Experimental study of the binders and aggregates' influence on the renders' performance in the hardened state

Extended Abstract

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1. Introduction

Increasingly demanding thermal comfort requirements [1, 2], in association with the need to enhance buildings' energy efficiency, have caused a demand for the improvement of the properties of thermal insulation products [3]. Therefore, related studies have focused on incorporating new materials in mortars, with the goal of improving their thermal performance without compromising their mechanical properties [4].

The incorporation of insulating materials in mortars has led to the definition of thermal mortars which, according to European standard EN 998-1 [5], are divided into two classes, T1 or T2, depending on whether their thermal conductivity is lower than 0.1 or 0.2, W/(m.K), respectively. Additionally, thermal mortars must display compressive strengths between 0.4 and 5 MPa, a capillary water absorption coefficient below 0.4 $kg/m^2.min^{0.5}$ and a water vapour permeability coefficient below 15.

When selecting a thermal coating solution, one must take into account its cost, compressive strength, water vapour permeability and, most importantly, thermal conductivity [6, 7]. This last property is related to the bulk density, temperature, moisture content and porosity of each material [8, 9].

In order to achieve the desired balance between thermal conductivity and mechanical properties, the mortars tested in this study contain both granulated cork and/or expanded clay as aggregates and different contents of cement, fly ash and aerial lime as binders.

Cork is an organic, cellular and renewable material known for its low density and thermal conductivity [10, 11]. As a result, the use of cork in concrete and mortars enhances their thermal behaviour, but it decreases their density, which has a negative impact on the mechanical properties [4].

Expanded clay is characterized by its low density, as well as its high porosity and thermal resistance. It presents one of the highest compressive strengths among lightweight aggregates as well as a low cost, which makes it widely used as an insulating material in construction [12-14].

Fly ash can be used as a cement replacement in order to improve the durability and mechanical properties (although a decrease is expected at early ages). However, its effect on thermal conductivity has not been thoroughly studied [15, 16]. Furthermore, the use of fly ash in mortars and concrete has a positive environmental impact: by reducing the cement content, there is a reduction in natural resources and energy consumption during cement production; also, since fly ash is a by-product of thermal power stations, its use in the construction industry slows down the built-up of landfills for its disposal [17].

The incorporation of aerial lime in cement mortars leads to higher deformability and porosity, making these mortars suitable for conservation works in old buildings, since they are compatible with the original and existing materials. They also present hydraulic properties, therefore having higher mechanical strength than aerial lime mortars [18].

Thus, the aim of this study is to analyse the binders' influence, in association with different insulating aggregates, on the performance in the hardened state of mortars with an improved thermal performance. To this effect, an experimental campaign was carried out with the following main goals:

- At a preliminary stage, to understand the influence of the admixtures (an air-entraining agent and a water retention agent) on some of the sand mortars' properties (bulk density, flexural and compressive strengths, dynamic modulus of elasticity, *Poisson* coefficient, ultrasonic pulse velocity and thermal conductivity);
- To evaluate the influence of increasing amounts of fly ash (or fly ash in combination with aerial lime) on the thermal, mechanical and physical performance of mortars with insulating aggregates, by testing their bulk density, open porosity, flexural and compressive strengths, dynamic modulus of elasticity, *Poisson* coefficient, ultrasonic pulse velocity, adhesion to the substrate, pendulum rebound index, capillary water absorption coefficient, drying index, water absorption under low pressure and thermal conductivity;
- To study the aggregates' influence (granulated cork, expanded clay or a mix of both) on the aforementioned properties and to understand how each one is affected by the changes in binder composition.

2. Experimental work

The experimental work was divided in two stages - a preliminary campaign and an experimental campaign. In the former, four mortars were produced, with only sand as aggregate: a reference mortar, A_{CE} (without admixtures and using cement as binder), mortars B_{CE} and D_{CE} (also using cement as binder, but the former with only a binding agent and the latter with both admixtures) and J_{CEFA50} (also with both admixtures but containing a mixture of 50% cement and 50% fly ash).

The mortars produced in the experimental campaign can be divided into five groups (CE, CEFA20, CEFA35, CEFA50 and CEFA10AL40), according to the different proportions of cement, fly ash and aerial lime used in the mix. Within each group there are four mortars with insulating aggregates plus a sand mortar for comparative purposes. An air-entraining agent and a water retention agent were introduced in the mixes as well. Table 1 lists each mortars' composition.

A 1:4 (binder: aggregate) volumetric ratio was used for all mortars. A size range distribution between 0.5 and 2 mm was adopted for the insulating aggregates, whereas for sand the particle size ranged from < 0,063 mm to 2 mm. The binders and aggregates' bulk densities were determined in accordance with standard NP EN 1097-3 [19] and are presented in Table 2.

For each mortar, 10 samples were produced: 6 prismatic samples measuring 40x40x160 mm, for all tests except thermal conductivity; in this test 4 prismatic samples measuring 80x70x25 mm were used. Additionally, 12 of the mortars were also applied on a brick substrate, in order to assess their adhesive strength, pendulum rebound index, water absorption under low pressure, ultrasonic pulse velocity and thermal conductivity. The storage and curing of the samples consisted of wet curing in polyethylene bags (7 days) followed by dry curing (21 days) in a climatic chamber under controlled conditions, (temperature of 20 ± 5 ºC and relative humidity of 65 ± 5%), in accordance with EN 1015-11 [20].

Table 1. Mortar composition

Mortars	Binders (% substitution by mass)			Aggregates (% substitution by volume)			Water/binder ratio	Admixtures (% of binders' mass)	
	Cement (CE)	Fly ash (FA)	Aerial lime (AL)	Granulated cork (GC)	Expanded clay (EC)	Sand (S)		Water retention agent	Air-entraining agent
$\mathrm{A_{CE}}$	100	-	-	-	-	100	1.00	-	-
$\mathrm{B_{CE}}$	100	-	-	-	-	100	1.05	0.075	-
$\mathrm{D_{CE}}$	100	-	-	-	-	100	0.75	0.075	0.05
$\mathrm{I_{CEFA50}}$	50	50	-	-	-	100	0.67	0.075	0.05
$\mathrm{CE^{100GC}}$	100	-	-	100	-	-	0.76	0.075	0.05
$\mathrm{CE^{100EC}}$	100	-	-	-	100	-	0.78	0.075	0.05
$\mathrm{CE^{60GC}{}_{40EC}}$	100	-	-	60	40	-	0.76	0.075	0.05
$\mathrm{CE^{60EC}{}_{40GC}}$	100	-	-	40	60	-	0.76	0.075	0.05
$\mathrm{CE^{100S}}$	100	-	-	-	-	100	1.00	-	-
$\mathrm{CEFA20^{100GC}}$	80	20	-	100	-	-	0.75	0.075	0.05
$\mathrm{CEFA20^{100EC}}$	80	20	-	-	100	-	0.74	0.075	0.05
$\mathrm{CEFA20^{60GC}{}_{40EC}}$	80	20	-	60	40	-	0.74	0.075	0.05
$\mathrm{CEFA20^{60EC}{}_{40GC}}$	80	20	-	40	60	-	0.74	0.075	0.05
$\mathrm{CEFA20^{100S}}$	80	20	-	-	-	100	0.90	-	-
$\mathrm{CEFA35^{100GC}}$	65	35	-	100	-	-	0.75	0.075	0.05
$\mathrm{CEFA35^{100EC}}$	65	35	-	-	100	-	0.74	0.075	0.05
$\mathrm{CEFA35^{60GC}{}_{40EC}}$	65	35	-	60	40	-	0.71	0.075	0.05
$\mathrm{CEFA35^{60EC}{}_{40GC}}$	65	35	-	40	60	-	0.72	0.075	0.05
$\mathrm{CEFA35^{100S}}$	65	35	-	-	-	100	0.90	-	-
$\mathrm{CEFA50^{100GC}}$	50	50	-	100	-	-	0.73	0.075	0.05
$\mathrm{CEFA50^{100EC}}$	50	50	-	-	100	-	0.73	0.075	0.05
$\mathrm{CEFA50^{60GC}{}_{40EC}}$	50	50	-	60	40	-	0.72	0.075	0.05
$\mathrm{CEFA50^{60EC}{}_{40GC}}$	50	50	-	40	60	-	0.72	0.075	0.05
$\mathrm{CEFA50^{100S}}$	50	50	-	-	-	100	0.90	-	-
$\mathrm{CEFA10AL40^{100GC}}$	50	40	10	100	-	-	0.98	0.075	0.05
$\mathrm{CEFA10AL40^{100EC}}$	50	40	10	-	100	-	0.98	0.075	0.05
$\mathrm{CEFA10AL40^{60GC}{}_{40EC}}$	50	40	10	60	40	-	0.97	0.075	0.05
$\mathrm{CEFA10AL40^{60EC}{}_{40GC}}$	50	40	10	40	60	-	0.97	0.075	0.05
$\mathrm{CEFA10AL40^{100S}}$	50	40	10	-	-	100	1.01	-	-

Table 2. Bulk densities of the mortars' compounds

Material	Cement	Fly ash	Aerial lime	Sand	Granulated cork	Expanded clay
Bulk density (kg/m^3)	1060	1046	583	1334	52	431

The dynamic modulus of elasticity and ultrasonic pulse velocity tests were carried out in accordance with standards ASTM E1876-01 [21] and EN 12504-4 [22], respectively. The flexural and compressive strengths were estimated through a correlation with the dynamic modulus of elasticity defined by Silva et al. [23], as well as by following EN 10-15-11 [20]. Bulk density was measured according to EN 1015-10 [24] and the open porosity tests followed NP EN 1936 [25]. In the latter test, the open porosity of mortars containing only granulated cork could not be determined with this method, since the low density of this material hampered the hydrostatic weighing of the samples. The mortars' thermal conductivity was assessed using the ISOMET 2114 equipment [26]. A pendulum hammer was used to determine the superficial hardness of the mortars, translated by a rebound index, whereas the procedure used to measure the adhesive strength was adapted from EN 1015-12 [27], by means of a pull-off test. The capillary water absorption coefficient was measured according to EN 1015-18 [28], followed by the drying index. The latter was then calculated by the method found in [29]. Water absorption under low pressure was evaluated using Karsten pipes following standard LNEC Fe Pa 39.1 [30].

3. Results

The results from both the preliminary and experimental campaign are shown in Table 3.

3.1 Preliminary campaign

The introduction of an air-entraining agent and a water retention agent caused an 18% decline in compressive strength and a 15% decline of the dynamic modulus of elasticity, when compared to the reference mortar (without admixtures). However, the flexural strength and ultrasonic pulse velocity showed little variation with the admixtures use (5% and 8% decline, respectively). The bulk density and thermal conductivity had a similar variation, 11% and 12% reduction, respectively. These results can be explained by the formation of air bubbles due to the air-entraining agent, which leads to a lower bulk density. As a result, the mortars have lower resistance and stiffness, and better insulation properties.

Although this subject is studied in further detail in the experimental campaign, this preliminary step made it clear that, by replacing half the cement with fly ash, the mortars become less compact and less mechanically resistant, more deformable, and show an improved thermal performance.

3.2 Experimental campaign

The experimental results obtained in this campaign are discussed below, regarding the influence of the aggregate and binder variation. However, the values of the adhesive strength, rebound index and water absorption under low pressure proved to be very inconsistent. In the adhesive strength and pendulum hammer tests, only a small sample of results could be obtained; in the former test, due to an inadequate method for sectioning the mortars, and in the latter due to the need to preserve the mortars for further testing (since the pendulum hammer tends to compact the mortars' surface). In the case of the water absorption test, the rough surface of the mortars might have affected the correct insulation of the tubes, which, along with the possible existence of micro-cracks in the mortars, originated high variation coefficients.

Regarding the thermal conductivity test, it is worth noting the high correlation found between the results obtained in the brick samples and the standard samples ($R^2 = 0.92$). The ultrasonic pulse velocity in brick samples was determined in two different ways: the mean and dromochronic methods. In both cases, there was also a high correlation between standard and brick samples ($R^2 = 0.92$ and 0.96 for the mean and dromochronic methods, respectively).

3.2.1 Influence of the aggregates' variation

Concerning the bulk density, the lowest values of the mortars with insulating aggregates were measured in granulated cork mortars and the highest in the expanded clay ones, which was to be expected considering the density of each material. The reduction in bulk density when compared with sand mortars was significant, with a decline between 59% and 61% for expanded clay and between 74% and 77% for granulated cork. Vale et al. [31] also concluded that mortars incorporating insulating aggregates present lower values of bulk density.

Mortars with insulating aggregates presented high values of open porosity, all of which above 50%. This represents an increase between 95% and 124% relative to the respective sand mortars. However, open porosity was not measured for the granulated cork mortars, as stated above.

When compared to the corresponding sand mortar, the granulated cork mortars presented the highest reduction in strength, between 72% and 75% for flexural strength and between 84% and 97% for compressive strength. Brás et al. [10] also noted a significant decrease in compressive strength (around 84%) for mortars with granulated cork, when compared to a reference mortar. Conversely, expanded clay mortars had the lowest decline, between 25% and 43% for flexural strength and between 34% and 55% for compressive strength. All mortars with insulating aggregates have compressive strengths between 0.4 MPa and 5 MPa, thus fulfilling the requirements of European standard EN 998-1 [5] for thermal mortars regarding this property.

The replacement of sand with insulating aggregates caused a significant decline in the dynamic modulus of elasticity. The greatest reduction occurred in mortars with granulated cork (between 96% and 97%), while the expanded clay mortars presented the least decrease (between 51% and 75%), when compared to the respective sand mortar. Vale et al. [31] have also recorded a decrease in the dynamic modulus of elasticity, with a 90% reduction for mortars with a cork percentage of 80%.

As for the dynamic modulus of elasticity, the ultrasonic pulse velocity decreased when sand was replaced with insulating aggregates; however, the decline was not as clear as before. Expanded clay mortars had the least variation in ultrasonic pulse velocity (between an increase of 6% and a decrease of 26%), whereas granulated cork had the biggest deviation (a reduction between 52% and 63%).

The incorporation of insulating aggregates caused a reduction in the capillary water absorption coefficient, when compared to the respective sand mortar. The reductions ranged between 4% and 61%; however, and contrary to the other properties, there was no clear difference between granulated cork and expanded clay mortars. The same trend was observed in the drying test, where the drying index of mortars with insulating aggregates was 13% to 54% lower than that of sand mortars.

Regarding thermal conductivity, all mortars with insulating aggregates have thermal conductivity coefficients below 0.1 or 0.2 W/(m.K), thus fulfilling the requirements for thermal mortars according to EN 998-1 [5]. Mortars with granulated cork presented the lowest thermal conductivity, with a reduction around 93-94%, while the highest values were achieved by mortars with expanded clay, which corresponds to a reduction between 84% and 88%, when compared to the respective sand mortars. Brás et al. [10] also observed that thermal conductivity decreases with the incorporation of cork.

3.2.2 Influence of the binders’ variation

Concerning bulk density and open porosity, no relationship between these properties and fly ash content could be established, since the values obtained for different compositions were very similar. Regarding aerial lime mortars, their open porosity was slightly higher than mortars with 50% cement and 50% fly ash.

The increasing proportions of fly ash only caused a significant reduction in strength with a minimum of 35% replacement, with the highest reduction registered for a 50% replacement (reductions of 4-24% for flexural strength and of 5-33% for compressive strength). Demirboga [16] also found that the reductions in compressive strength due to fly ash increased with the growth in fly ash content. The results for aerial lime mortars were similar to the ones found in mortars with a 50% replacement of fly ash, where for flexural strength the reduction was of 7-29%, while for compressive strength the decrease was of 10-39%. Expanded clay mortars were the least susceptible to cement replacement, with a maximum reduction of 10% found in CEFA10AL40^{100EC}.

The partial replacement of cement with fly ash also caused a decline in dynamic modulus of elasticity. Expanded clay mortars were also the least susceptible to cement replacement, with a maximum reduction of 17% for CEFA10AL40^{100EC} as opposed to a reduction of 51% for CEFA10AL40^{100GC} (both compared to their respective cement mortar). For mortars with a mixture of granulated cork and expanded clay, a significant variation occurred only for a minimum of 50% of fly ash, while for granulated cork 20% replacement meant a 20% reduction. In this case mortars with aerial lime showed a bigger reduction in ultrasonic pulse velocity than mortars with 50% fly ash.

The decline in ultrasonic pulse velocity followed the reduction in cement content; still, mortars with insulating aggregates proved to be less susceptible to cement replacement than sand mortars. Again, expanded clay mortars showed the least reduction, with the lowest value occurring for CEFA10AL40^{100EC} (the decline was only 9%). It was also noted that for 20% and 35% cement replacement there was no significant variation in ultrasonic pulse velocity (between an increase of 3% and a decrease of 7%).

Overall, the replacement of cement with fly ash led to a marked increase in the capillary water absorption coefficient (between 10% and 184% compared to the corresponding cement mortar). Despite a higher initial rate of absorption, it was not possible to establish a connection between the presence of fly ash in the mix and the total amount of water absorbed by the mortars at the end of the capillary tests. However, mortars containing a mixture of cement, fly ash and aerial lime (CEFA10AL40 mortars) registered the highest values of water absorption. Regarding the drying test, no relationship could be established between the drying index and the binders under study.

The partial substitution of cement with fly ash caused a decline in thermal conductivity, with the greatest decrease (between 19% and 25%) registered for 50% replacement. Regarding mortars with aerial lime, they showed similar results to those for 50% replacement with fly ash. Demirboga [16, 32] and Barbero-Barrera et al. [33] also concluded that the incorporation of fly ash and lime in mortars reduce the thermal conductivity of the corresponding mortars.

In order to assess which mortars present a better compromise between compressive strength and thermal conductivity, the ratio between these properties was calculated. The highest values were found in expanded clay mortars with a fly ash content up to 35% (CE^{100EC}, CEFA20^{100EC} and CEFA35^{100EC}), which means these are the mortars that, while still complying with the thermal mortar category, are able to achieve the highest compressive strength.

4. Conclusions

In the preliminary campaign, it was observed that the incorporation of a water retention agent and an air-entraining agent led to mortars with lower strengths, low bulk density and stiffness and a better thermal performance.

In the experimental campaign, the replacement of sand with insulating aggregates originated lighter mortars with higher deformability and open porosity, a better thermal performance and lower strengths and density. Mortars with expanded clay presented the lowest decrease in mechanical properties, whilst the greatest reduction occurred for granulated cork mortars. Mortars with a combination of both aggregates showed intermediate characteristics. Expanded clay mortars were the least susceptible to changes in cement content regarding their mechanical strengths, dynamic modulus of elasticity and ultrasonic pulse velocity.

Regarding binders, the incorporation of fly ash as cement replacement led to mortars with higher deformability, a better thermal performance and lower strengths and density. No correlation between fly ash content and bulk density, open porosity or the drying index could be established. Mortars with a combination of 50% cement, 10% fly ash and 40% aerial lime presented similar results to mortars with 50% cement and 50% fly ash, except for open porosity which was slightly higher.

The values of adhesive strength, rebound index and water absorption under low pressure were very inconsistent. Thus, it was not possible to determine the influence of binders or aggregates on these properties.

All mortars with insulating aggregates are considered to be thermal mortars according to the EN 998-1 standard, taking into account only their compressive strength and thermal conductivity requirements. However, the capillary water absorption coefficient failed to meet the standards' criteria (still, this can be corrected through the addition of a hydrofuge). Nevertheless, all mortars showed an improved thermal performance. While granulated cork mortars presented the lowest thermal conductivity overall, the best compromise between compressive strength and thermal conductivity was found in expanded clay mortars with cement or with fly ash as partial substitution of cement.

Table 3 - Test results

	f_{ctm} (MPa)	**f_{cm} (MPa)**	**E_d (MPa)**	**v**	**UPV (m/s)**			**fu (MPa)**	**Rebound index**	**Bulk density (kg/m^3)**		**Open porosity (%)**	**C (kg/m^2.min$^{0.5}$)**	**Drying index**	**C_A (kg/m^2.min$^{0.5}$)**	**λ_{28d} (W/m.K)**		**λ_{dry} (W/m.K)**
					Standard sample	**Brick sample**				**Geo-metric method**	**Hydro-static method**					**Standard sample**	**Brick sample**	
						Mean	**Dromo-chronic**											
A_{CE}	2,36	8,91	11942	0,30	2930	n/a	n/a	n/a	n/a	1849	n/a	n/a	n/a	n/a	n/a	1,581	n/a	1,445
B_{CE}	2,18	7,95	10251	0,14	2793	n/a	n/a	n/a	n/a	1791	n/a	n/a	n/a	n/a	n/a	1,551	n/a	1,436
D_{CE}	2,21	8,09	10561	0,14	2702	n/a	n/a	n/a	n/a	1653	n/a	n/a	n/a	n/a	n/a	1,384	n/a	1,289
I_{CEFA50}	1,77	5,90	6154	0,15	2086	n/a	n/a	n/a	n/a	1588	n/a	n/a	n/a	n/a	n/a	1,016	n/a	0,898
CE^{100GC}	0,64	1,37	505	0,25	1160	1745	1387	0,11	71	487	(-)	(-)	0,71	0,24	0,94	0,099	0,084	0,087
CE^{100EC}	1,40	4,21	3446	0,24	2331	3244	2295	0,09	66	751	780	57,6	0,64	0,18	2,22	0,198	0,148	0,174
CE^{60GC}_{40EC}	0,93	2,35	1267	0,2	1648	n/a	n/a	n/a	n/a	618	639	54,7	0,94	0,16	n/a	0,138	n/a	0,119
CE^{60EC}_{40GC}	1,12	3,06	1994	0,22	1963	n/a	n/a	n/a	n/a	674	699	56,6	0,99	0,19	n/a	0,167	n/a	0,141
CE^{100S}	2,45	9,42	13729	0,15	3131	3999	2745	(-)	103	1909	1868	25,7	1,65	0,30	1,43	1,636	1,267	1,466
$CEFA20^{100GC}$	0,59	1,21	404	0,24	1190	1617	1418	0,03	89	456	(-)	(-)	1,07	0,16	2,76	0,091	0,083	0,081
$CEFA20^{100EC}$	1,40	4,18	3414	0,25	2228	3140	2391	0,29	81	749	779	55,1	1,28	0,24	1,25	0,184	0,168	0,167
$CEFA20^{60GC}_{40EC}$	0,92	2,29	1216	0,24	1664	n/a	n/a	n/a	n/a	615	623	53,9	1,47	0,20	n/a	0,128	n/a	0,117
$CEFA20^{60EC}_{40GC}$	1,10	2,97	1897	0,26	1857	n/a	n/a	n/a	n/a	669	667	57,5	1,45	0,19	n/a	0,151	n/a	0,140
$CEFA20^{100S}$	2,39	9,07	12860	0,14	2925	3877	3038	0,65	107	1913	1880	25,8	1,54	0,34	1,34	1,575	0,818	1,461
$CEFA35^{100GC}$	0,55	1,10	345	0,16	1110	n/a	n/a	n/a	n/a	451	(-)	(-)	2,01	0,18	n/a	0,084	n/a	0,075
$CEFA35^{100EC}$	1,35	4,00	3162	0,31	2324	n/a	n/a	n/a	n/a	741	738	57,9	1,24	0,18	n/a	0,168	n/a	0,152
$CEFA35^{60GC}_{40EC}$	0,92	2,28	1210	0,23	1618	n/a	n/a	n/a	n/a	631	634	53,1	1,03	0,17	n/a	0,121	n/a	0,111
$CEFA35^{60EC}_{40GC}$	1,09	2,94	1862	0,23	1831	n/a	n/a	n/a	n/a	680	677	52,5	1,21	0,18	n/a	0,133	n/a	0,123
$CEFA35^{100S}$	2,14	7,74	9807	0,14	2540	n/a	n/a	n/a	n/a	1898	1863	26,4	2,23	0,28	n/a	1,354	n/a	1,319
$CEFA50^{100GC}$	0,49	0,93	256	0,15	974	1297	837	(-)	92	434	(-)	(-)	1,64	0,17	4,74	0,080	0,066	0,075
$CEFA50^{100EC}$	1,35	4,00	3154	0,24	2196	2518	1854	0,08	79	754	738	52,9	1,03	0,23	0,96	0,155	0,126	0,144
$CEFA50^{60GC}_{40EC}$	0,82	1,94	910	0,23	1483	n/a	n/a	n/a	n/a	593	589	51,9	1,21	0,15	n/a	0,108	n/a	0,106
$CEFA50^{60EC}_{40GC}$	0,96	2,45	1365	0,28	1693	n/a	n/a	n/a	n/a	601	638	53,3	1,19	0,16	n/a	0,126	n/a	0,119
$CEFA50^{100S}$	1,96	6,82	7899	0,18	2301	3004	2260	(-)	92	1908	1870	26,6	2,30	0,27	6,89	1,171	0,995	1,079
$CEFA10AL40^{100GC}$	0,48	0,91	249	0,14	968	1555	1165	0,08	95	440	(-)	(-)	2,36	0,21	3,31	0,079	0,087	0,072
$CEFA10AL40^{100EC}$	1,30	3,77	2852	0,26	2132	2554	2076	0,03	78	771	770	58,7	1,76	0,20	1,72	0,168	0,138	0,154
$CEFA10AL40^{60GC}_{40EC}$	0,73	1,64	685	0,21	1287	n/a	n/a	n/a	n/a	580	575	56,7	2,35	0,22	n/a	0,113	n/a	0,107
$CEFA10AL40^{60EC}_{40GC}$	0,92	2,30	1225	0,23	1573	n/a	n/a	n/a	n/a	651	663	57,9	2,22	0,21	n/a	0,130	n/a	0,123
$CEFA10AL40^{100S}$	1,74	5,72	5830	0,15	2015	2800	2138	(-)	85	1863	1817	29,1	2,64	0,29	5,91	1,076	0,771	1,012

Legend: f_{ctm} - flexural strength; f_{cm} - compressive strength; E_d - dynamic modulus of elasticity; v - *Poisson* coefficient; UPV - ultrasonic pulse velocity; f_u - adhesive strength; C - capillary water absorption coefficient; C_A - water absorption under low pressure; λ - thermal conductivity; n/a - not applicable; (-) - null test.

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