Maturix CO₂ Calculator Methodology

Introduction

The Maturix CO2 calculator has been designed as part of the ConSave project. The calculator's aim is to help the different actors understand how their decisions affect their CO2 emissions. To achieve this, the calculator displays the relationship between concrete class, early strength choice and CO2 emissions. The calculator is to be used by general contractors, ready mixers, sustainability consultants or anyone interested in making more informed decisions regarding their concrete and CO2 emissions.

Background

According to the Chatham House Report authored by Lehne and Preston (2020), every year, more than 4 billion tonnes of cement are used worldwide. This corresponds to approximately 8% of the total global CO2 footprint. A concrete mix is composed of cement, water, sand and aggregates. The most carbon-intensive part is the production of cement as this requires using fossil fuels to heat a mixture of limestone and clay to more than 1,400°C in a kiln. During this process, roughly 600 kilograms of carbon dioxide are released for every tonne of cement produced (Springer Nature Limited, 2021).

Due to the high potential for CO2 savings, researchers and private enterprises have been researching ways to reduce the cement content. Two of the most common approaches are reducing the amount of cement by recipe optimisation and substituting part of the cement with other materials.

On another front, there have also been changes in the building regulations from governments and institutions. In Denmark, for example, this governamental effort has materialised with the FBK (frivilligs bæredigtighedsklasse). The FBK is a new regulation that aims to help the industry become more sustainable by reducing greenhouse gas emissions. This started as a volunteer basis but is planned to become compulsory in 2023. Another example is the new requirement, which will be introduced in the building legislation in 2023. The requirement will include large buildings (>1000 m2) and limit their carbon footprint to 12 kg CO2 e/m2 /year documented by Life Cycle Analysis (LCA).

The problem

As mentioned in the background section, currently, a great amount of research data has been published about measures to reduce the cement content and thus the CO2 footprint of concrete. However, many times, these findings are not being applied practically in job

sites. This is caused by a combination of factors such as the tendency to use traditional methods, the difficulty to change already established practices and the slow rate of adoption for new technologies.

Moreover, there is a fairly common issue that jeopardises these aforementioned measures, which is the overengineering of concrete. We define concrete over-engineering as "the use of a concrete mix or concrete class that exceeds the specified compressive strength by one or more strength classes". For example, if a concrete floor specification requires a strength class C20/25 concrete mix but instead a C30/35 is used. This problem is caused, mainly, by a combination of risk mitigation practices and early strength requirements. Normally, a higher strength class will be ordered to:

- Achieve a higher early strength earlier, so as to be able to continue with the planned activities.
- Or to prevent potential risks such as the concrete structure not reaching the desired strength level after the 28th day mark.

However, the strength class is also sometimes dictated by the requirement for low w/c ratio which is typically linked to durability requirements. A low w/c ratio will result in higher strength.

This problem is important because the higher the cement content, the higher the CO_2 footprint will be. Therefore, if a higher strength class is used, the CO_2 footprint will typically increase too if it is based on the same cement. Thus, if the raise in strength class can be minimised or avoided, a portion of the CO_2 emissions could be prevented.

About the ConSave Project

The ConSave is a joint-project between the Danish Technological Institute, Dansk Beton, the Technical University of Denmark, and Maturix. The project runs from August 2021 to August 2023 and is supported by MUDP under the Danish Environmental Protection Agency.

Project goals

The ConSave project aims to contribute to solving the problem mentioned above in three ways. In this Methodology paper, we will only explain the first one, CO_2 calculator, in detail as the rest are still in development.

CO₂ Calculator

Developing a CO_2 calculator that helps the different actors understand how their decisions affect CO_2 emissions. The calculator shows the relationship between concrete class, early strength choice and CO_2 emissions. The aim is to make this relationship visible to the relevant actors so that they can choose the best concrete for the job. Hopefully, this will help to minimise the over-engineering that occurs due to requirements for early strength and risk mitigation.

Methods and Data Sources

In order to function, the calculator requires CO_2 data as well as early strength data.

CO₂ data

The CO_2 data was obtained from Environmental Product Declarations (EPD). EPDs are independently verified and registered documents that analyse the environmental impact of products during all or some of their life-cycle. You can read more about it here. As defined in the ISO 14044:2006, the EPD life-cycle is divided in:

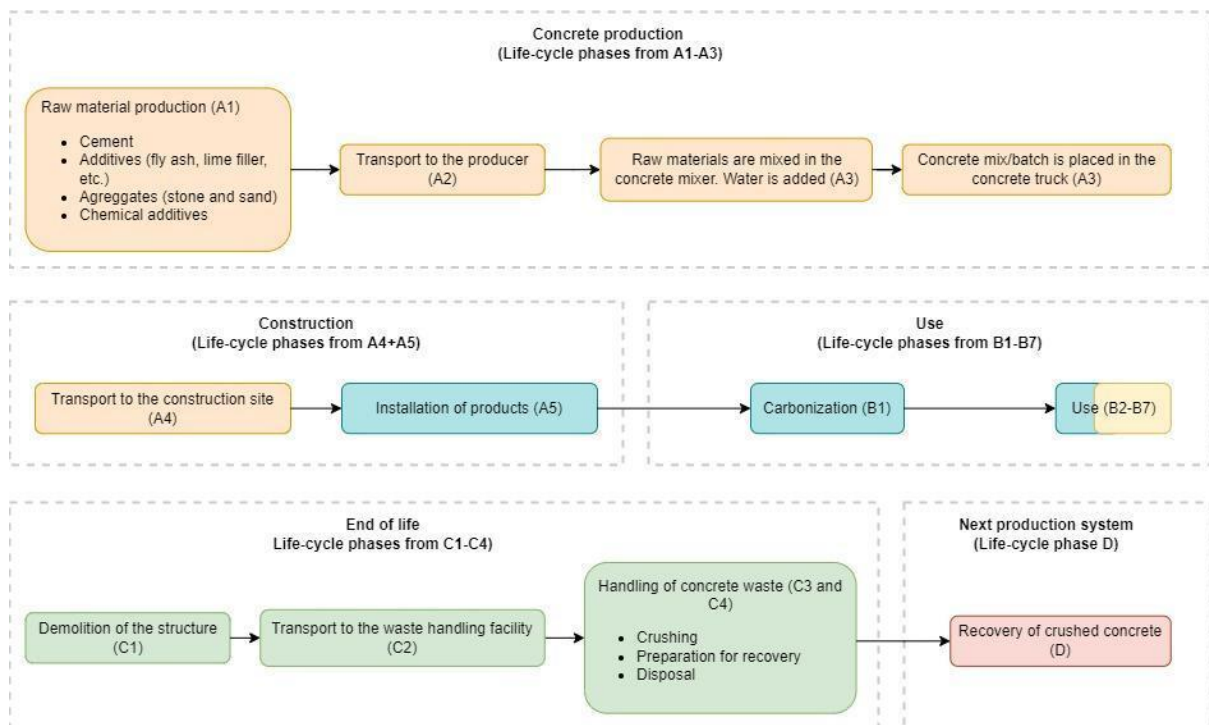| Production				Building Process				Use				End of life				Outside boundaries
Raw materials	Transport	Manufacturing	Transport	Installation	Use	Carbonization	Reparation	Replacement	Renovation	Energy Use	Water Use	Demolition	Transport	Waste Treatment	Disposal	Reuse and Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D

Figure 1: EPD phases.

Figure 1. Continued.

Some of the environmental impacts reported in the EPDs are the equivalent CO_2 emissions, acidification of fjords and water or eutrophication among others. For the calculator, we decided to only include the global warming potential (GWP = CO_2 emissions) as this is the most used parameter in the construction industry. Furthermore, the CO_2 emissions displayed in the calculator are only from the Concrete Production (A1-A3) phase. This decision was taken due to the increased variability in the CO_2 results during the later phases.

EPD types

There are four main types of EPDs according to EPD International AB:

- The Product EPD, provides data about a specific product made by one manufacturer.

- The Group EPD, provides data about similar products made by the same manufacturer.

- The Sector or Industry Average EPD, is developed by an industry association and declares the average product of multiple companies in a clearly defined sector and/or geographical area.

The calculator's CO_2 data was taken from the Danish Industry EPDs made by the Dansk Beton Fabriksbetonforeningen. These included: Ready-mixed concrete (exposure classes X0, XC1), Ready-mixed concrete (exposure classes XC2, XC3, XC4, XF1 and XA1), Ready-mixed concrete (exposure classes XD1, XS1, XS2, XF2, XF3 and XA2) and Ready-mixed concrete (exposure classes XD2, XD3, XS3, XF4 and XA3). In some of the EPDs, there were different types of concrete mixes for the same strength class. In this case, the CEM I values were used. All the mentioned EPDs can be found in the [EPD Danmark website.](#)

Early strength data

For the early strength data, the use of Maturity Curves* was chosen as this is what Maturix has the deepest knowledge of. In the Maturix In-situ software, there is a Concrete library with more than 1000+ concrete mixes grouped by strength class. Each concrete class group is composed of mixes that have different strength development profiles, from fastest to slowest. The Maturity Curves used for the maturity calculations were obtained by selecting the average strength development profile from each of the strength classes groups. An example of this can be seen below:
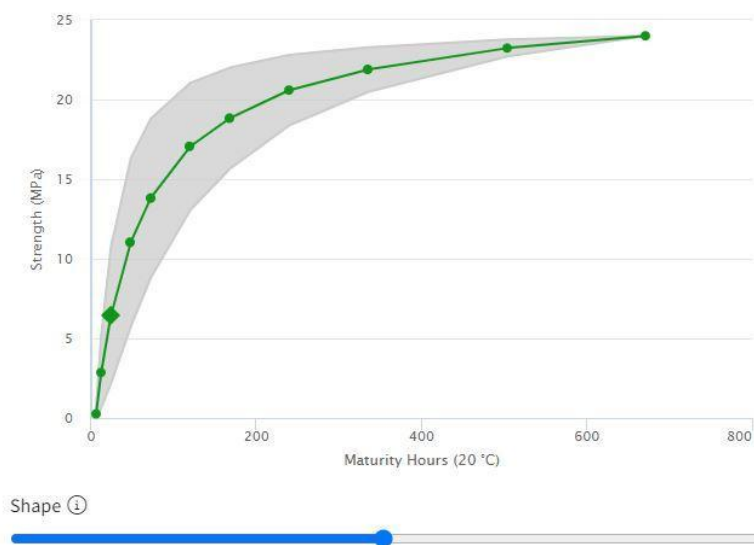

Figure 3: Maturity Curve Profile example.

*Maturity Curves are the basis of the Maturity Method. If you are unfamiliar with this we recommend reading:
- [Introduction to Concrete Maturity](#)
- [What is the Maturity Method?](#)

Ambient temperature
During the early development phases of the calculator, the calculator did not include the ambient temperature. Therefore, this was assumed to remain constant at 20 °C. This is because, according to ASTM 1074, the temperature needs to be kept constant at 20°C or 23 °C in the US during the maturity calibration. However, this had an issue: temperature has an effect on the amount of time that a concrete takes to develop its strength.

When using the Freiesleben Hansen & Pedersen maturity model (Arrhenius), the most accurate approach would be to use the internal temperature history of the concrete mix and convert it to the reference temperature (20 °C) using rate factors. The internal temperature may be affected by many factors such as concrete geometry, type, placement, curing methods and weather. This makes it challenging to create an average temperature profile for each strength class without requiring extensive generalisations and assumptions.

In order to overcome this, the ambient temperature is used as the internal temperature. This means that if a 40 °C is selected in the ambient temperature dropdown, this will be used in the formula as the internal concrete temperature.

This approach comes with its own limitations as, often, the ambient temperature might be lower than the internal concrete temperature due to the exothermic nature of the cement hydration process. But it was a compromise made in order to include temperature and to simplify the calculator process. Therefore, it is important to notice that the maturity displayed in the calculator are only estimates.

Scope
The CO_2 data displayed in the calculator is from Denmark while the early strength data comes from the Maturix database which contains a blend of concrete mixes from different parts of the world. During the research process, it was found that CO_2 varies greatly depending on the country due to different regulations, production processes and energy sources among other things. Therefore, CO_2 data from other countries for the different strength classes may be different from the ones displayed in the Maturix CO_2 calculator.

Sources

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5. *EPD Types | EPD International*. (2022). EPD International AB. https://www.environdec.com/all-about-epds/what-is-an-epd