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Non-structural lightweight concrete with volcanic scoria aggregates for lightweight fill in building's floors

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HIGHLIGHTS

- Non-structural lightweight concrete (NSLWC) with scoria aggregates was characterized.
- Its behavior was compared to that of common NSLWC with expanded clay and EPS aggregates.
- NSLWC with scoria could show, at least, similar compressive and tensile strength.
- Also had less shrinkage, higher punching strength and better behavior at high temperatures.
- However, presented greater density and slightly higher thermal conductivity.

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ABSTRACT

This paper aims to characterize the mechanical and physical behavior of non-structural lightweight concrete (NSLWC) produced with volcanic scoria, regarding its application in building's floors. The density, thermal conductivity, capillary absorption, compressive, tensile and punching strength, elasticity modulus, shrinkage, abrasion resistance and behavior at high temperatures of different NSLWC fill solutions were analyzed. For comparison purposes, conventional NSLWC with expanded clay and expanded polystyrene aggregates were also studied. Despite its greater density and slightly lower abrasion resistance and thermal conductivity, NSLWC with scoria showed similar mechanical strength, less shrinkage, higher punching strength and better behavior at high temperatures than conventional NSLWC.

1. Introduction

Lightweight concrete, having dry density up to 2000 kg/m^3 and thermal conductivity usually lower than 1 W/m °C, has been used when low weight and insulating properties are relevant [1,2].

Lightweight concretes can be categorized in three different classes, according to their main physical properties. Structural lightweight concrete has usually an equilibrium density between 1120 and 1900 kg/m^3 and a minimum compressive strength of about 17 MPa [3]. Non-structural concrete can be divided in low-density or insulating concrete and moderate strength or semi-structural concrete. The low-density concrete has typically densities below 800 kg/m^3 and is employed primarily in non-structural applications for thermal and sound insulation [4,5]. These concretes with higher insulating properties are not intended to be exposed to weather and generally have compressive strength below 3.4 MPa [5]. The moderate strength concrete with intermediate thermal resistance and compressive strengths between 3.4 and 17 MPa can be used at the lower densities as non-structural fill for thermal and sound insulation of floors and roofs or at the higher densities as cast-in-place walls, floors and roofs, masonry blocks and other solutions, not classified as structural concrete [4,5]. Although there are innumerous examples of application of structural lightweight concrete, the demand of lightweight aggregate (LWA) in the construction industry is higher for non-structural lightweight concrete (NSLWC) [1,6]. Moreover, non-structural LWA requires fewer raw materials to be produced and the resources are depleted at a lower rate [7]. In the present study, only non-structural lightweight concrete used for lightweight fill solutions in building's floors is covered.

The reduction of the concrete density implies the increment of its porosity, which can be achieved by either the incorporation of voids in the paste or in the aggregate [2,6]. Hence, there are essen-

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Acronyms

EPS	Expanded polystyrene	LUC	Uno concrete with Leca
EPTC	Traditional concrete with EPS	LWA	Lightweight aggregate
EPUC	Uno concrete with EPS	NSLWC	Non-structural lightweight concrete
LSL	Lightweight screed with Leca	NWA	Normal weight aggregate
LSS	Lightweight screed with scoria	STC	Traditional concrete with scoria
LTC	Traditional concrete with Leca	SUC	Uno concrete with scoria

tially three distinct ways to produce lightweight concrete: cellular concrete; no-fines concrete; lightweight aggregate concrete. The cellular concrete is obtaining by the addition of prepared foam or by the generation of gas within the cementitious paste [4,8]. The production of lightweight aggregate concrete by the direct replacement of normal weight aggregates (NWA) with LWA is the most effective way to reduce density, because aggregates usually occupy more than 70% of the volume of concrete [2]. The density and mechanical strength of this type of concrete strongly depends on the type and volume of LWA [9]. Non-structural insulating concrete can also consist of a highly porous aggregate, such as expanded polystyrene (EPS), with a highly air entrained cement paste [10].

The no-fines or pervious concrete is predominantly made with only coarse aggregates and cement paste, with little or no fine aggregate fraction. The absence of fines in the mixture decreases its compactness, thus reducing its density and strength. In this type of concrete the void content generally ranges from 18 to 35% and density can be about 30% lower compared to normal concrete with the same type and volume of coarse aggregate and sand [11]. Various environmental benefits are attributed to the use of pervious concrete in roadway pavements [12]. However, according to Alduaij et al. [13] lightweight aggregate concrete can have higher mechanical strength and lower density than no-fines concrete produced with NWA and the same cement content, and hence, the use of LWA can be more efficient. The replacement of coarse NWA by LWA in pervious concretes, as done in the present study, leads to further reductions in their density, being possible to attain minimum values as low as 400–500 kg/m^3 [14,15]. These permeable concretes with low density and compressive strength can be used for filling and regularization of building's floors with good insulating properties, low weight and reduced cost [5,14,15]. Although pervious concrete has been used for paving for over 30 years, only few investigations have been carried out to determine its performance, and are essentially limited to the use of NWA [11,12,16].

Today, the manufactured LWA, from natural raw material or industrial by-products, is the most used to produce NSLWC, because is more abundant and with less variability in the final product. However, more sustainable alternative solutions to the commonly used concrete with manufactured LWA are necessary. For this purpose, some non-structural solutions have been suggested with natural lightweight aggregates [15,17], recycled aggregates [18–20], cork granulates [21] or other organic materials [14,22], essentially based on laboratory tests. The concrete produced with recycled ceramic aggregates [18] or with aggregates from construction and demolition waste [19] was unable to attain lightweight solutions, with densities higher than 2000 kg/m^3. Dry densities of about 1450 kg/m^3 were obtained by Bogas et al. [20] in concrete produced with recycled aggregates from old non-structural lightweight concrete. Pinto et al. [14] reported the production of pervious corn cob concrete with densities as low as 360 kg/m^3 and thermal conductivity similar to that of expanded clay pervious concrete, but compressive strength lower than 0.1 MPa. The use of volcanic aggregates has been studied, mainly for structural concrete [23–25]. Uysal et al. [26] found that the use of Pumice aggregate in structural lightweight concrete can reduce its thermal conductivity up to 46%. The use of Pumice in pervious concrete was analyzed by Zaetang et al. [15], which found that the thermal conductivity can be reduced 3–4 times when compared with pervious concrete with NWA. However, to the best of the author's knowledge, some relevant properties in pervious concretes with volcanic aggregates, especially when designed for pavement applications, such as the punching strength, shrinkage or resistance to high temperatures, have not been studied in detail yet.

In the present study, natural scoria from Azores, Portugal, is used to produce non-structural lightweight concrete mainly designed for lightweight fill in building's floors. Volcanic scoria is basically basaltic pumice with a sponge-like structure created by the release of gases during the solidification of lava. Pumice aggregates are limited by their few extraction sites and by their already defined characteristics with a given density that limit their range of application [1]. However, comparing to the most common manufactured aggregates, natural LWA can be a more economic and environment-friendly material, as they involve less production costs and lower levels of energy waste. Moreover, in isolated regions, such as the Azores islands, the use of natural aggregates is the only reasonable option due to the high exportation cost of manufactured LWA.

Accordingly, this paper aims to study and characterize the mechanical and physical behavior of non-structural lightweight concrete with volcanic scoria aggregates originated from Azores, Portugal. To this end, a comprehensive experimental campaign was carried out and the most relevant properties of these concretes regarding their application for lightweight fill in building's floors are analyzed, namely: physical properties (density, thermal conductivity, capillary absorption and water permeability); mechanical strength (compressive, tensile and punching strength, elasticity modulus, abrasion resistance and drying shrinkage); behavior at high temperatures. In parallel, conventional non-structural concrete produced with expanded clay lightweight aggregates and expanded polystyrene were also tested for comparison purposes. It is thus possible to conclude about the feasibility and suitability of producing non-structural concrete with scoria LWA.

2. Experimental program

The experimental methodology involved the production and characterization of non-structural concrete produced with volcanic scoria from Azores, also known as "bagacina", which was designed to be used in lightweight fill for floors. To this end, the most common systems used for filling and regularization of building's floors were studied, namely: Traditional solution; Uno solution. The Traditional solution (TS) consists of a two layers system where a lightweight screed of about 5 cm thick is placed over a pervious lightweight aggregate concrete (Fig. 1). The stronger screed on