OFFwind Highlights No. 3 – JUNE 2024

LOW CARBON CONCRETE

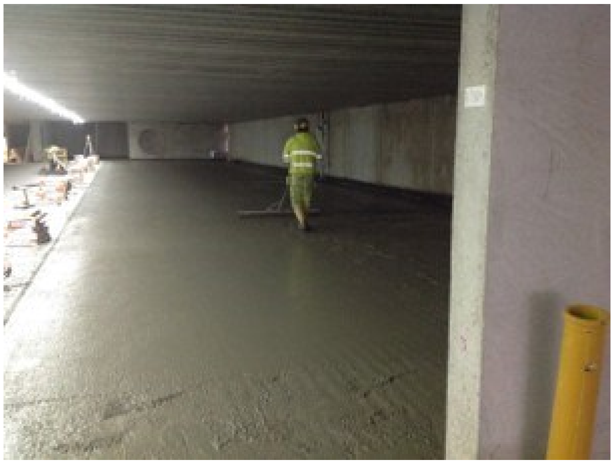
The use of concrete currently has a significant part of the carbon dioxide emissions into the atmosphere. But the future may look completely different. Let's take a closer look.

When we talk about climate change, the emissions of greenhouse gases and especially carbon dioxide have been much talked about in the public debate. The focus has long been on the possibilities of reducing the use of fossil fuels. Especially emissions from road traffic and air traffic have been the subject of discussions.

But it is obvious that society needs to review all sectors and all opportunities to reduce carbon dioxide emissions. Within the construction industry, it is the emissions from the use of steel and concrete that both can and should be reduced. Together, these two building materials contribute to approx. 14% of the total carbon dioxide emissions. Each account for approx. 7% of the emissions worldwide. At the same time, it is obvious that it is not possible to completely replace these materials with others. In order to develop the build environment, these are needed. It is also not realistic to imagine that nations with a growing economy should refrain from the use of steel and concrete. Concrete is the world's most used building material and bridges, foundation structures, retaining walls etc. will continue to be built from concrete in the future.

Picture 1. Bridge of steel and concrete

Concrete is an important building material for wind turbines, both onshore and offshore. The OFFwind – Offshore Wind Turbine Farms project also aims to bring out different aspects of how offshore wind power can be built with less carbon dioxide emissions.



Picture 2. Parking facilities of concrete

The green conversion itself requires the availability of steel and concrete. Production of electricity from wind power is very difficult, or impossible, without these materials.

Picture 3. Concrete and steel works together

This article explains in general why the use of concrete creates relatively large carbon dioxide emissions and how to reduce the emissions and, in the best case, create the use of concrete as a carbon sink.

Picture 4. Foundations of concrete

How do the emissions from concrete occur?

First, we need to see how concrete is produced. Simply explained, concrete consists of approx. 75% stone material (aggregate) of various grain sizes. It is mixed with approx. 15% cement or other binder and approx. 10% water. In addition, small amounts of chemicals. The water reacts with the binder and creates a very firm and hard product. This final product, also known as cement gel, shows a very high compressive strength. Simply the stones are "glued together" by the cement gel. Cement is made from a raw material, limestone, which is found in various forms in many parts of the world.

Picture 5. Aggregate for mixing concrete

Chemically, the limestone consists largely of calcium carbonate, CaCO3. In order for the limestone to be able to act as a binder, it must be ground and burned, whereby the burned product, called clinker, needs to be ground once more.

The limestone then becomes cement, it can react with water and form the cement gel.

During the combustion process, $CaCO_3$ is converted to a certain extent into CO_2. We have a process where calcium carbonate bound to the rock releases carbon dioxide that rises into the atmosphere. Combustion requires high temperatures, approx. 1450 C. The heating has traditionally been done with fossil fuels, but nowadays it has been possible to use bioenergy or other forms of energy. However, combustion still creates carbon dioxide emissions.

Smaller emissions also come from other parts of the process, for example from quarrying limestone and transport.

What can be done?

There are various ways and methods to reduce emissions from the concrete industry. We can divide these into four groups:

- The use of other building materials
- The use of other binders
- Capture of carbon dioxid in cement industry
- Optimizing of prosesses etc

Use of alternative building materials

In Finland, roughly four different frame materials are used.

- Concrete
- Steel
- Wood
- Aluminium

Of these, only wood can to some extent replace concrete with the intention of reducing emissions from concrete. Wood is now also used as a frame material in multi-storey buildings. Smaller bridges can also be built from wood. But wood works quite differently from concrete, above all when it comes to moisture and climate resistance. Too much deforestation is negative considering the climate and wooden constructions tend to be more expensive than concrete. Steel and concrete structures are considered to have a longer lifespan than wooden structures.

For these reasons, the possibilities of replacing the concrete with wooden constructions are very limited when it comes to infrastructure constructions.

In certain types of construction, eg. halls and multi-storey buildings, steel and concrete can be alternative frame materials.

But steel, like concrete, still causes large carbon dioxide emissions. The production of steel traditionally takes place in blast furnaces, which require a temperature of about 3000 C. Until now, fossil fuels have had a great importance for the steel industry, but nowadays people strive to use energy sources other than fossil fuels.

Blast Furnace Slag from the steel industry

When iron ore is refined into steel, a residual product, slag, is formed. By grinding the slag into a fine-grained powder, a product is obtained that is largely reminiscent of traditionally produced portland cement. By replacing part of the cement with slag in the concrete mix, a concrete with different properties is obtained. However, several of these characteristics are positive.

With slag, concrete

- *Is easy to mold.*
- *Obtains very good final compressive strength.*
- *The initial strength is lower, but this can be counteracted by heating the concrete mass or by adding chemicals.*
- *The concrete has a better durability against sulphate.*

Slag in concrete has been used for tens of years and thus the properties of concrete with slag are well known and documented. Sufficient quantities of slag are available on the market. However, it should be remembered that the production of steel creates large carbon dioxide emissions and requires a large amount of energy. If we look at the production of steel and concrete as a whole, large emissions are still caused.

In Finland, there is an environmental classification of concrete which is largely based on the proportion of slag that is mixed with the concrete.

Considering basic constructions for wind turbines, concrete with slag content can be considered the most realistic possibility to reduce carbon dioxide emissions.

Volcanic ash

Ancient concrete constructions, such as the Parthenon temple in Rome, have in the past been built with volcanic ash.

These concrete structures have had a lifespan of several thousand years. The good properties of using ash are known, but volcanic ash is available only in some parts of the world.

In Iceland, ash has been used for several years. Within the cement industry, efforts are being made to be able to use ash in other parts of Europe as well. It is possible that volcanic ash will be on the market in Europe in the near future.

Fly ash from power plants using coal

Ash from coal-fired power plants has been used in Finland as a binder in concrete for tens of years.

The ash gives a fairly low compressive strength but can still replace part of the cement. The ash also improves the tightness of the concrete, for example.

Coal is a fossil fuel, and efforts are being made to replace coal with other energy sources. This means that the availability of ash of sufficiently good quality will be in short supply in the future. In Norway, it is practice replacing part of the cement with ash from coal-fired power plants in Germany.

Clay, silica etc.

Potentially, there are several residual products from industry which can conceivably function as binders in the concrete. Even clay from nature can be burned and acquire cement-like properties.

Picture 6. Clay is normally soft, not suitable for taking up loads. Surprisingly clay can become raw material for concrete.

One way to utilize residual products is the use of geopolymers. These act as an activator for the process. In Finland, there are companies that manufacture concrete products without cement, but with the help of geopolymers.

However, the use of alternative binders requires research and long-term experience to be able to replace traditional binders in significant quantities.

Silica is an industrial waste product. Silica has long been used in concrete, especially in bridge constructions.

The concrete achieves a very high density and compressive strength, but microcracks can form. The product is more expensive than regular cement.

Can we capture the carbon dioxide from cement production?

The technology for capturing carbon dioxide already exists. The first large cement manufacturer that will use this kind of technology is in Norway. At the cement factory in Breivik (Norcement, Heidelberg Group) the aim is to put the new technology into use already this year (2024).

The process takes place as follows:

- The carbon dioxide is bound to monoethanolamine
- Released again, the carbon dioxide is very clean
- The process requires very large amounts of energy
- For the emission reduction to become real, the energy must be fossil-free
- Liquid CO_2 is transported to areas that have been used in oil production, at least 900 m deep
- The carbon dioxide remains liquid and is gradually mineralized into rock

However, the conversion of cement manufacturing is costly and at present it is difficult for cement manufacturers to change production without support from governments.

However, there is a clear objective to eventually make the use of concrete climate neutral. The organization for European cement manufacturers, CEMBUREAU, strives for concrete to be climate neutral by 2050. In order to achieve this, cement production generally needs to be restructured.

LCA, Life Cycle Assessment for concrete

LCA provides a comparative value how different building materials can be compared. This means different aspects are estimated how the material effects the climate change. These aspects can be:

- Production
- Transportation
- Emissions during construction, machines etc
- Life span
- Maintenance
- Recycling
- Residual products

There is one main factor why the emissions from concrete can be highly reduced. We call this factor carbonation of concrete. This means that a concrete structure, especially if the surface is unprotected, binds the carbon dioxide in the air back to the concrete. This process is negative in the sense that the pH value of the concrete decreases and there is a risk that the reinforcement in the concrete will rust and be damaged. However, the process is positive from the point of view of the climate, as significant amounts of carbon dioxide are bound to the concrete.

The big question is what happens to the concrete structure after its service life has ended. If the concrete can be crushed to a suitable fraction and if the crushed concrete can be preserved for a longer period of time, most of the carbon dioxide emissions from manufacturing can be bound to the crushed concrete.

In addition, if the cement industry succeeds in converting production to eliminate most of the current carbon dioxide emissions, the use of concrete will act as a carbon sink in the future.

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Co-funded by the European Union

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