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EN 998-1 performance requirements for thermal aerogel-based renders

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HIGHLIGHTS

- Performance of renders with aerogel and cement-fly ash.
- Relevant properties for thermal renders required by EN 998-1 standard.
- Correlation of renders performance and two hybrid silica aerogels.
- Key parameters: aerogel pore structure and hydrophobicity.

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ABSTRACT

Given that silica-based aerogels are appealing nanomaterials as aggregates in thermal renders, two types of hybrid silica aerogels were selected to produce cement-fly ash renders classified as T1, with category CSI in compressive strength, and acceptable water behavior (capillary absorption and moisture vapour transmission).

The work highlights the relevance of understanding how each characteristic of the aggregate influences the behaviour of the final render, focusing on EN 998-1 requirements. Correlations between pore and molecular structure of the hybrid aerogels and the corresponding standard properties (compressive strength, capillary absorption and moisture vapour transmission) of the renders are discussed for further improvement of the renders' overall performance.

1. Introduction

The industry of thermal renders is trying to meet the European directives (2012/27/EU [1], 2010/30/EU [2], Barbero et al. [3]) regarding buildings' enhanced thermal performance. In agreement with the EN-998-1 standard [4], thermal renders should fulfil the requirements in Table 1. Besides, the dry bulk density, reaction to fire, adhesion and durability should be declared by the manufacturer, according to this standard (Table 1).

Silica aerogels are considered super-insulating materials, since they exhibit very low thermal conductivities, ranging from 0.012 to 0.021 W/m.K [12,13]. Therefore, the use of silica and silica-based aerogels in building insulation systems is steadily increasing [14–17].

The behaviour of renders with incorporation of silica aerogels has been studied by several authors (Table 2) and values of thermal conductivities between 0.014 and 0.076 W/m.K clearly demonstrate the potential of these materials as aggregates.

However, in the works referred in Table 2, information on the aerogel-based thermal renders compounds is scarce and only in few cases the amount (by volume) and the nature of the incorporated aerogel are indicated. The absence of information on renders' properties is also visible: in certain studies only the dry bulk density and/or the compressive strength are mentioned. Furthermore, only in recently emerging studies aerogel-based renders are analyzed in detail, concerning their structure and other relevant properties, and even in these, sometimes the information appears in the form of graph, and the exact values of the properties are not clear.

This work is a step forward to previous ones by Júlio et al. [30,31] that compared the effects of several silica aerogels on the physical performance of cement-based renders.

The behaviour of the aerogel-based renders (dry bulk density, thermal conductivity, compressive strength, capillary absorption

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Nomenclature

Symbols

ρ	dry bulk density
ρ_e	envelope density
f_u	adhesion
RF	reaction to fire
D	durability
C_S	compressive strength
Cc	capillary water absorption
AV	capillarity absorption asymptotic value
μ	moisture vapour transmission resistance coefficient
λ	thermal conductivity coefficient
λ_{28days}	thermal conductivity coefficient at 28 days
λ_{dry}	thermal conductivity coefficient at dry state
S_{BET}	specific surface area obtained by BET equation
C_{BET}	BET constant *C*
V_p	total pore volume at single point P/P0 = 0.98
Φ_{BJH}	BJH average mesopore diameter
P_{app}	apparent porosity accessed by Hg porosimetry
LHB	lipophilic/hydrophilic balance, estimated by: A[CH_3 related bands]/A[Si-OH]
N.S.	not specified
% vol	percentage of incorporated aerogel (by total volume)
CA	commercial supercritical hybrid silica aerogel
SA	subcritical hybrid silica aerogel synthesized on purpose
FA	fly ash
CEM	Portland cement I 42.5 R

and moisture vapour transmission resistance) is correlated with their morphology and porous structure, in order to understand the role of the aerogel, assessing in detail The properties that are relevant to thoroughly fulfil the requirements of a thermal render, in agreement with EN 998-1 [4], are assessed in detail.

2. Experimental procedure

The cement-based renders were prepared with a constant binder:aggregate volume ratio of 1:4. The binder consisted of a fly ash (FA)-Portland cement (CEM)-mixture (50 wt%), mixed in the lab. The aggregate was either a subcritical hybrid silica aerogel (SA) synthesized on purpose [30], or a commercial supercritical hybrid silica aerogel (CA) (Fig. 1). The volume percentage of each aggregate was 100% (in total replacement of silica sand – SS) – detailed renders' formulation in Table 3. They are named by the aggregate and by the binder in weight: e.g. SA-$FA_{50}CEM_{50}$ refers to synthesized aerogel as aggregate with mixed fly ash-cement (50 wt%) binder.

The water:binder ratio was optimized in each formulation to reach a paste's flow value of 160 ± 10 mm for all renders (Fig. 2), in line with EN 1015-2 [32], and the amount of surfactant was adjusted to the hydrophobicity degree of the aerogel used [30], to keep the production conditions.

Cement, aggregates and admixtures were dry-mixed. To compensate for the extreme fragility of CA, which crumbles upon

Table 1
Properties for declared values and with requirements to fulfil according to EN 998-1 [4].

Declared values				Properties with requirements to fulfil			
ρ [kg/m^3]	f_u [N/mm^2]	RF (class)	D	C_S [MPa]	*Cc* [kg/(m^2.min$^{1/2}$)]	μ	λ [W/m.K]
				CS I (0.4 to 2.5) to CS II (1.5 to 5.0)	W1: ≤0.40	≤15	T1: ≤0.10 T2: ≤0.20
EN 1015-10 [5]	EN 1015-12 [6]	EN 13501-1 [7]	N.S.	EN 1015-11 [8]	EN 1015-18 [9]	EN 1015-19 [10]	EN 1745 [11]

ρ – dry bulk density; f_u – adhesion; RF – reaction to fire; D – durability; C_S – compressive strength; *Cc* – capillary water absorption; μ – moisture vapour transmission resistance coefficient; λ – thermal conductivity coefficient; N.S. – not specified.

Table 2
Properties of aerogel-based thermal renders.

Composition		Declared values	Properties with requirements to fulfil EN 998-1 [4]				Ref.
Aerogel (% vol.)	Binder	ρ [kg/m^3]	C_S [MPa]	*Cc* [kg/(m^2 .min$^{1/2}$)]	μ	λ [W/m.K]	
60–90	Mineral binder	200				0.025[b]	[18]
96–99	Calcium hydroxide	115–125				0.014–0.016[b]	[19]
	Cement		34.77			0.076[e]	[20]
	Cement	144–318	0.13–above 0.5			0.015–0.066[c]	[21]
	Lime, gypsum, cement	450–630				0.150–0.250[d]	[22]
	Alumina cement, Portland cement, lime, calcium sulphate		0.08			0.034–0.095	[23]
	–	153	0.43			0.042[b,d]	[24]
	Mineral and/or hydraulic binder	156		1.425[a]	4.25	0.027[d]	[25,26]
12.25–49.5	Lime putty		<0.3[f]		5.24–8.08[f]	0.050–0.350[f]	[27]
25–95	Lime plaster	345–630				0.036–0.114	[28]
25–90	Lime plaster	199–789			5.93–9.86	0.027–0.113	[29]

% vol. – percentage of incorporated aerogel (by total volume); ρ – dry bulk density; C_S – compressive strength; *Cc* – capillary absorption; μ – moisture vapour transmission resistance coefficient; λ – thermal conductivity coefficient.
[a] 0.184 kg/(m^2.s$^{1/2}$) in [25].
[b] According to EN 12667.
[c] According to ASTM C518.
[d] At dry state.
[e] At 28 days curing.
[f] Approximate value (graphically obtained).