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Abstract

A Modular Reactor for Thermochemical Energy Storage Examination of Ettringite-Based Materials †

Bao Chen [1,2,*], Frédéric Kuznik [1], Matthieu Horgnies [2], Kévyn Johannes [1], Vincent Morin [2] and Edouard Gengembre [2]

1 Université de Lyon, CNRS, INSA-Lyon, Université Claude Bernard Lyon 1, CETHIL UMR 5008, F-69621, Villeurbanne, France; frederic.kuznik@insa-lyon.fr (F.K.); kevyn.johannes@insa-lyon.fr (K.J.)

2 LafargeHolcim Innovation Center, 95 rue du Montmurier BP15, 38291 Saint Quentin Fallavier, France; matthieu.horgnies@lafargeholcim.com (M.H.); vincent.morin@lafargeholcim.com (V.M.); edouard.gengembre@lafargeholcim.com (E.G.)

* Correspondence: bao.chen@insa-lyon.fr

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Abstract: More attention on renewable energy has been attracted after the achievement of Paris Agreement against climate change. Solar-based technology is supposed to be one of the most promising green energy technologies for residential buildings since its wide thermal usage for hot water and heating. However, the seasonal mismatch between its energy-production and consumption makes buildings need an energy storage system to improve the efficiency of renewable energy use. Indeed, even if different kinds of energy storage systems using sensible or latent heat already exist, thermochemical energy storage can be then recommended by considering the problems of energy dissipation during storage and low energy density for the first two methods. As potential thermochemical storage materials, ettringite ($3CaO{\cdot}Al_2O_3{\cdot}3CaSO_4{\cdot}32H_2O$) based materials possess high energy densities (~500 kWh/m^3), low material cost (<1000 €/m^3) and low storage temperature (~60–70°C), compared to salt hydrates of similar energy density like $SrBr_2{\cdot}6H_2O$ (42 k€/m^3, ~80°C), $LaCl_3{\cdot}7H_2O$ (38 k€/m^3, ~100°C) and $MgSO_4{\cdot}7H_2O$ (5 k€/m^3, ~150°C). Therefore, ettringite-based materials have the possibility to be largely used in building sector by being coupled to normal solar collector systems via reversible chemical reactions (Equation (1)): (i) charging mode: hot air or hot water (>70°C) from solar collectors dehydrates ettringite to meta-ettringite, and consequently store heat to chemical energy; ii) discharging mode: humid air is pumped to material container to rehydrate meta-ettringite, and consequently release stored chemical energy as heating. However, the lack of extensive examination leads to poor knowledge on their thermal properties and limits maturity of this technology. Therefore, the aim of this work is to characterize the capacity of an ettringite-based material (named C80P20, containing ~70 wt.% ettringite) in terms of thermal energy storage by Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC). Besides, a modular reactor adapting to thermal characterizations of C80P20 particles has been developed for various weights (up to 300 grams). In our case, the energy density of pure ettringite is around 1012 J/g while 708 J/g for C80P20 powder in TGA-DSC. First preliminary results from modular reactor demonstrate a general energy density of 150 kWh/m^3 released by the hydration process of C80P20 grains (pre-dehydrated at 80 °C) at 25 °C and 85% relative humidity. Moreover, the reactor is intended to study the durability of the energy storage material over time, and also as function of the number of charging/discharging cycles.

$$3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O \quad (\text{ettringite}) + \text{heat} \\ \leftrightarrow 3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot (32 - X)H_2O(\text{meta} - \text{ettringite}) + XH_2O \qquad (1)$$

Keywords: dehydration; ettringite; hydration; modular reactor; thermochemical energy storage