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Review paper

Acoustic and thermal performances of ceramic tiles and tiling systems

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Abstract

Acoustic and thermal performances of floating floor and/or radiant floor can be improved by using ceramic tiles with tailored porosity and microstructure. Porcelain stonewares are still the most widespread typology of tiles, due to their high physical and mechanical performances coming from a very low level of open porosity and water absorption (≤ 0.5 wt%). However their closed porosity values, usually neglected, can be significantly different from one product to another. As a consequence, the properties directly dependent on the total porosity, such as thermal and acoustic ones, may be strongly diverse among commercial tiles.

Several commercial porcelain stoneware tiles having different composition, microstructure and porosity, were selected for the present work. These tiles, alone or coupled with different types of resilient underlayer materials (glass fibre, cork and rubber), were studied on the basis of dynamic stiffness. Their acoustic and thermal properties were investigated in terms of thermal conductivity and walking noise reduction.

Keywords: B. Microstructure-final; C. Thermal conductivity; D. Traditional ceramics; Walking noise

Contents

1. Introduction

Nowadays porcelain stoneware tiles are the most widespread typology of tiles due to their high physical and mechanical properties, related to their high density values and to their low level of open porosity.

This kind of product can be used both as floor and wall coverings in indoor and/or outdoor application environment. Anyway, even if commercial porcelain stoneware tiles are characterised by low open porosity values (water absorption must be lower than 0.5% [1,2]), their total porosity (the sum of the open porosity and of the closed porosity) is not negligible and can be significantly different, in terms of percentage, shape and size, from one product to another [3]. As a consequence, the properties directly dependent on the total porosity, such as thermal and acoustic ones, may be strongly diverse among commercial tiles.

Commercial porcelain stoneware tiles are always more frequently coupled with other materials able to improve the required property for a specific application, such as thermal and/or acoustic insulation. In fact the innovative construction materials aim at

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attaining an efficient building energy management, answering to the requirements of thermal and acoustic technical standards [4,5].

Floating tile systems are currently used also in domestic environment in order to reduce walking noise or vibration [5]. On the other hand, radiant floor is a widely adopted solution for domestic applications, being one of the more commonly used heating system in northern Europe countries [6,7].

Computer simulations about the effect of several design parameters on the floor heating system and on the floating tile system have concluded that, both for thermal and acoustic performances, the most important factors are the floor material type and thickness [8–12].

Traditional ceramic tiles are the base for modular products which can be applied anywhere, such as new buildings or retrofitting of existing buildings. Porcelain stoneware is the most widespread and effective floor covering for radiant floor heating, because of its thermal properties since it conducts heat well and adds thermal storage. Common floor coverings like vinyl and linoleum sheet goods, carpeting, or wood can also be used, but any covering that insulates the floor from the room will decrease the efficiency of the system.

A lot of works are available in literature about the processing of ceramic tile materials, the possibility to use different raw materials and new trends [13–16]. However, their technical properties have been scarcely studied, being mainly focused on the mechanical properties [17–21]. Only few works concerns thermal properties of clay based materials [22,23] and no one deals with acoustic properties of ceramic tiles.

In the present work, thermal and acoustic properties of several commercial porcelain stoneware tiles having different composition, microstructure and porosity, were analysed in terms of thermal conductivity and reduction of walking noise. Furthermore, these tiles coupled with other materials such as glass fibre, cork or rubber were also investigated.

This work represents a preliminary study to set up a data base of thermal and acoustic properties of commercial porcelain stoneware tiles and tiling systems (tiles coupled with other materials) that will be useful for scientists and professionals of the floor tile market.

2. Experimental

Four commercial porcelain stoneware tiles characterised by different colours, surface finishing and thickness, were selected for the present work (Table. 1). The tiles were coupled with other materials such as glass fibre, cork or rubber. The tiling systems denomination, the coupling material and its thickness are reported in Table. 2.

Table 1
Synoptic table of the main tile characteristics (UGL: unglazed; GL: glazed).

Tile	**A**	**B**	**C**	**D**
Colour	GREY	BEIGE	GREY	BROWN
Surface finishing	UGL	UGL	GL	GL
Size (mm)	600 × 600	600 × 600	600 × 600	600 × 600

Table 2
Tiles and tiling systems thickness.

Tile	**Tiling system**	Coupling material	Thickness (mm)	
			Tile	*Coupling material*
A	**A-R**	Rubber, R	10.0	1.0
B	**B-F**	Glass fibre, F	7.0	0.5
C	**C-F**	Glass fibre, F	3.0	0.5
	C-C1	Cork, C1	3.0	1.5
	C-C2	Cork, C2	3.0	2.5
	C-CR	Cork and rubber, CR	3.0	2.0
	C-CF1	Glass fibre and cork, CF1	3.0	0.5 F+1.0 C
	C-CF2	Glass fibre and cork, CF2	3.0	0.5 F+2.0 C
D	**D-F**	Glass fibre, F	4.7	0.5

The microstructure of the tiles cross section was analysed by a scanning electron microscope (SEM, Zeiss EVO 40, D) equipped with an energy dispersion X-ray attachment (Inca, Oxford Instruments, UK). For the analysis, specimens of about 20×20 mm^2 were polished, by using a diamond dish, and gold sputtered, to make the surfaces conductive.

The microstructure of the coupling materials (glass fibre, cork and rubber) was observed both by optical microscope (OM, Leica, DM-LM, D) and SEM.

On the tile samples, water absorption and hydrostatic density were determined following the standard UNI EN ISO 10545-3 [2]. The total porosity values were calculated on the basis of real density of the powdered tile samples conforming to the Standard ASTM C329-88 [24]. The total porosity and the pore size distribution were also determined by image analysis (LEICA, LAS v.3.8, D), on the basis of at least ten optical microscope images for each tile samples.

Quantitative mineralogical composition of the tile samples was determined by X-ray diffraction analysis (PW3830, Philips, NL). Powdered tile specimens, diluted with 10 wt% of corundum NIST 676 as internal standard, were side loaded to minimise preferred orientation. Data were collected in the angular range 10–80° 2θ with steps of 0.02 and 5 s/step. The Rietveld-RIR refinements were performed using the software GSAS-–EXPGUI [25].

Both on tiles and tiling systems (tiles with coupling materials), dynamic stiffness determination was carried out following the standard UNI EN 29052-1 [26] by a resonance method in which it is determined the frequency of resonance of the vertical vibration of a mass–spring system. The loading mass (steel material) is 200×200 mm^2 size. The total load on the specimen is 7.5 kg.

The walking noise reduction, ΔL_w, was measured on tiles and tiling systems, according to the standard UNI EN ISO 10140-3 [27]. The irradiated noise in the emitting chamber, $L_{n,walk}$, was determined, by using a walking machine, following the method described in the pr EN 16025 [28]. A standard walking machine (Nor 277, Norsonic) was used in the emitting chamber and, on the test floor of the receiving chamber, the sample has been installed. The walking machine worked on 8 different positions. The generated noise was measured in the receiving chamber after its characterisation in terms of echo