Acoustic behaviour of mortars with improved thermal performance

Extended Abstract

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1. Introduction

In order to improve buildings' thermal and acoustic performance, regarding not only their thermal and acoustic properties but also the indoor environmental quality and environmental impact, there has arisen a need for improvement of the properties of thermal insulation materials. This need is reflected in the requirements and regulations [1, 2] concerning buildings' thermal and acoustic performance, which have become significantly more demanding in recent decades [3]. In order to meet such a goal without affecting strength and durability, a number of new products and production methods with improved thermal and acoustic performance have been developed [4].

In this regard, studies in the field have brought in new materials as mortars' components, aiming to improve their thermal and acoustic performance while maintaining appropriate mechanical and physical properties to fulfill their initial functions [5]. Thermal renders are one such available solution; usually these are comprised of lightweight materials and have a bulk density lower than 600 kg/m^3 [3].

According to EN 998-1 standards [6], thermal mortars are characterized, among other criteria, by a thermal conductivity (λ) lower than 0,1 and 0,2 W/(m.K), categorized respectively as T1 and T2. They are also characterized by the CS I or CS II strength classes (0,4 to 5 MPa), capillary water absorption coefficient lower or equal to 0,40 kg/m$^{2}\cdot$min^{0,5} (W1 class), and water vapour permeability coefficient of 15.

In order to improve mortars' thermal and acoustic properties, a number of innovative solutions have been developed incorporating lightweight insulating materials. Aside from important factors such as costs and environmental impact, a compromise between thermal and acoustic performance must also be considered when choosing insulating materials [7]. In this study, mortars incorporating organic aggregates are tested, specifically cork, expanded clay, and expanded polystyrene (EPS), because these materials are frequently found as components of mortars used in construction. Silica nanoaerogel is also used due to its excellent thermal insulating properties, despite it being a material not yet frequently found in construction renders due to its cost.

Silica aerogel is a nanostructured material characterized by its open pore structure with 95% air content, wich gives it a bulk density of 3 to 500 kg/m^3, a very low thermal conductivity (0,01 to 0,02 W/m.K) and an acoustic impedance between 103 and 106 kg/m^{2}s [8]. This material is extremely light, hydrophobic and non-flammable, with cost and difficulty of production being its main drawbacks, which limits it to high technology applications [8-

10]. Not many studies have been conducted regarding its acoustic capabilities when used as aggregate in building renders, although it is expected to attain a high acoustic performance due to its insulating properties.

Expanded clay combines a low bulk density (300 to 700 kg/m^3), high porosity and thermal resistance (up to 1000ºC) with a high structural strength and low cost, which makes it widely used as an insulating material in construction. This material has a high percentage of semi-closed pores (up to 90% of its volume), which contribute to its low thermal conductivity (approximately 0,10 W/m.K) and high chemical resistance, as well as a potential for high acoustic absorption for select grain sizes [11-13].

Cork is an organic, cellular and renewable material which features a low density (100 to 140 kg/m^3) and low thermal conductivity (0,035 to 0,070 W/m.K), as well as good acoustic and mechanical properties [5, 14, 15].

Expanded polysterene (EPS) is a thermoplastic polymer featuring a rigid cellular structure, composed primarily of air (98%), which affords it an extremely low density and thermal conductivity (0,04 W/m.K) [16, 17].

An experimental campaign was conducted in order to better understand the acoustic behaviour of thermal mortars. Both traditional and industrial formulations were subjected to various tests to study the effect of the incorporation of insulating aggregates on the acoustic performance of thermal mortars, having the following as main objectives:

- to evaluate the influence of the incorporation of insulating aggregates (silica aerogel, granulated cork, expanded clay and EPS), as well as additions (air entrainment agent, rheologic agent and liquid resin) on the acoustic behaviour of thermal mortars;
- to characterize thermal mortars by testing sound absorption, bulk density, open porosity, permeability and airflow resistivity, ultrasonic pulse velocity, dynamic elasticity modulus, shear modulus and *Poisson* coefficient, compressive strength, thermal conductivity, characteristic thermal length and characteristic viscous length (the latter estimated from images taken using a binocular lens and X-ray microtomography);
- to relate the physical and mechanical properties of thermal mortars with their acoustic behaviour, in order to understand which factors are the most influent;
- to compare the experimental sound absorption results with those predicted by the Attenborough and Allard-Johnson models and evaluate their sensitivity/applicability in thermal mortars.

2. Experimental work

The aim of the experimental work was to relate the acoustical performance of thermal mortars with their respective physical and mechanical properties. In order to achieve this goal, nine traditional and two industrial mortars were produced, all of which are shown in tables 2.1 and 2.2. The production of the mortars was carried out in four separate phases, with each test being carried out in cylindrical or prismatic samples according to their respective demands or specifications.

A 1:4 volumetric ratio was chosen for all traditional mortars, since this is the most commonly used ratio for traditional cement-based mortars in Portugal [18]. The same volumetric ratio was maintained throughout the production of all traditional mortars, thus enabling one to compare the results according to the incorporation of different aggregates. For the same reason, the same binder was also used in all traditional mortars; a Portland cement of the CEM II B/L type 32,5 N class was chosen, while the water/cement ratio used for each mortar were selected in order to meet the requirements necessary for ensuring a consistence according to the EN 1015-2 standard [19].

Five mortars containing isolating aggregates were produced, replacing sand as the aggregate. The first three contain varying amounts of silica aerogel along with granulated cork and expanded clay, in proportions of 60% aerogel + 40% expanded clay (mortar A^{Trad}_{AG+AE}), 60% aerogel + 40% cork (mortar B^{Trad}_{AG+GC}) and 100% aerogel (mortar C^{Trad}_{AG}). Two other other mortars were produced, one containing 100% expanded clay (mortar C^{Trad}_{AG}) and another containing 100% cork (mortar E^{Trad}_{GC}). Furthermore, four control mortars were produced in which sand was used as the main aggregate, varying the particle size and additions in order to study their effect on the tested parameters (mortars $F^{controlo}$, G^{Ref}, $H^{controlo}$ and $I^{controlo}$). Apart from these, two industrial mortars were also produced, one containing cork (mortar J^{Ind}_{GC}) and another containing EPS granules (mortar K^{Ind}_{EPS}). The production of industrial mortars followed the manufacturers' instructions regarding the amounts of water that should be added to the powder product.

In addition to the insulating aggregates, three additions were also used in the traditional mortars, namely air entrainment agent, rheologic agent and liquid resin, in order to study their influence on the acoustical behaviour of thermal mortars. Two different particle grading sizes were adopted: one was selected according to the "Mesquita" curve with fractions ranging from 0,063 to 2 mm, and another containing fractions of sizes [0,5 to 1 mm] and [1 to 2 mm] ("Curve 2") according to the grain sizes of the light aggregates.

Table 2.1 – Traditional render compositions

Traditional mortars	Binder	Insulating aggregate/ % substitution (volume)	Granulometry	Aggregate dimension (mm)	Water/ cement ratio	Additions
A^{Trad}_{AG+AE}	CEM II 32,5 N	60% aerogel + 40% expanded clay	Curve 2	0,5 a 2	1,01	Yes
B^{Trad}_{AG+GC}		60% aerogel + 40% granulated cork	Curve 2	0,5 a 2	0,86	Yes
C^{Trad}_{AG}		100% aerogel	Curve 2	0,5 a 2	0,66	Yes
D^{Trad}_{AE}		100% expanded clay	Curve 2	0,5 a 2	0,55	Yes
E^{Trad}_{GC}		100% granulated cork	Curve 2	0,5 a 2	0,85	Yes
$F^{controlo}$		100% sand	Mesquita	< 0,063 a 2	0,40	Yes
G^{Ref}		100% sand	Mesquita	< 0,063 a 2	1,10	No
$H^{controlo}$		100% sand	Curve 2	0,5 a 2	0,95	No
$I^{controlo}$		100% sand	Curve 2	0,5 a 2	0,40	Yes

Table 2.2 – Industrial render compositions

Industrial mortars	Binder	Insulating aggregate/ % substitution (volume)	Aggregate dimension (mm)	Other aggregates	Amount of water per bag (L/kg)	Additions
J^{Ind}_{GC}	Natural hydraulic lime	Cork (n.i.)	≤ 3	Diatomite/ clay	0,55	Natural additions; polypropylene fibers; air entrainment agent
K^{Ind}_{EPS}	Lime/ white cement and synthetic binders	70-80% EPS	1,5 a 2	Sand	0,7	Not specified

Legend: n.i. – no information regarding percentage of substitution.

For each mortar, 7 samples were produced: 2 cylindrical samples with 28,5 mm diameter and 40 mm thickness, 2 cylindrical samples with 99,5 mm diameter and 40 mm thickness, and 3 prismatic samples measuring 40x40x160 mm. The storage and curing followed the EN 1015-11 standard [20], according to which wet curing in polyethylene bags (7 days) was followed by dry curing (21 days) in a climatic chamber under controlled conditions, corresponding to a temperature of 20ºC ± 5ºC and relative humidity of 65% ± 5%.

To characterize the acoustic performance of the thermal mortars, sound absorption tests were carried out on the cylindrical samples by means of the impedance tube method, in accordance with EN 10534-2 [21]. Furthermore, in order to characterize these mortars physically and mechanically, other tests were carried out to evaluate the bulk density, open porosity, thermal conductivity, permeability and airflow resistivity, dynamic modulus of elasticity, shear modulus, *Poisson* coefficient, compressive strength and ultrasonic pulse velocity, according to European and American standards [22-25]. The characteristic thermal and viscous lengths for each mortar were calculated by estimating pore diameter and width from images taken using a binocular lens and X-ray microtomography. The Noise Reduction Coefficient (NRC), an indicator used to describe materials' acoustic performance, was calculated by following ASTM C423 [26]. The mortars were also classified according to the scale present in EN 11654 [27].

An adapted hydrostatic method was followed to estimate open porosity on thermal mortars, since their low density makes the water displacement method impossible. The samples were immersed in test tubes, measuring their dry and saturated volumes in order to estimate open porosity. A stainless steel support was used to keep the samples in place, while a cork stopper closed the tubes to avoid water evaporation, which would have provoked wrongful variations in the measured volume. Bulk density in the hardened mortars was also evaluated using the same method, in addition to the geometric method (dividing mass by volume) and the hydrostatic method.

3. Results

The experimental tests were conducted according to the standards shown on tables 1 and 2, which also presents the respective results on prismatic and cylindrical samples, respectively.

Table 1 - Test results on the prismatic samples in the hardened state

Mortars	MV (kg/m^3)	σ (%)	Cs (MPa)	E_d (MPa)	G (MPa)	ν	V (m/s)
Standards	EN 1015-10 [22]	EN 1015-10 [23]; n/a	EN 1015-11 [20]	ASTM E1876-01 [24]			EN 12504-4 [25]
A^{Trad}_{AG+AE}	565	26,7	0,68	787	288	0,178	1647
B^{Trad}_{AG+GC}	457	30,0	0,70	427	152	0,200	1290
C^{Trad}_{AG}	465	18,8	0,34	342	117	0,276	1165
D^{Trad}_{AE}	825	58,1	1,66	1581	734	0.087	1938
E^{Trad}_{GC}	408	30,7	0,39	250	99	0,267	922
$F^{controlo}$ (2nd batch)	1354	47,5	0,40	2595	1247	0,040	1832
$F^{controlo}$ (4rd batch)	1609	36,3	3,04	5536	2541	0,089	2169
G^{Ref}	1876	25,6	9.96	12765	3563	0,254	2962
$H^{controlo}$	1920	24,5	8,45	13247	5713	0,158	2952
$I^{controlo}$	1952	23,6	10,73	14326	6436	0,113	3146
J^{Ind}_{GC}	708	50,0	2,02	1254	515	0,218	1551
K^{Ind}_{EPS}	436	16,7	0,78	572	248	0,155	1427

(Legend: MV – bulk density in hardened state; σ – open porosity; Cs – compressive strength; E_d – dynamic elasticity modulus, G – shear modulus, ν – *Poisson* coefficient; V – ultrasound pulse velocity)

Table 2 – Test results on the cylindrical samples in the hardened state

Mortars	MV (kg/m^3)	σ (%)	λ_{dry} (W/m·K)	E_d (MPa)	G (MPa)	ν	δ (d)	r (kPa·s/m^2)	α_{max}	α_{med}	NRC	Λ' (µm)	Λ (µm)
Standards	EN 1015-10 [22]	EN 1015-10 [22]; n/a	Isomet 2114 [23]	ASTM E1876-01 [24]			-		EN 10534-2 [21]		-	-	-
A^{Trad}_{AG+AE}	690	18,4	0,08	1334	559	0,193	64,0	289	0,24	0,14	0,15	150	1,5
B^{Trad}_{AG+GC}	528	10,0	0,08	481	201	0,197	4,7	4103	0,22	0,11	0,10	150	1,5
C^{Trad}_{AG}	508	15,0	0,07	550	222	0,237	11,2	1694	0,27	0,11	0,10	150	1,5
D^{Trad}_{AE}	801	56,0	0,14	1287	556	0,157	114,9	155	0,80	0,38	0,40	50	8,5
E^{Trad}_{GC}	491	23,3	0,08	416	178	0,170	76,6	239	0,48	0,28	0,30	100	1,0
$F^{controlo}$ (1st batch)	1586	37,9	0,30	1684	736	0,144	109,0	177	0,56	0,34	0,40	100	16,5
$F^{controlo}$ (3rd batch)	1690	33,8	1,23	9930	4222	0,176	199,5	129	0,30	0,18	0,20	100	16,5
G^{Ref}	1906	24,0	1,44	10049	4325	0,167	36,9	611	0,16	0,09	0,10	100	1,0
$H^{controlo}$	1937	24,7	1,48	10031	4381	0,145	254,0	96	0,25	0,14	0,15	100	1,0
$I^{controlo}$	1864	26,3	1,11	8678	3764	0,153	212,9	119	0,69	0,29	0,35	200	33,5
J^{Ind}_{GC}	699	31,8	0,13	1186	500	0,185	4,3	4517	0,28	0,11	0,10	100	1,0
K^{Ind}_{EPS}	382	25,9	0,07	371	151	0,225	3,5	5279	0,21	0,09	0,10	100	1,0

(Legend: MV – bulk density in hardened state; σ – open porosity; λ – thermal conductivity; ; E_d – dynamic elasticity modulus, G – shear modulus, ν – *Poisson* coefficient; δ – arflow permeability; r – airflow resistivity; α_{max} – maximum sound absorption coefficient; α_{med} – average sound absorption coefficient; NRC – Noise Reduction Coefficient; Λ' – thermal length; Λ – viscous length)

The results show that, with the introduction of insulating aggregates, both in traditional and industrial mortars, the physical and mechanical properties of the mortars change substantially. There are significant decreases in values of all characteristics, some of which were to be expected, such as the bulk modulus and thermal conductivity.

The bulk density values of the mortars incorporating insulating aggregates range between 382 and 801 kg/m^3, a significant decrease relatively to the control mortars, which record values between 1586 and 1937 kg/m^3. According to EN 998-1 [6], they can be classified as lightweight mortars, since their bulk density is lower than 1300 kg/m^3. Regarding the dynamic elasticity modulus and shear modulus, a sharp decrease (around 85 to 160%) has been observed relatively to the control mortars, while on the other hand the *Poisson* coefficient has increased. At the same time, the ultrasound pulse velocity has decreased, all of which indicate that the mortars incorporating insulating aggregates are overall less compact than the control sand mortars, owing both to the aggregates' low density and to the additions used in the mix, most notably the air entrainment agents, which increase the void content of the mortars. This effect also makes these mortars less resistant to compression, as can be noted on table 3.2, with values ranging between 0,34 and 2,02 MPa, while traditional sand mortars recorded values up to 10 MPa. However, these values correspond to CS I or CS II strength class mortars, thus complying with the EN 998-1 standards applied for thermal mortars [6].

The mortars incorporating insulating aggregates have also registered a sharp decrease in their thermal conductivity, achieving values between 0,07 and 0,13 W/m.K. According to EN 998-1, they can be classified as T2 thermal mortars ($\lambda < 0,20$ W/m.K).

The open porosity values obtained for all mortars is shown to be very inconsistent, with values ranging between 10 and 56% for thermal mortars. However, these values could be influenced by the uncertainty connected with the hydrostatic test method, raising the necessity for alternate tests to determine parameters such as pore volume and pore distribution in order to validate these results. The test was also influenced by the hydrophobicity of the aerogel and EPS aggregates, which hinder water absorption in the mortars and introduce uncertainty in the results.

The sound absorption results obtained for all the mortars can be summarized in figure 1, showing an overall increase of absorption with an increase in frequency. With the exception of the mortar with 100% aerogel (C^{Trad}_{AG}), the peak occurs between the 400 and 1000 Hz range. This peak is especially evident in the 100% clay (D^{Trad}_{AE}) and 100% cork (E^{Trad}_{GC}) mortars, as well as two of the sand mortars ($F^{controlo}$ and $I^{controlo}$).

The sand mortars were not expected to achieve absorptions higher than those with aggregate substitution, which may have been caused by the additions used in their constitution, namely the air entrainment agent, which introduced significant changes in the porous structure comparatively to those without additions. Table 1 shows that these mortars ($F^{controlo}$ and $I^{controlo}$) indeed attained relatively high values of open porosity relatively to the other mortars. However, it should be noted that these are not thermal mortars, since their bulk densities and thermal conductivities are higher than the limits prescribed by EN 998-1 [6]. It can also be noted that the mortars containing aerogel haven't recorded a significant increase in absorption relatively to the others.

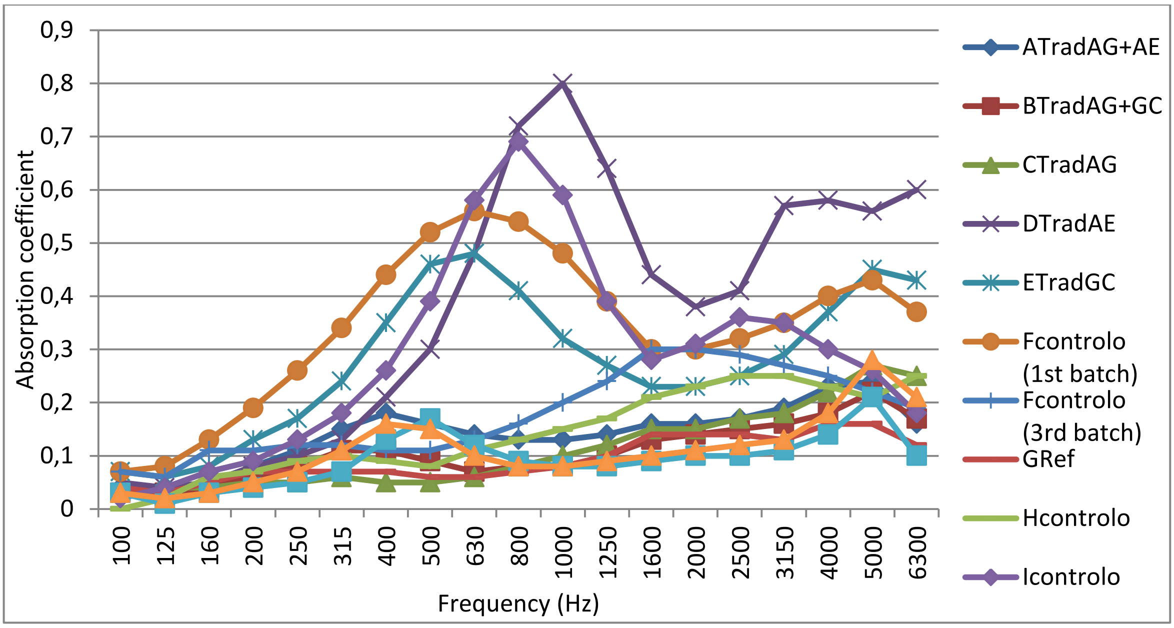

Figure 1 – Absorption coefficients obtained for all mortars

The mortars' performance can be compared by means of the NRC indicator (*Noise Reduction Coefficient*), defined in ASTM C423 [26] and classified according to EN 11654 [27]. The sand and 100% clay mortars $F^{controlo}$ (1st batch) and D^{Trad}_{AE} have obtained NRC=0,40, while the 100% cork mortar E^{Trad}_{GC} obtained NRC=0,30, which means they are classify as hardly absorbing (class E). The same result was obtaine for sand mortars mortars $F^{controlo}$ (3rd batch) and $I^{controlo}$. As to the remaining mortars, they have obtained NRC values lower than 0,15, which means they can be classified as non-absorbent according to EN 11654.

Although no classifications above D (absorbent materials) were expected, the relatively low values obtained for the aerogel and industrial mortars were not expected, due to their aggregates' physical properties. Indeed, although the manufacturers of the industrial mortars indicate maximum values for the aborption coefficient of approximately 0,70, these weren't confirmed experimentally. Once again the results might have been influenced by a number of causes related to the production of the samples, which raises the necessity for more tests in order to obtain more detailed conclusions.

There doesn't appear to be a significant correlation between sound absorption and the bulk density; inded, for both the maximum and average absorption values, the linear correlation was lower than 0,30. Regarding the open porosity, which should be one of the most influent factors in the acoustic behaviour of the mortars, no correlation was found, although in the case of most of the thermal mortars a non-standardized test method was adopted, which raises doubts as to its validity. The open porosity values vary widely among different samples with no relation to their sound absorption, with the industrial cork mortar (J^{Ind}_{GC}), for instance, recording a higher porosity value (31,8%) than its traditional counterpart E^{Trad}_{GC} (23,3%), without an increase in absorption. It can be concluded that further tests are necessary to ascertain the validity of this test method. In any case, open porosity is not the only factor governing sound absorption in porous materials, much of it being dependent on factors such as tortuosity or pore shape.

As to the airflow resistivity results, the industrial mortars recorded the highest values, along with the 100% aerogel mortar. On the other hand, the clay, cork and sand mortars registered the lowest resistivities. It becomes apparent that the mortars with the lowest resistivities fared the best in terms of acoustic absorption, having attained power correlations up to 0,80 (figures 2 and 3). This result confirms that airflow resistivity is indeed a significant indicator of the acoustic behaviour of these materials. It should be noted, however, that not all the control mortars registered an improvement on absorption; in fact this only occurred on those containing air entraining agents.

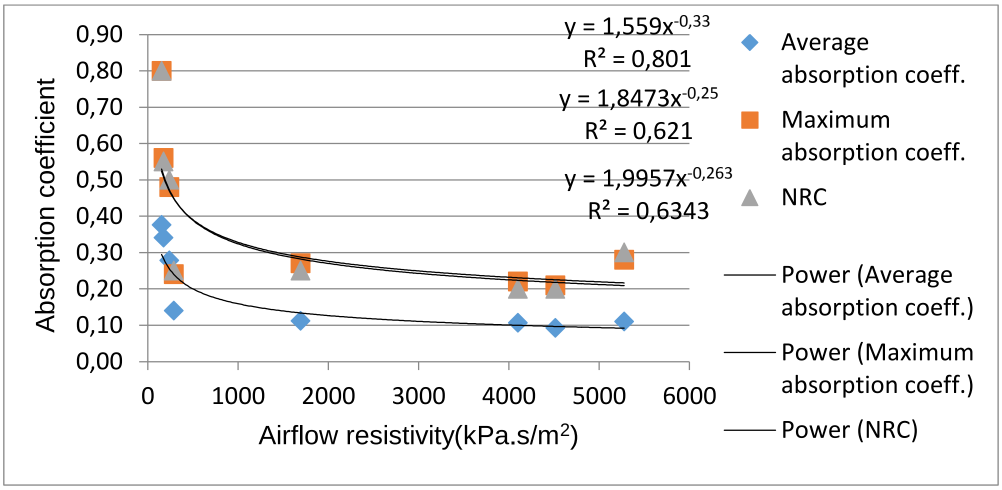

Figure 2 – Correlation of airflow resistivity with sound absorption and NRC for the 1st batch of mortars produced

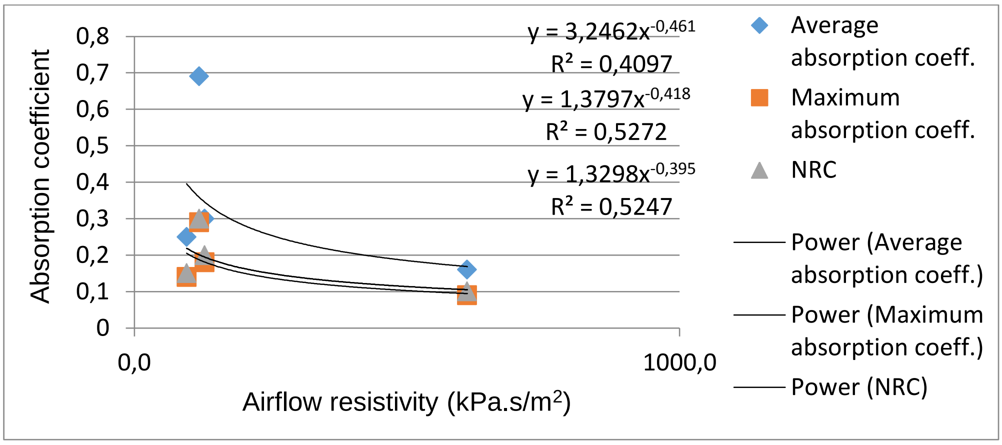

Figure 3 – Correlation of airflow resistivity with sound absorption and NRC for the 3rd batch of mortars produced

The remaining parameters have also shown a low correlation with acoustic absorption. For the dry thermal conductivity, a correlation coefficient lower than 0,40 was obtained. Indeed, while thermal conductivity is most affected by closed porosity, sound absorption depends mainly on open porosity and high tortuosity and viscous effects [28]. Regarding the compressive strength, ultrasound pulse velocity, dynamic elasticity modulus, shear modulus and *Poisson* coefficient, all of which indirectly measure the rigidity and compactness of materials, the correlation was also evaluated and found to not exceed 0,40.

Lastly, estimates for the characteristic thermal and viscous lengths were obtained by measuring the pore size and length. This was accomplished through observation of the samples via binocular lens and X-ray microtomography, examples of which can be found in figure 4.

Figure 4 – Mortar D^{Trad}_{AE} as seen through binocular lens (left) and X-ray microtomography (right)

For this estimation, pores were assumed to be roughly spherical in shape, while pore connections were assumed to be cylindrical, which is similar to the hypothesis assumed by other authors [29]. The thermal length (Λ') is given by the ratio of the total inner surface area to the total volume of the pores [30], as seen on equation 2, while the viscous length (Λ) is given by equation 1, in which the numerator is a surface integral where the velocity v_i of the fluid, as indicated by the index w, applies to the inner walls of the pores, while the denominator is the corresponding volume integral that applies to the whole volume of pores.

$$\frac{2}{\Lambda} = \frac{\oint_S \; v_i^2\,(r_w)dS}{\int_V \; v_i^2(r)dV} \tag{1}$$

$$\frac{2}{\Lambda'} = \frac{A}{\mathrm{V}} \tag{2}$$

In spherical pores, the volume is given by $V = \frac{4}{3} * \pi * \left(\frac{\phi}{2}\right)^3$, while the area is given by $A = \pi * \phi^2$, in which ϕ is the diameter of the pores. The thermal length can then be written as shown on equation 3:

$$\Lambda' = \frac{\phi_{pore}}{3} \tag{3}$$

On the other hand, admitting cylindrical pore canals of diameter ϕ and length L, whose surface area is given as $A = L*\phi*\pi$, the viscous length is given by equation 4:

$$\Lambda = \frac{L\;\phi_{canal}}{\phi^2_{poros}}\Lambda' \tag{1}$$

Assuming these equations, the viscous and thermal lengths can then be estimated by measuring the pore diameter, as well as the passage diameter and length. The visual estimation is very crude, and in cases where the mortars' pore structure is very closed and the connections are narrow, a ratio of 1/100 was admitted for Λ/ Λ'. In the latter, the effect of the pores being closed resulted, in most cases, in a higher airflow resistivity and lower open porosity, since this structure offers resistance to the passage of air. The estimated values for the thermal and viscous lengths are presented in table 2.

4. Acoustic modelling

The Attenborough and Allard-Johnson models are among the most commonly used to describe the acoustic behaviour in porous media, which is why they were adopted in this study. The parameters considered in these models are the open porosity, airflow resistivity, tortuosity, pore shape factor (in the Attenborough model) and the thermal and viscous lengths (in the Allard-Johnson model). Out of these, the open porosity, airflow resistivity and thermal and viscous lengths were estimated experimentally.

A sensitivity analysis was conducted on these models, through which it was found that the most influent factors in sound absorption are the viscous length and tortuosity; an increase in the first causes the absorption coefficient to increase, while the latter has the opposite effect. To a lesser degree, an increase in the pore shape factor, open porosity and airflow resistivity causes a decrease in sound absorption, while the thermal length was found to have no effect in sound absorption values. It's worth noting that this theoretical curve behaviour is valid only for the studied mortars, since the sensitivity analysis was conducted by considering the experimental results.

By fitting the model curves to the experimental data, both models were able to predict the an increase in sound absorption with frequency, which were also obtained for the aerogel and industrial mortars; however, the theoretical values were generally lower than those obtained experimentally. The 100% expanded clay and granulated cork mortars, as well as the sand mortars which additions, could not be fitted accurately to the predicted curves, which registered significant peaks of absorption in the mid-frequency range. This behaviour could likely be explained by the experimental conditions during sound absorption tests, such as resonance being caused by the samples' irregular surface.

5. Conclusions

In the present dissertation, the acoustic behaviour of thermal mortars was studied experimentally, in order to study the effect of the incorporation of various insulating aggregates (silica aerogel, granulated cork, expanded clay and EPS), and additions (air entrainment agent, rheologic agent and liquid resin). The sound absorption was tested and found to be highest in mortars incorporating expanded clay and cork granulate aggregates. The incorporation of silica aerogels did not have a substantial effect in increasing absorption in these mortars, despite the improved thermal performance. However, the recorded acoustic behaviour was strongly affected by the presence of additions in the mix, especially air entrainment agents, which significantly alter the porous structure of the mortars.

Among the studied physical and mechanical properties, the airflow resistivity was found to be the most influential in predicting the acoustic behaviour of the mortars. Relatively high correlation coefficients were obtained between the sound absorption and airflow resistivity (up to 0,80). However, the hydrostatic test method used to measure open porosity in thermal mortars was not standardized and introduced some uncertainty in the results. Indeed, this parameter was expected to strongly influence absorption in these materials. However, porosimetry measurements carried out outside the scope of this work (on the same mortars) obtained values much higher than those recorded here, which confirms the test tube method can be improved and that open porosity in these mortars is consistent with sound absorption.

The acoustic behaviour of the thermal mortars was fitted to the theoretical Attenborough and Allard-Johnson models. The most influent parameters in these models considering experimental data were the tortuosity and the viscous length. The theoretical curves did not match those obtained experimentally, as regards the sound absorption coefficient; however, the absorption curves predicted an increase of sound absorption consistent with the usual behaviour for porous media. This tendency was also found in the acoustic behaviour of the aerogel and industrial mortars.

In general, it was found that mortars with improved thermal performance can also function as acoustic insulators, by a careful choice in aggregates and additions. Through this dissertation it was possible to identify a tendency in the improved acoustic behaviour of mortars containing expanded clay and air entrainment agents, which are mostly influenced by airflow resistivity. However, the acoustic behaviour of porous media depends on many other factors, raising the need for further studies in order to ascertain their influence in the acoustic behaviour of thermal mortars.

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