

# Capturing and sequestering large quantities of CO<sub>2</sub> in recycled concrete

## Accelerated re-carbonation of concrete

### Recycling concrete: an obligation



With two tons per person and per year, concrete is the manufactured material most consumed worldwide. The bulk of concrete is made up of aggregates representing some two thirds of the total mass. At this stage in time, the concrete manufacturing process uses up approximately 40% of the total aggregate store available. However, not only is this resource not renewable, it is also more and more difficult to procure. The Greater Paris Region - the Ile de France area - imports nearly half of all the aggregates it consumes (approximately 13 million tons per year<sup>1</sup>) and forecasts are showing an increase in consumption by an additional 5 million tons per year<sup>2</sup> because of the «Greater Paris» metropolis planning project. The question is therefore how to produce concrete whilst saving on the use of aggregates?

At the same time, the volume of de-constructed material from buildings and infrastructures is increasing and will become even more prevalent in the coming years. Indeed, buildings built during the Reconstruction period of the 1950s' have run their course. The volumes of concrete to be recycled will increase considerably.

At present, such material is processed in two ways: a) it is buried in a landfill, or b) it is recycled in road earthworks, as low added value backfill. Unfortunately, there are limits to the road industry's recycling capacities and if nothing is done, the cost of processing deconstructed material could increase drastically.

Recybéton® is the name of a French national project launched in 2012 and extending over a 5 years period. It brings together contractors, material manufacturers and construction industries as well as research centres such as Ifsttar, among others. The project aims at increasing the re-use of concrete generated by deconstruction, in new concrete structures.

A number of technical limitations remain however. Aggregates produced by crushing recycled concrete are of rather poor quality: they are more porous than natural aggregates; also, their mechanical properties are lower. Also, a major obstacle is the fact that they absorb too much water (from 5 to 10% more) and more slowly (about 20 minutes). The workability of concrete made in the usual way and using mixed recycled aggregates drops during its transport in a concrete mixer lorry, to the point that it could become improper for use on reaching final destination.

### Carbonation in all its stages

To produce cement, limestone (CaCO<sub>3</sub>) is heated with silica at a high temperature (1,500°C). This produces lime (CaO) and most of the CO<sub>2</sub> contained in the limestone is released: it is called de-carbonation of limestone. Lime then recombines with silica to form clinker: it is then crushed and supplemented to produce cement in powder form. It is estimated that this process (heating energy plus de-carbonation) accounts for approximately 7% of the global CO<sub>2</sub> emissions.

*Photo : Concrete from deconstruction*

<sup>1</sup> Livre blanc UNPG 2011 (White Book)

<sup>2</sup> Source DRIEE Ile de France (Regional and InterDepartment Agency for Environment and Energy)



When concrete is made, cement reacts with water: silica and calcium hydrates are produced. These hydrates govern the concrete's mechanical resistance. However, hydrate molecules do not remain stable over time - they are described as «metastable», i.e. when encountering atmospheric CO<sub>2</sub>, they naturally re-carbonate by slowly reabsorbing CO<sub>2</sub>, and re-transform into calcium and silica gel. The mineral cycle has gone full circle.

### Drawing an advantage out of a problem

Manufacturers have always feared carbonation. It increases concrete acidity (lowering the pH) and results in irreversible corrosion of the metal structures reinforcing the concrete. Fortunately, this natural chemical reaction is very slow acting: in an outdoor structure in use, only 2 to 3 cm in depth are re-carbonated after 50 years! Ifsttar's objective has been to speed up this reaction in recycled concrete. The process under study focuses on bringing in contact crushed aggregates from de-construction and CO<sub>2</sub> from the air, under very high concentration and pressure, using a fairly conservative supply of energy.

Using this natural phenomenon to capture and sequester atmospheric CO<sub>2</sub> in the cement matrix of de-construction aggregates will improve considerably on the environmental balance of concrete as a material. The first laboratory tests demonstrated that using 1 ton of recycled concrete potentially led to the capture and sequestering of 150 kg of CO<sub>2</sub>. That was without counting on the sparing of 650 kg of natural quarry aggregates, as those would not be required. To be added to that, there are the net savings in CO<sub>2</sub> that are possible when using new

manufacturing processes for the new constructions made of concrete. The objective therefore, is developing a process to be used by the industry, and contributing to the development of a sunrise sector of circular economy.

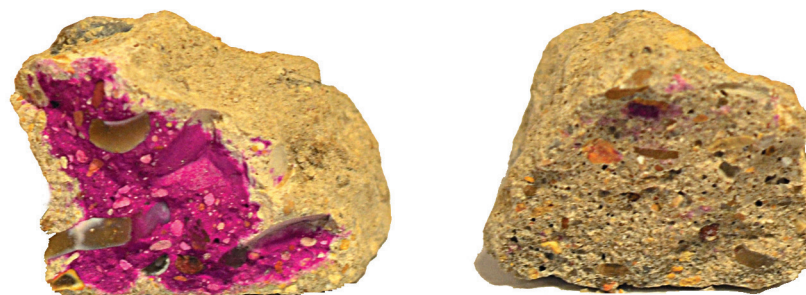
And there is more! In addition, the laboratory has discovered a definite improvement of the mechanical quality of re-carbonated aggregates. Water absorption is both more limited and quicker than in non re-carbonated recycled aggregates. An additional advantage that will help turn into a reality the recycling of concrete inside concrete.

### Considerable potential

In France, material recovered from building and public works deconstruction represents close to 300 million tons per year. 36% of this is concrete-based material. At present, it is estimated that only half of it is recycled to produce fresh concrete. By generalising recycling and by applying this new technique of accelerated re-carbonation to nearly 100 million tons of aggregates per year, this should make it possible to capture and sequester from 10 and 15 million tons of CO<sub>2</sub> per year, i.e. the equivalent of over 10% of all GHG emissions produced by the transportation sector.

### Moving on to demonstrators

An increasing number of studies is being carried out in laboratories. Demonstrators will soon be built with interested contractors, i.e. buildings built in re-carbonated recycled concrete. Ifsttar is already in contact with recyclers, the pre-cast industry and building contractors.



*A coloured pH indicator is used to make carbonation visible. Since carbonation lowers pH, the indicator turns pink wherever the material has not undergone carbonation. On the left, aggregates of recycled concrete have been carbonated at natural speed (carbonation only over a few millimetres from the surface). On the right, the same aggregates have been carbonated using the accelerated method (thorough mass carbonation).*

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