air-entraining agent and superplasticizer admixture, and also by comparing the lightweight concrete with EPS and the lightweight concrete with vermiculite. The statistical analysis using the factorial design of this paper also makes it different from others papers with the same subject. The scope of the study is to compare properties of lightweight concrete with vermiculite and EPS containing additives and observe which of these materials would be best suited for use in lightweight concrete.

2. Materials

The local industry of civil construction generally uses vermiculite to manufacture lightweight concrete. But the vermiculite needs to be purchased. Thus, this study was designed to compare the properties of concrete with vermiculite, commonly used with the properties of concrete with EPS. The EPS is a material from the recycling almost at no cost. The use of recycled EPS, besides not having cost, provides an environmental gain.

2.1. Vermiculite

The vermiculite used in this study is superfine (Fig. 1) and was provided by the company Refratarios de Santa Catarina Ltda. Vermiculite was placed in water 24 h before use to not absorb water mixture. The grain diameter of vermiculite with irregular shape was mostly 3 mm, and the bulk density was 1.1 kg/dm^3 (with water absorbed).

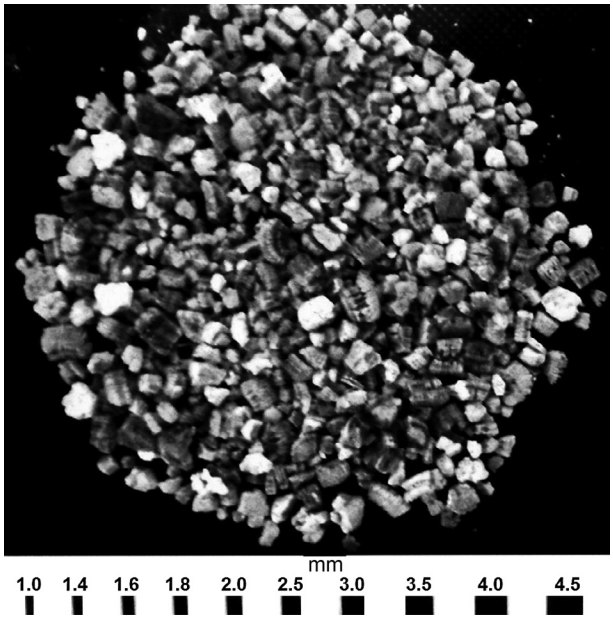

Fig. 1. Photograph showing the aspect of vermiculite.

2.2. Expanded Polystyrene – EPS

The EPS used in this study is derived from recycling. Was provided by the company Styroville in granulated form after crushed (Fig. 2). The grain diameter of EPS beads with rounded but irregular shape was mostly 4 mm, and the bulk density was 25 kg/m^3 (0.025 kg/dm^3).

2.3. Admixtures

The most important application of air-entraining admixtures is for concrete mixtures designed to resist freezing and thawing cycles. A side effect from entrained air is the improved workability of concrete mixtures, particularly those containing less cement and water, rough textured aggregates or lightweight aggregates. Air entrainment is, therefore, commonly used in making mass concrete and lightweight concrete mixtures [7].

The air-entraining agent used was Micro Air® FC, that is a reddish liquid, free from chlorides, used in concrete and mortar. The air-entraining agent introducing

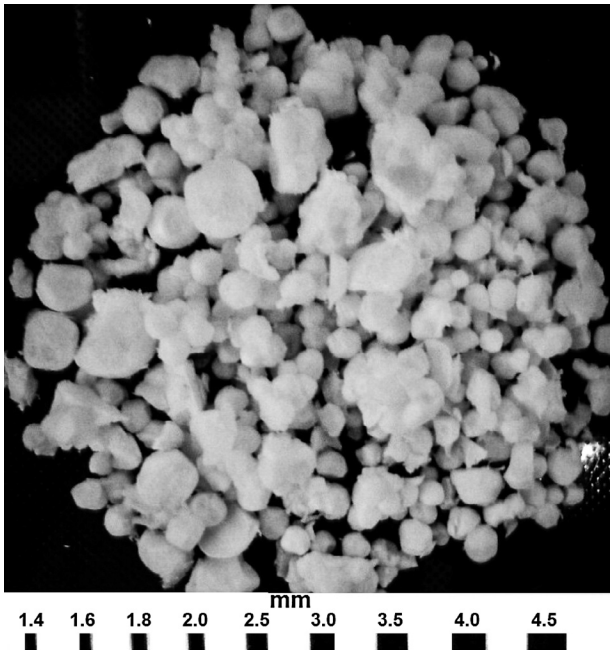

Fig. 2. Photograph showing the aspect of EPS.