Carbon dioxide capture by a process of concrete rubble carbonation

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Highlights

- Concrete dissolution conducted in a stirred batch or continuous reactor
- Evaluation of the effect of three parameters on the concrete dissolution (DOE approach)
- Modelling the dissolution of shrinking particles

1. Introduction

Concrete is the second most used material after water, and its production is responsible for 8% of global carbon dioxide emissions [1], mainly because of the decomposition of calcium carbonate ($CaCO_3$) into calcium oxide (CaO) and carbon dioxide (CO_2) during cement production. Each year, a lot of construction and demolition waste are generated [2]. The project aims to recycle the concrete rubble by dissolving the calcium it contains. The calcium can react with the CO_2 emitted during the cement production. The $CaCO_3$, which has precipitated, can then be used to produce fresh cement.

2. Methods

The process contains three main unit operations (**Figure 1**). Before final coupling, these three operations are studied separately starting with the dissolution of concrete. The experiments were conducted in a stirred batch reactor. The pH was monitored *in-situ*, and aliquots were titrated with EDTA to follow calcium ions concentration evolution over time. A design of experiments (DOE) approach was used to evaluate the effect of three parameters on the initial rate of the concrete dissolution: the initial pH, the solid-liquid ratio and the initial mean diameter of the concrete particles.

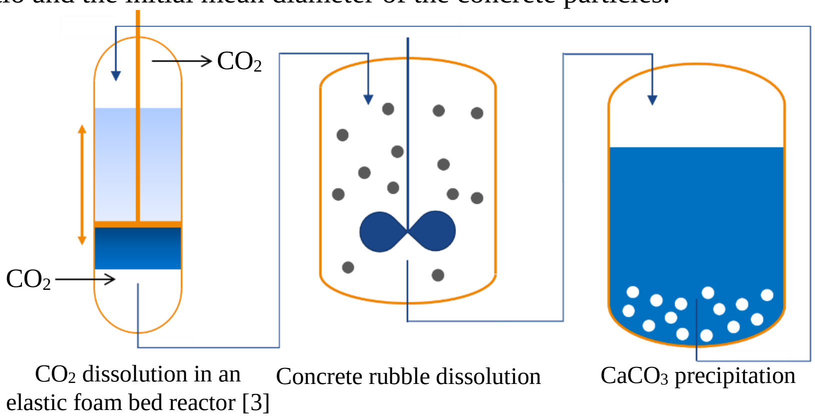

Figure 1. Example of succession of the three main unit operations

Concrete is a complex material, containing many different elements and mineral phases, identified respectively by X-ray fluorescence and X-ray diffraction. As a first approach, a solid-liquid mass transfer model was developed, based only on the dissolution of $Ca(OH)_2$ shrinking particles [4], (which is the first hydrate responsible of calcium leaching during concrete dissolution [2]). Two equations are important in this system, the calcium balance in the batch reactor, and the solid-liquid transfer equation, in order to follow the evolution of the calcium ions concentration and the radius of the particles over time.

The saturation state in the reactor, responsible of the transfer driving force, was discussed, and the transfer coefficient was estimated by minimizing the gap between experimental and model data.

3. Results and discussion

The results of DOE explain the influence of the three parameters on the dissolution rate. Cement being an alkaline material, the dissolution rate decreases with pH. As expected, the initial rate of dissolution increase with high solid liquid ratio and with low particle diameters. The initial particles diameter effect is higher than the effects of the other parameters. It correlates with the high proportion of cement, in other terms of dissolvable calcium, in the smallest particles of concrete [5].

The design of experiments conducted for the concrete rubble dissolution is based on 15 different experiments. The first five points of each experiment, corresponding to five minutes of initial dissolution, have been used to estimate a transfer coefficient for each particle size range, by minimizing the gap between experiences and model with the function lsqnonlin of Matlab. The results seem coherent for the experiments with the smallest particles (figure 2). The gaps observed between model and experience for the biggest particles might be caused by a wrong estimation of the saturation state of the reactor. The existence of many soluble mineral phases, other than $Ca(OH)_2$, in the cement matrix misestimates the calcium concentration at saturation and so the initial dissolution rate.

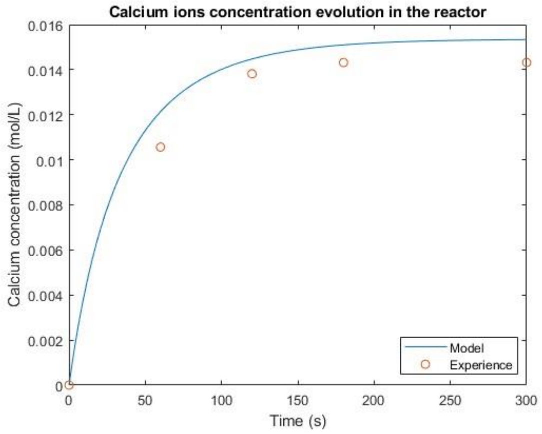

Figure 2. Model experiment comparison after transfer coefficient estimation for concrete particle dissolution with diameters of 0 to 250 µm, an initial pH of 2, a solid concentration of 25g/L at room temperature

4. Conclusions

The effects of the initial pH, the size distribution of the particles and the solid-liquid ratio on concrete dissolution rate were studied in a batch reactor thanks to a DOE approach. A model of the dissolution of $Ca(OH)_2$ particles was developed and it represents well the dissolution of the smallest concrete particles. A model has to be developed in order to have good representations of the concrete dissolution for each size range of particles, including the saturation of the other mineral phases.

The two other operations (CO_2 dissolution and $CaCO_3$ precipitation) will be studied before the congress. The $CaCO_3$ precipitation will be modelled through a population balance solved by the method of moments. The transfer characteristics (k_La) of the elastic foam bed reactor for CO_2 dissolution will be estimated.

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Keywords

CO_2 capture; Concrete; Carbonation; Dissolution