E3

Development of Lightweight Magnesium Silicate Hydrate Mortars containing foamed glass

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Introduction

Lightweight aggregates (LWA) are widely used in the production of lightweight materials to obtain low densities, better workability and improved thermal properties. These properties are key in making buildings more energy efficient since thermal conductivity heavily influences the energy associated with heating/cooling buildings. Portland cement (PC) has traditionally been the primary binder material to produce concrete, with global production reaching 4.3 billion tonnes in 2014. However, global PC production accounts for 6% of worldwide industrial energy consumption and 2.8 billion tonnes of greenhouse gas emissions annually. Hence, a focus has been placed on the development of binders more sustainable than PC. This research investigates the potential of magnesium silicate hydrate (M-S-H) as a binder to develop lightweight mortars using foamed glass as a LWA.

Materials and methods

Foamed glass LWA physical properties:

Materials size range (mm)	Particle size distribution (wt. %)	Bulk density (kg/m^3)	Particle density (kg/m^3)	Crushing resistance (N/mm^2)	Water absorption (wt. %)
LWA 0.25-0.5	36.2	340	700	2.6	21
LWA 0.5-1.0	11.8	270	500	2.0	18
LWA 1.0-2.0	10.6	230	400	1.6	19
LWA 2.0-4.0	41.4	190	320	1.4	14

Production of the M-S-H mortar:

Water
w/b ratio = 0.6
+
NaHMP
1 total wt. %

+

Binder
40 wt. % MgO
+
60 wt. % SF

+ **1:1 ratio**

100, 75, 50, 25 wt. % Silica Sand
+
0, 25, 50, 75 wt. % LWA

=

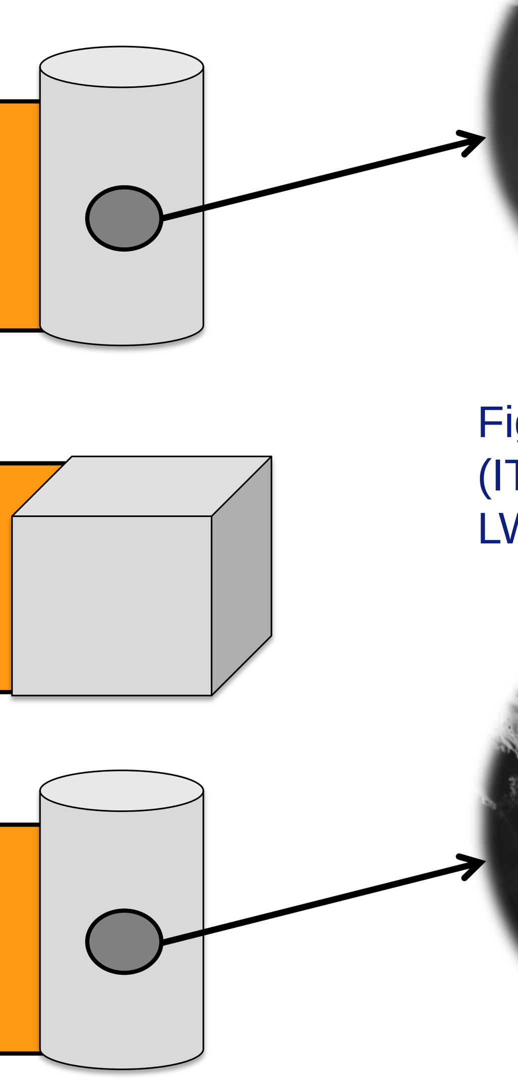
M-S-H Mortar

Mortar sample sets

M-S-H
0%, 25%, 50% and 75% LWA addition

PC I
0%, 25%, 50% and 75% LWA addition

PC II
0%, 25%, 50% and 75% LWA addition



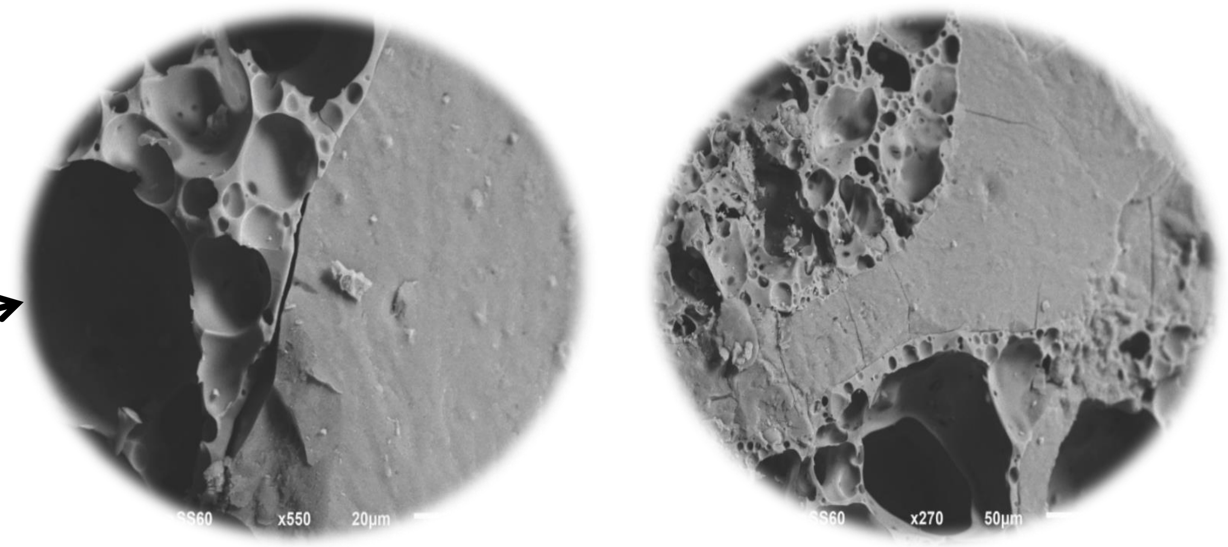


Fig. 1. SEM micrographs of the interfacial transition zone (ITZ) between the LWA and M-S-H cement pastes at 50% LWA addition after 14 days curing time.

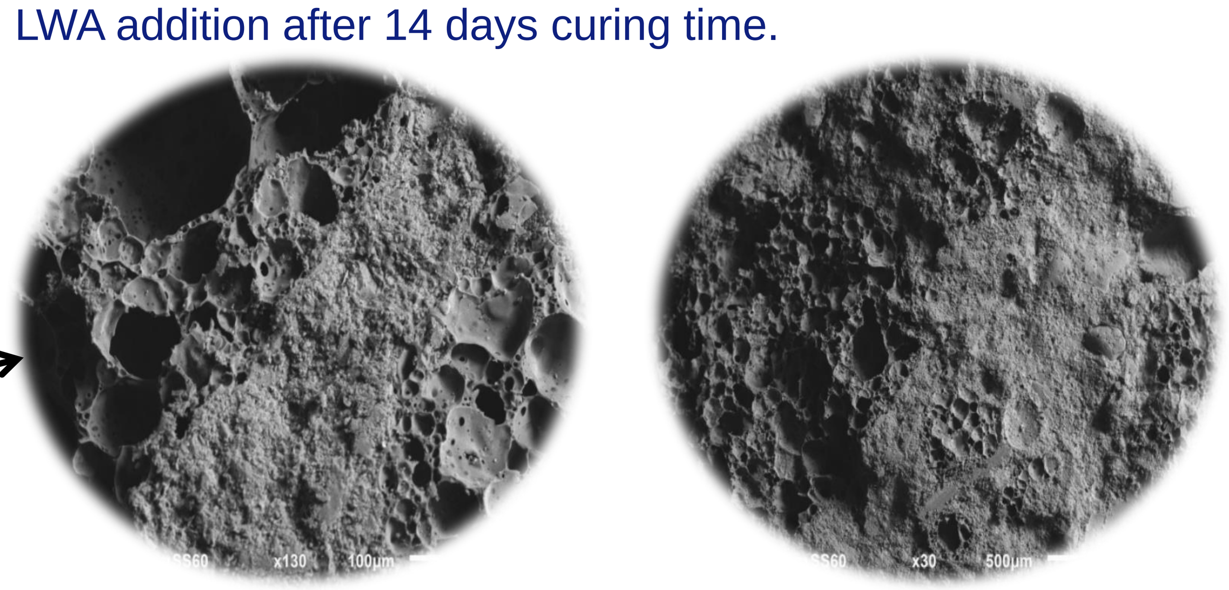


Fig. 2. SEM micrographs of the interfacial transition zone (ITZ) between the LWA and PC pastes at 50% LWA addition after 14 days curing time.

Test and results

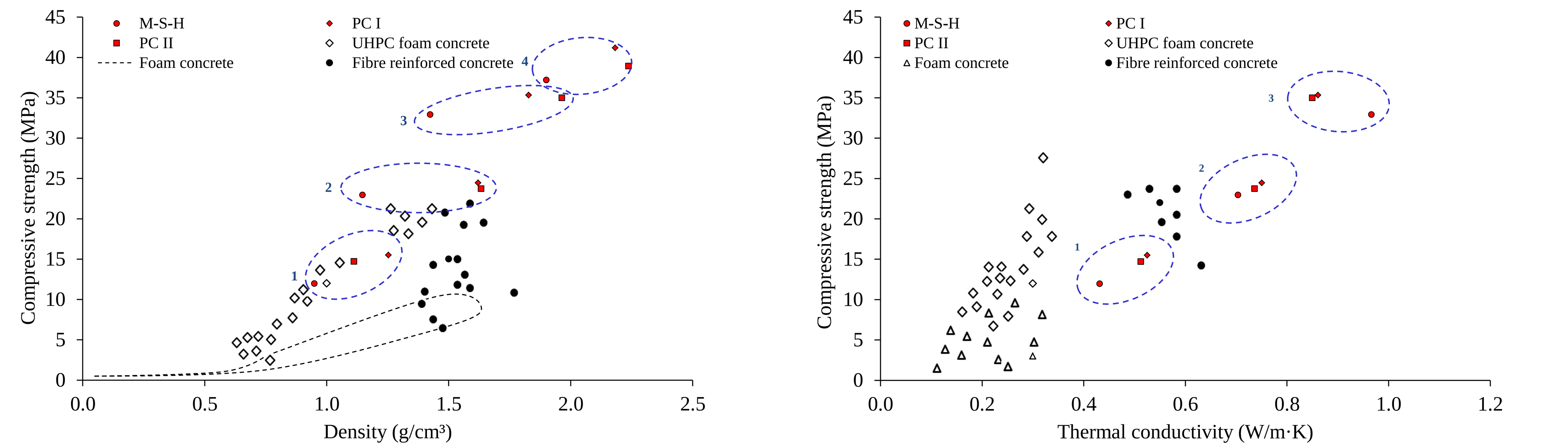


Fig. 3. Relationship between the compressive strength and density/thermal conductivity for different types of lightweight concrete where: PC I = Cubic PC series; PC II = Cylindrical PC series; M-S-H = Cylindrical M-S-H series; UHPC = ultra-high performance; 1 = 25% LWA addition; 2 = 50% LWA addition; 3 = 75% LWA addition; 4 = 0% LWA addition.

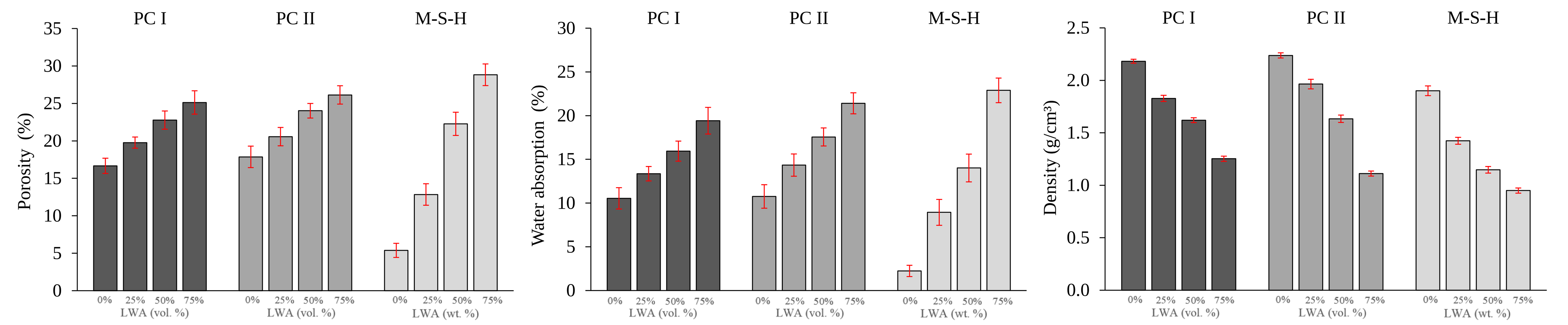


Fig. 4. Effect of LWA addition on the porosity, water absorption and density of mortar samples for 14 day curing time where: PC I = Cubic PC series; PC II = Cylindrical PC series; M-S-H = Cylindrical M-S-H series.

Conclusions

- Studied lightweight aggregate, commercially available foamed glass, is useful to decrease setting times, thermal conductivity and density for the production of lightweight mortars.
- Foamed glass excessively reduces certain mechanical characteristics of the lightweight mortars, since density appears to strongly influence mechanical strength.
- M-S-H mortars with 75% of silica sand replaced by LWA had a dry density of 0.950 g/cm^3 and thermal conductivity of 0.436 W/mK. Equivalent PC mortars had 20% greater density and 17% greater thermal conductivity. The compressive strength of the PC mortars was higher by 26% due to shrinkage cracks forming in the M-S-H matrix.
- The properties of the mortars produced in this study were similar to literature data for other lightweight mortar systems.
- Lightweight M-S-H mortars using recycled foamed glass is potentially a low carbon sustainable alternative to PC containing materials, but further research is needed to optimize the processing and properties.

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