Concrete testing in a climate chamber with CO_2 control

The standard DIN EN 206 assumes concrete structural components to have a service life of at least 50 years. Corrosion of the steel reinforcement in ferroconcrete caused by its exposure to CO_2 (carbonation) can shorten the service life. Holcim HüttenZement GmbH is using a Memmert ICH C climate chamber with CO_2 control to find out which characteristics concrete needs to have to minimise carbonation.

Carbonation - briefly explained

Amazingly, concrete and beer have quite a lot in common: Both have just a few ingredients, there are a lot of formulations and recipes for them, and both concrete as well as beer age when exposed to the elements. While the shelf life of the Germans' favourite beverage is primarily affected by oxidation processes, ferroconcrete is most commonly afflicted by corrosion of the steel reinforcement caused by the elements. One of the main causes for this is the penetration of chlorides into the concrete. The second main cause of premature ageing of reinforced concrete is CO_2, which may penetrate the outer layers of the concrete from the air or from water containing CO_2. This chemical process is referred to as carbonation in the jargon.

The main ingredients of concrete are water, aggregates and cement. Admixtures and/or additives are often added to the concrete mix to improve its workability or durability. As concrete has extremely high compressive strength, but low tensile strength, it is generally reinforced with steel rods or bars. Initially, the steel reinforcement is completely enclosed by concrete and thus well protected against corrosion. The highly alkaline, water-soluble calcium hydroxide $Ca(OH)_2$, which is formed when the concrete hardens due to the reaction of calcium silicates with water, is responsible for this. The high pH of the water in the pores of the hydrated cement forms an inert passivation layer of iron oxide on the steel reinforcement, preventing the formation of rust. If, over time, the combination of humidity and CO_2 affect the structure, the calcium hydroxide reacts to form calcium carbonate ($CaCO_3$), lowering the pH. As a consequence, the reinforcement is no longer protected against corrosion. The depth of the carbonation front depends on a number of criteria such as moisture content, porosity and the age of the concrete.

Concrete exposure classes are used as a guide

Exposure Class XC: Corrosion of the Reinforcement Induced by Carbonation	Conditions	Classification examples
XC1	Dry or permanently wet	Concrete inside buildings with low air humidity (e.g. bathroom, kitchen, laundry). Concrete permanently submerged in water
XC2	Wet, rarely dry	Parts of water tanks/reservoirs, foundation components
XC3	Moderate humidity	Components frequently/constantly exposed to outdoor air (e.g. open structures, indoor areas with high humidity, commercially used kitchens and bathrooms, laundries, wet rooms in indoor swimming pools and cattle stalls, etc.
XC4	Alternately wet and dry	External components directly exposed to rainfall

Exposure class XC for concrete according to DIN EN 206-1

In Europe, the standard DIN EN 206-1 specifies how the effect of different environmental influences are classified into what is referred to as concrete exposure classes. These classes are not mutually exclusive, meaning that several exposure classes may apply to a single structure. Depending on the class, the standard specifies tolerance limits for the water/cement ratio, minimum cement content and the air content of the concrete, amongst others, to guarantee the durability of the concrete used for all conceivable applications. Carbonation of the concrete is defined as class XC.

The European Committee for Standardisation (CEN) is currently revising the EN 206 standard a new approach to guarantee the durability of concrete: classification into resistance classes based on how fast the carbonation front advances through the concrete. Initial practical trials of the classification of various concrete grades are currently being carried out in various locations, including at Holcim HüttenZement GmbH in Dortmund, Germany.

Determining carbonation depth

As is the case in most industries, it is possible to use artificial ageing to predict service life. This is done by immersing test specimens – concrete cubes or beams – in water for 28 days. Then they are dried in a standard atmosphere (20 °C and 65% rh) for 14 days in a climate chamber or a room with a controlled climate before lab manager Dr. Christine Eckhardt's team puts them into storage for 70 days at 20 ?, 55 % rh and 3 % CO2 in a Memmert constant climate chamber ICH750C. The depth of carbonation is determined after 56, 63 and 70 days.

This is done by splitting the test specimen and spraying the test surface with an indicator. At high pH values, the surface turns red/violet (see image), meaning that adequate corrosion protection is ensured, whereas the surface remains colourless where CO2 has penetrated. The depth of carbonation is measured with vernier calipers.

The Memmert climate chamber ICH: a flexible, mobile room with climate control

The Memmert climate chamber ICH C, in which the concrete cubes are exposed to CO2 in a constant atmosphere, is fitted with telescopic slides and reinforced stainless steel gratings to help you make the most of the available chamber volume of 749 litres. Each grating holds approx. 50 kilograms, with each test specimen weighing 12 kilograms. Dr. Eckhardt particularly appreciates the flexibility of the climate chamber. "Basically, the ICH is designed for semi-mobile use, as it can easily be moved from one room to another. It has its own climate control unit. The CO2 supply can be adjusted separately, meaning that I don't need a huge climate chamber and don't have to control the climate of the whole room in order to perform carbonation

Evidence of concrete cone failure with carbonation to behind the upper reinforcement layer using phenolphthalein solution. (URL: https://commons.wikimedia.org/w/ir)

Building materials testing in Memmert drying oven

Julius Berger Nigeria PLC uses several Memmert drying ovens to dry and condition building material samples.

more information.

experiments."

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Overview of main topics

- Concrete testing, building material testing, concrete tests
- Carbonation, carbonation depth
- Carbonation front
- Artifical ageing
- Memmert climate champer

Sources and background knowledge:
www.concrete.org

Memmert laboratory equipment for material testing

Heating oven (drying oven) UN/UF
Vacuum drying oven VO
Constant climate chamber HPP
Climate champer ICH
Climatic test chamber CTC
Temperature test chamber TTC
Humidity chamber HCP

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