BREAKING NEWS

RE-CON line

no. 04 _ **March** 2024

Dear reader,
Welcome to Issue 4 of Breaking News RE-CON line newsletter, the first of 2024. Its focus is ***recarbonation, the capability of concrete to re-absorb CO_2 from the atmosphere****. A recent report highlights that up to 20% of CO_2 emitted from the calcination process can be reabsorbed into a concrete structure due to re-carbonation which results from the reaction between calcium hydroxide and CO_2 in the concrete structure. Find out more in the coming sections.*

Sven-Henrik Norman *- Corporate Product Manager - RE-CON line*

In the previous issues we explained the benefits of the solutions included in the RE-CON line: RE-CON ZERO EVO transforms returned concrete into reclaimed aggregates; RE-CON DRY WASHING utilizes RE-CON ZERO EVO aggregates to wash empty, dirty trucks and reduce the waste stream of washout slurry. And finally RE-CON AGG, the liquid admixture range that makes it possible to use recycled, manufactured or local water-demanding sand and aggregates with no additional cost of cement in the mix design. **The main article in this issue explores the impact of CO_2 reduction** made possible by using RE-CON ZERO EVO and RE-CON DRY WASHING.

At the same time, the **cost saving potential for ready-mix concrete producers through the use of RE-CON line solutions should not be overlooked**. More and more of our customers are discovering and appreciating it: we will provide several examples of these advantages in the upcoming issue of the RE-CON line newsletter.

Finally in this issue, we will also tell you about **a brand-new product in the range: RE-CON PH 1000**. Thomas Beck, Mapei R&D Manager for Concrete Admixtures in the Nordic region, will explain the function and benefits of **reducing the pH of water emitted during concrete production**. This is an environmental issue that has become the focus of attention in the concrete industry. Use the contact details in the last page for feedbacks, subscriptions and suggestions for new business stories related to the Re-CON Line.

THIS ISSUE FOCUSES ON

RE-CON ZERO EVO

RE-CON DRY WASHING

RE-CON PH 1000

RE-CON AGG range

CO_2 SAVINGS WITH RE-CON LINE SOLUTIONS

RECARBONATION OF TRANSFORMED WASTE STREAMS FROM READY-MIX CONCRETE PRODUCTION

In this article, we will talk about **how carbon takes different forms during the lifecycle of concrete**. We explain the concept of recarbonation and how it can be used to give a better comparison of **a building's total carbon footprint over its service life**. Finally, we give **examples of CO_2 savings potential by using RE-CON line solutions**, such as RE-CON ZERO EVO and RE-CON DRY WASHING, to transform waste streams, such as returned concrete and cementitious residues in concrete trucks, into concrete aggregates. When used in new concrete, they increase even more the total potential of absorbed CO_2.

CONCRETE AS A BUILDING MATERIAL: PROS AND CONS

Concrete is the second most used material in the world, after water. It is also well known that **cement (or more correctly Portland clinker cement) is a major contributor to global CO_2 emissions**. Compared with wood as a building material, concrete is "front heavy" because of these emissions. Unlike wood, which binds CO_2 through the growing of forests, cement and concrete start their service life in a building with a larger carbon footprint than wood. Concrete, however, is still the **preferred building material because of its higher strength, fire resistance and durability** compared to wood. We simply cannot build everything we need in society solely from one of those two materials. The best material for this purpose should also be chosen from a technical, economic and environmental perspective. It is important, therefore, to **consider all the environmental aspects of concrete**. It is true to say that concrete has a higher initial carbon footprint compared to wood, but the **durability of a building made with a concrete structure is higher** than the equivalent massive timber structure. Higher durability means a longer service life. This means the total emissions over 100 years needs to be compared. In this timeframe, a wood structure will require more energy and generate higher emissions from maintenance and renovation over a 100 year life span. In addition to this, one important factor is overlooked in a 100 year perspective of carbon footprint comparisons: **the capability of concrete to re-absorb CO_2 from the atmosphere**. A report by Stripple et al punto[1] concludes that **up to 20% of CO_2 emitted from the calcination process can be reabsorbed** into a concrete structure due to re-carbonation, i.e. **limestone being formed from the reaction between calcium hydroxide and CO_2** in the concrete structure. Figure 2 illustrates this cyclical process.

Figure 1 _ An example of a concrete structure: the Heydar Aliyev Center in Baku designed by Zaha Hadid

CALCINATION: BURNING LIMESTONE INTO CEMENT

The chemical process whereby **carbon dioxide is driven out of the limestone** raw material (calcium carbonate) is called **"calcination"**. For every ton of pure Portland clinker produced by the burning of limestone rock, around 500 kg of CO_2 is released through the calcination process:

$CaCO_3 + Heat \rightarrow CaO + CO_2$

In addition to this there is, of course, the energy consumed to produce the heat in the cement kiln, but this is a variable unconnected to this circle model.

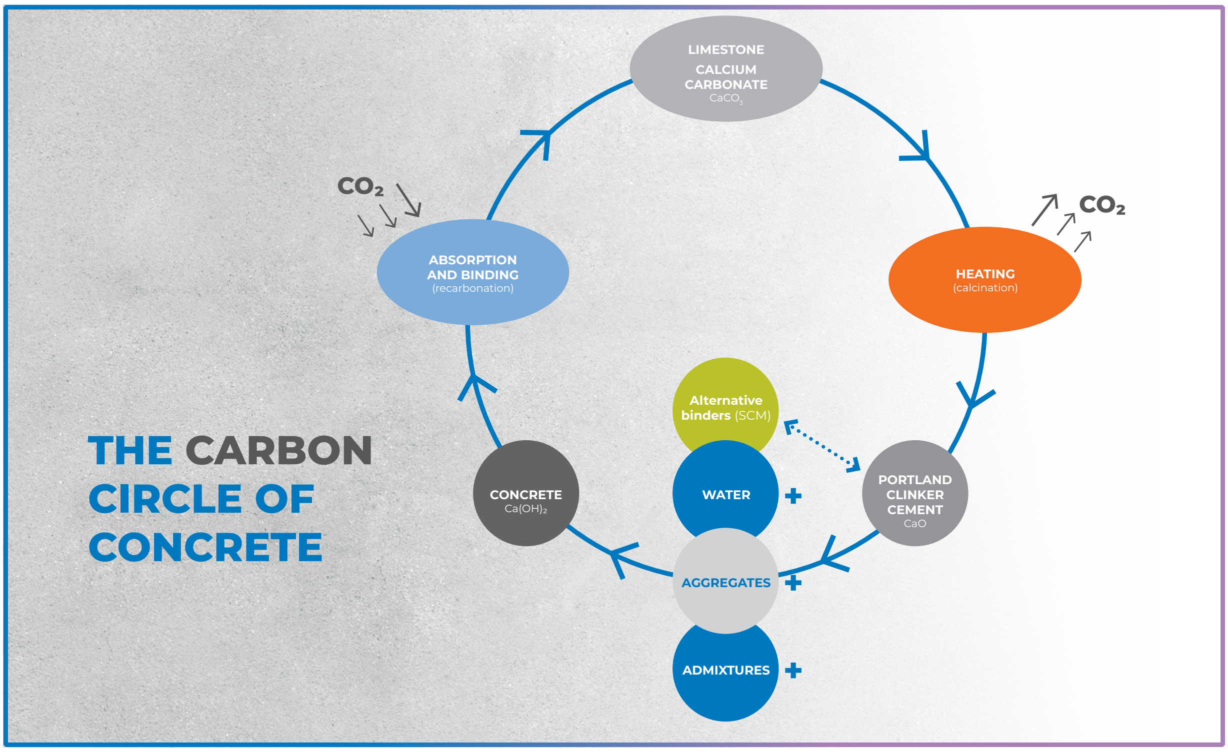

Figure 2 _ The carbon circle of concrete

CONCRETE REACTION

The mixing of cement and water (with sand, aggregates and admixtures) into concrete forms a new step in the carbon circle: calcium hydroxide.

$CaO + H_20 \rightarrow Ca(OH)_2$

SECONDARY CEMENTITIOUS MATERIALS (SCM)

Basically, what all SCMs have in common is that they **contain silica dioxide (SiO_2)**. This silica must also be amorphous, i.e. reactive. In nature, **silica dioxide as a rock mineral has a stable crystalline structure that does not react easily** with other substances. But **if the SiO_2 has been formed through heating and then rapid cooling**, like a volcanic eruption directly cooled by air or through industrially produced materials like fly ash or slag, it has a less rigid crystal structure and can, therefore, **react with the calcium hydroxide** from the previous step in the process. The reaction is described as:

$Ca(OH)_2 + SiO_2 \rightarrow CaSiO_3 + H_2O$

and is called a **"secondary pozzolanic reaction"** from the term "Pozzolan" which comes from the town of Pozzuoli in Southern Italy whose natural volcanic sand was already being used in ancient times by the Greeks and Romans to make concrete. It is an interesting observation that we too, almost 2000 years after the construction of buildings such as the Pantheon in Rome, have now started to use more and more of these secondary cementitious materials in our modern concrete to replace Portland clinker.

CLOSING THE CIRCLE: LIMESTONE FORMATION IN CONCRETE

When concrete is exposed to CO_2 in the atmosphere, this chemical reaction of carbonation takes place:

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

This closes the circle and **limestone is formed again from calcium hydroxide reacting with carbon dioxide**. The process involving carbonate and hydroxide ions occurs in several steps, as described by Stripple et al[1]. The speed of the process (carbonation rate) depends on many factors, such as the strength class (water/cement ratio) of the concrete. **Water plays a major role in the chemical reaction**, so moisture and ambient humidity are important. Finally, the level of exposed surface of raw concrete in the structure also determines how much of the total carbonation potential is utilized during the service life of the concrete.

TAKING ADVANTAGE OF RECARBONATION IN CONCRETE

We know a lot about the recarbonation process in concrete because it can be negative from a durability aspect. **Before concrete recarbonates, it has a high pH** which acts as protection against corrosion of steel reinforcement. The carbonation front moves from the surface towards the center at a rate of millimeters per year. **Carbonated concrete has a lower pH** and, therefore, has lower protection of the steel against corrosion. It is important to design a covering of the steel reinforcement which is thick enough to last for the duration of the designed service life of the concrete structure.

If the correct measures are taken, or if concrete is reinforced with a material other than steel (e.g. synthetic fibers), **recarbonation will make a positive contribution into lowering the long-term carbon footprint** of concrete without shortening its service life. The rate of carbonation depends on several factors. The strength class (water/cement ratio) and exposure factors combined with the environment are the main ones. The optimum **combination of access to atmospheric CO_2 and ambient humidity determines the conditions for recarbonation speed** in mm/year. From these basic technical conditions and known calculation methods, **a prediction can be made of how much CO_2 a concrete structure can absorb** in a given period of time. Löfgren[2] explains how this can be **inserted into a Life Cycle Assessment (LCA)** model for a concrete structural element. By using the guidelines from industry standard EN 16757, annex BB and further details from CEN/TR 17310:2019, he illustrates an example of recarbonation potential shown in Figure 3. For example, the yellow curve represents an interior concrete wall made from C30/37 concrete. As much as **34% of the CO_2 emissions stemming from the production of the cement for that wall will be absorbed in 100 years** if the wall thickness is 100 mm and the concrete remains unpainted and exposed to air on both sides.

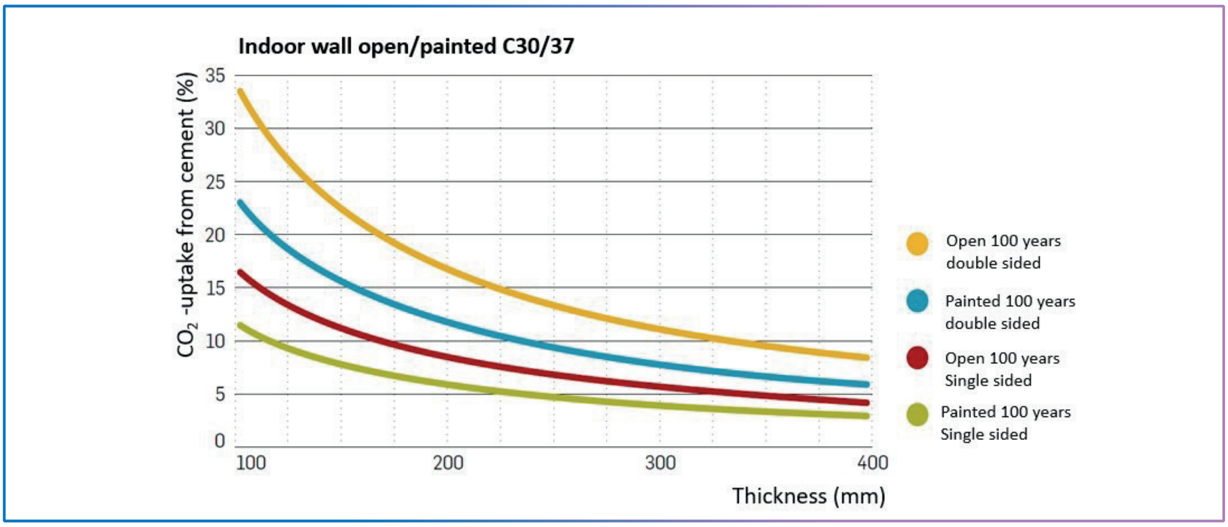

Figure 3 _ Carbon dioxide uptake in percent of emissions from the cement from production of indoor wall after 100 years, without surface ("open") and with painted surface, for different wall thicknesses and single or double sided exposure. Source: Ingemar Löfgren, the importance of concrete's carbon dioxide absorption from a life cycle perspective", Husbyggaren (House builder), no. 1, 2021.

It should be noted that such project specific Life Cycle Assessments presented as Environmental Product Declarations[3] are not yet officially recognized. Some Nordic EPD programme operators have issued Environmental Product declarations of pre-cast concrete elements with GWP_{100} CO_2-equivalents defined in the use phase. This is only possible when the exact exposure conditions are known and there may be uncertainties around the compliance shows the ISO 14025 standard.

RE-CON LINE SOLUTIONS: TAKING RECARBONATION ONE STEP FURTHER

The **solutions in the Mapei RE-CON line help concrete producers transform waste streams** of returned concrete and truck washout slurry **into recyclable aggregates**. This means considerable **cost savings** from reduced purchase of virgin material, transport in and out of the concrete plant, high operational costs for washing and reclaiming and, finally, reduced landfill costs for residual waste. Figure 4 shows how waste streams are replaced by the **RE-CON line** products and methods. The dry, dust free and low noise method **RE-CON ZERO EVO reclaims returned concrete by powder** into a granular material. **RE-CON DRY WASHING utilizes this material for cleaning dirty concrete trucks** by absorption rather than washing with large amounts of water. The fines are agglomerated into aggregates rather than becoming a waste disposal problem for the concrete producer. Finally, the **liquid admixtures in the RE-CON AGG range mitigate the challenging properties of recycled aggregates** and make it possible to produce concrete with recycled aggregates without increased water demand and increased cement dosage.

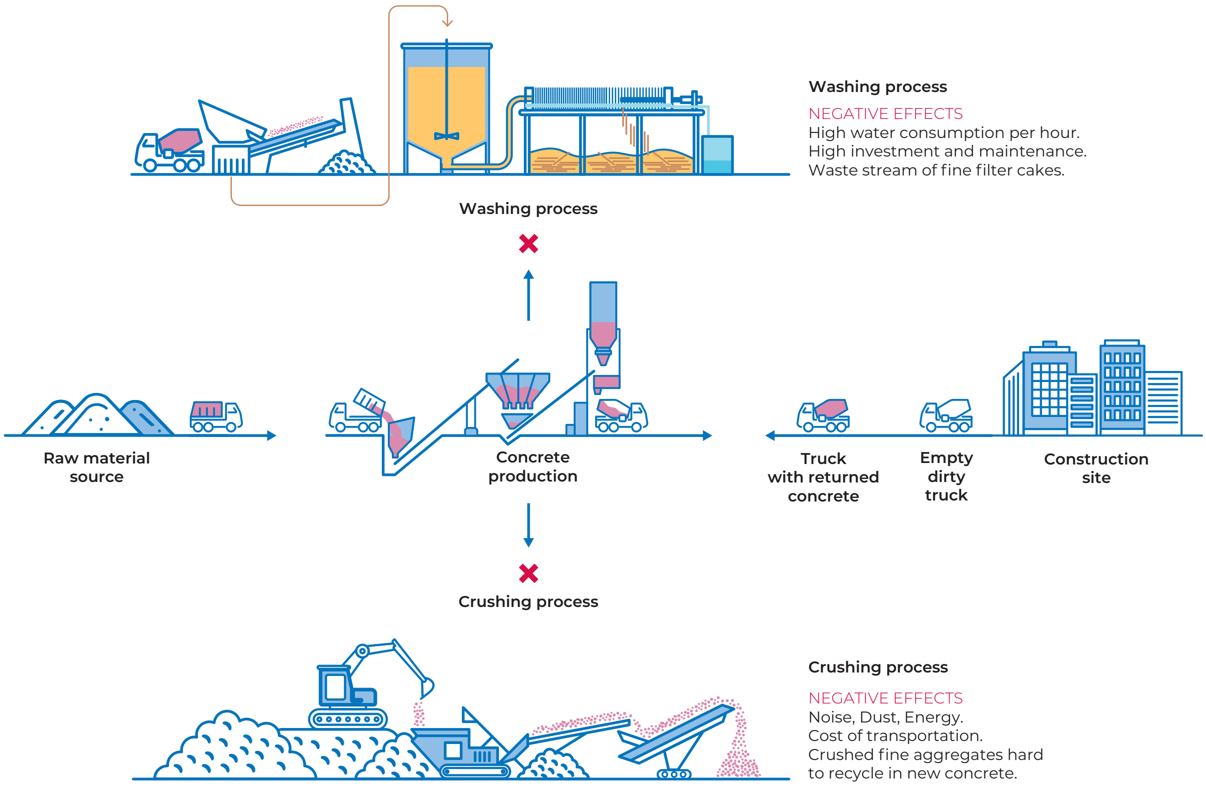

Figure 4 _ Schematic view of the use of RE-CON line solutions and how they contribute to reducing the cost and negative effects of waste stream handling.

RECLAIMED AGGREGATES FROM WASTE WITH INCREASED CARBONATION POTENTIAL

The **RE-CON ZERO EVO** and **RE-CON DRY WASHING** processes yield a **reclaimed aggregate material with higher cementitious material content**. This material has been studied in a major research project in Norway. Led by Mapei, the **RECONC project focused on studying the carbonation potential** of the aggregates directly after the **RE-CON ZERO EVO** process (see Figure 5) and after 8 cycles of **RE-CON DRY WASHING**. The number of cycles you can re-use the aggregates in the **RE-CON DRY WASHING** process depends on local conditions but is generally between 10-20.

Figure 5 _ Extreme closeup of a particle after RE-CON ZERO EVO and RE-CON DRY WASHING process. The cementitious paste has formed a hardened shell around the core stone particle. The grey paste represents on average 30-36% acid soluble content by weight, i.e. material open for potential recarbonation.

To study the exact potential, **particles of a different age in the process were placed in carbonation chambers** and subjected to accelerated levels of CO_2 in gas form: 4000-5000 ppm compared to a normal atmospheric conditions of 400 ppm. This was carried out to simulate long term exposure over 50-100 years.

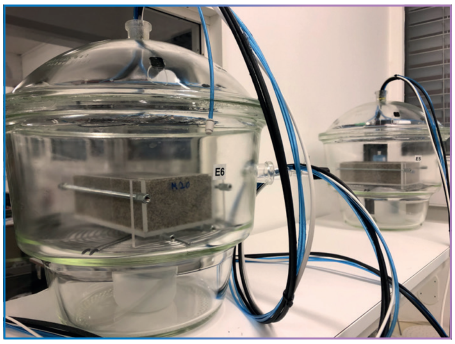

Figure 6 _ CO_2 chamber at SINTEF were used to test the level of CO_2-uptake of RE-CON ZERO aggregates and RE-CON DRY WASHING aggregates.

As shown in figure 7, the RE-CON ZERO aggregates and RE-CON DRY WASHING aggregates showed different levels of CO_2-uptake during these tests. The RE-CON ZERO EVO aggregates were only subjected to cementitious material once in the treatment process. The RE-CON DRY WASHING aggregates were subjected 8 additional times, which explains the higher CO_2 uptake. **The results showed recarbonation potential of the RE-CON ZERO EVO aggregates** of 30 kg CO_2 per tonne of material and the same aggregates after 8 cycles of dry washing **had an additional 7,5kg of CO_2 per tonne of recarbonation potential**.

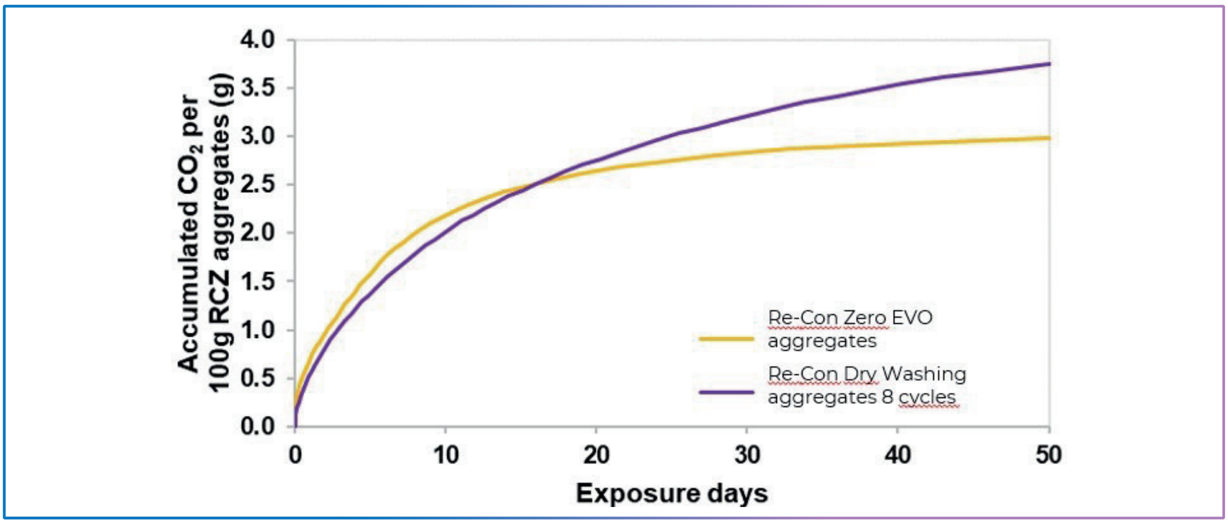

Figure 7 _ CO_2 uptake as studied in accelerated carbonation chambers.

IMPLEMENTING LAB TEST RESULTS IN LCA SIMULATION

With the first lab results available, the project team decided to **use the data in a Life Cycle Assessment (LCA) simulation of a concrete mix design where a part of the aggregates was replaced with RE-CON DRY WASHING aggregates**, using the nomenclature and methodology described in EN 15804. As shown in Figure 8, at the Production phase, there is a small decrease in the total GWP_{100} value per cubic meter of concrete, because RE-CON DRY WASHING aggregates have a lower GWP_{100} per ton of aggregate compared to virgin raw aggregate. During the 100-year use phase, the C35/45 **concrete containing natural aggregates has a carbonation potential of 100 kg of CO_2**. The actual amount would be reduced by the conditions of exposure etc., as described earlier in this article. Simulations using 40% or 100% replacement of aggregates shows an increased theoretical potential of recarbonation after 100 years. **The increase is significant and could contribute to making a concrete mix design more competitive** from a total lifetime carbon emissions perspective.

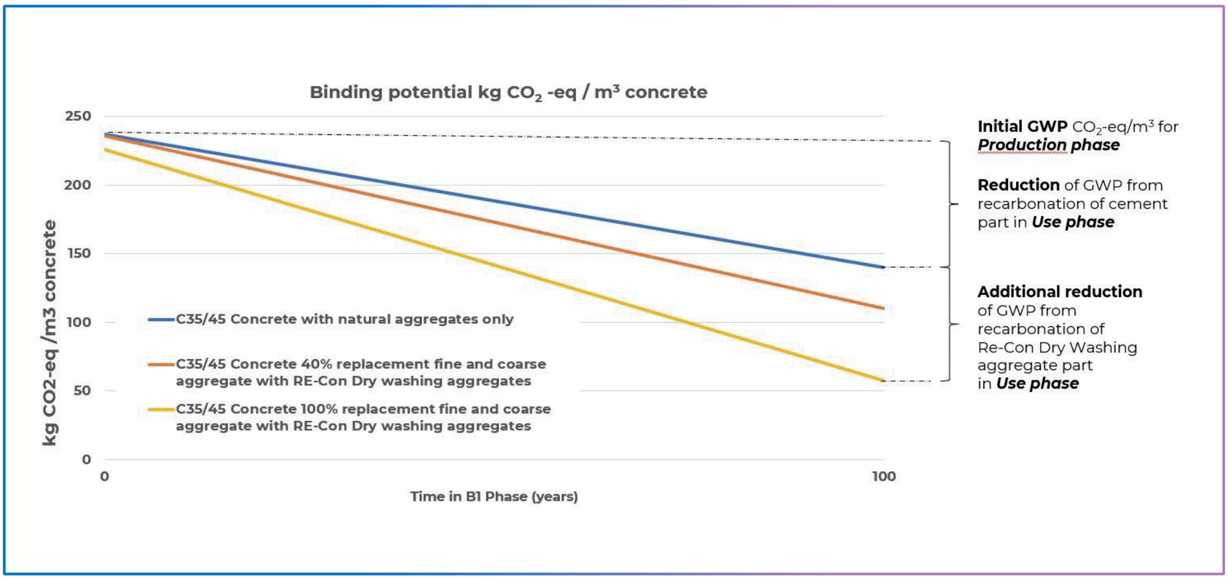

Figure 8 _ Recarbonation levels analyzed in a Life Cycle Assessment simulation of a concrete mix design.

COST SAVINGS AND CO_2 REDUCTIONS: A WIN WIN SITUATION

The RE-CON line offers a methodology to **reduce waste from concrete production by transforming it into a CO_2 absorbing aggregate**. Compared to other solutions, RE-CON line has no need for expensive equipment or complex mechanical processes. It is **a low-cost, low-energy and dust free method for greener and more cost-effective concrete production**. It will be interesting to follow the development in the industry in coming years. Will concrete producers be able to declare the recarbonation potential in the LCA Use phase of a certain mix design? Or will new accelerated carbonation technologies make it possible to recarbonate the aggregates from RE-CON ZERO EVO and RE-CON DRY WASHING so that a "carbon-negative" aggregate is achieved already in the LCA Production phase?

At Mapei, we follow this development closely and contribute continuously with new products, solutions and research and development.

References:

1 Stripple, Ljungkrantz, Gustafsson, Andersson. CO_2 uptake in cement containing products. Report no B 2309, October 2018, commissioned by Cementa AB and IVL research foundation.

2 Ingemar Löfgren. "Betydelsen av betongens koldioxidupptag ur ett livscykelperspektiv (The importance of concrete's carbon dioxide absorption from a life cycle perspective)", Husbyggaren (House builder), no. 1, 2021.

3 EPD International AB Box 210 60, 100 31 Stockholm, Sweden, https://www.environdec.com/all-about-epds/what-is-an-epd

NEW PRODUCT COMING SOON: RE-CON PH 1000

Many concrete mixing plants are located in urban areas and **the leakage of water with a high pH, and that may contain excessive levels of heavy metal contaminants** such as hexavalent chrome from cement, is an environmental problem that needs to be addressed.
Mapei's RE-CON line is already helping in this respect because RE-CON ZERO and RE-CON DRY WASHING greatly reduce the concentrations of solids and high pH cementitious residue in washing water at the mixing plant. However, **there will always be a certain amount of water with a high pH level that needs to be emitted from the plant**, which is why Mapei's Nordic R&D team has **developed an easy-to-use pH regulating liquid product called RE-CON PH 1000**.

The development and use of a new admixture

by Thomas Beck, R&D Manager for Concrete Admixtures in the Nordic region, Mapei Group

HOW WAS RE-CON PH 1000 DEVELOPED AND FOR WHAT PURPOSE?
RE-CON PH 1000 was developed **because of a new national regulation for concrete production in Norway**. The Norwegian environmental authorities now require process water from concrete production, which **must be discharged via either a sewage system or back into nature** (on the ground or into a river, lake or ocean), to be adjusted for pH, and its **pH level is not allowed to be higher than 9.5**. As most people who work with cement and concrete already know, after water has been used to clean mixing machines or concrete trucks, its **typical pH level is 11.5 - 13**.
There are many ways of overcoming this challenge. Some **large concrete producers invest in equipment** which filters the cleaning water and then recycles the water for the production of fresh concrete. This type of equipment, however, is normally quite expensive. **For smaller concrete producers**, it would be more interesting to be able to **adjust the pH of cleaning water and let it out from the plant**. That is why we have developed a new product for the RE-CON line, which is for adjusting pH only.

WHICH TESTS AND EQUIPMENT WERE INVOLVED IN THE DEVELOPMENT PROCESS?
In the development process we only used "common chemical knowledge" about acids and alkaline solutions. We invested in a digital pH-meter and collected samples of cleaning water from our customers (concrete producers) and carried out tests and experiments in the lab. The purpose of the product is **to lower pH, but it is important not to go directly to a very low pH**.

WHAT IS ITS IMPACT ON THE PH OF WATER?
The pH of water i**s a number which tells us something about the concentration of acid or hydrogen-ions** (H+) dissolved in the water. Most living species (plants, animals, fish, birds and humans) are at their most comfortable when pH is in the neutral range (pH 5 – 9). The **pH-scale is logarithmic**, which means that if pH goes from 5 to 3, the concentration of acid (or H+) is 100 times higher. This is why **we had to select the type of acid in the product carefully**. If a strong acid were to be used, it would have been very easy to reduce the pH and, once you have neutralized the alkaline chemical compounds, the excess of strong acid would have easily resulted in a pH level of less than 1. It is not sustainable to release such low pH water into nature and it can also be very harmful for plants and fish. **We opted for a so-called weak organic acid,** which acts as a buffer (that is to say, a solution which resists changes in pH when acid or alkali is added to it). Once this buffer has been used to neutralize the strong alkaline chemical compounds, the excess weak acid does not immediately result in a very low pH; rather, **pH drops to a typical level of more than 4**. This is much better from an environmental point of view.

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