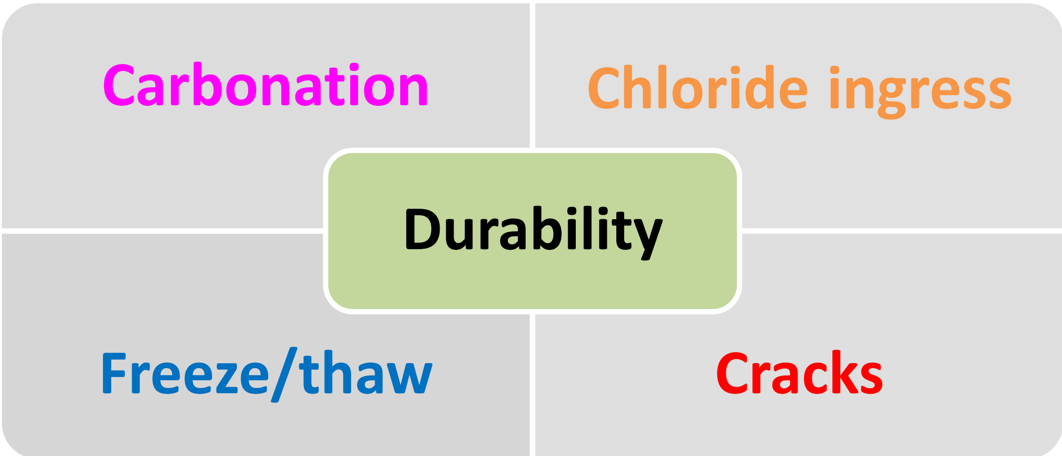
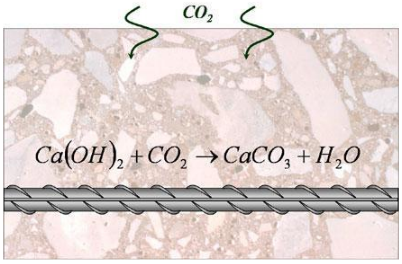
TESTING OF CONCRETE DURABILITY

At the level of the material, the concrete cover presents protection of reinforcement from external influences that can cause its corrosion by reducing the transport of pollutants. One of the main transport mechanisms through the concrete is diffusion. Whether it is the diffusion of chloride ions or molecules of CO_2, the structure of the cement matrix protects the reinforcement forming a protective passivation layer around the reinforcement bar itself.



The use of standards for testing the concrete durability provides only testing of material properties. In addition, based on those material properties, using analytical models defined in the fib Model Code it is possible to predict the service life of the structure. Also, there are some recommendations that can be used to define the service life, which should be provided with designed concrete cover (*Concrete design for a given structure service life durability indicators - AFGC*).

Carbonation



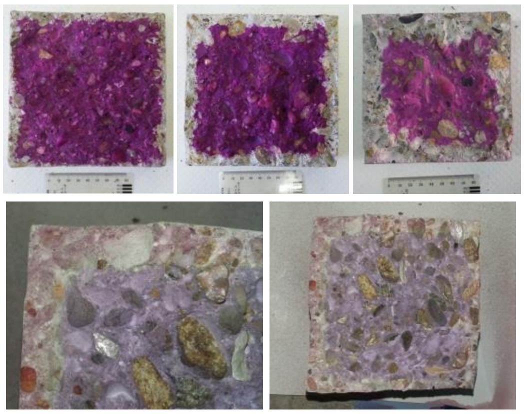
Carbonation is a process of neutralization of the cement matrix due to reaction with carbon dioxide (CO_2) from the environment. This process leads to a reduction of concrete pH value and enables reinforcement corrosion. Two main parameters of concrete resistance to carbonation are carbonation depth and inverse carbonation resistance.

1. Accelerated carbonation test (carbonation chamber MEMMERT ICH 260C)
    - Volume 61x46x78cm
    - CO_2 range 1-20%
    - Temperature range 10-50^{o}C
    - Humidity range 10-80%
    - Output: carbonation depth (mm)
    - Testing is performed according to EN12390-12, ISO1920-12, EN13295, NT BUILD 357

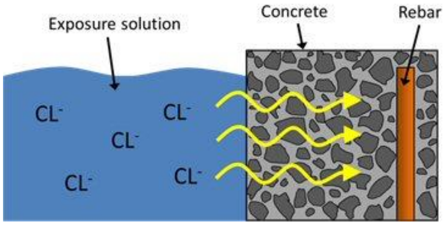
2. Natural carbonation test
    - Output: carbonation depth (mm)
    - Testing is performed according to EN12390-10

Carbonation depth measurement

1. Phenolphthalein test
    - EN14630
2. Rainbow indicator test
    - More accurate pH value measurement



All methods are for evaluating the carbonation resistance of concrete mixes by comparison with a concrete mix with known carbonation resistance. It is not a method for the determination of carbonation depths in existing concrete structures. A specimen is a concrete prism. Sample will be exposed to high concentrations of carbon-dioxide in the carbonation chamber, with controlled humidity and temperature conditions. At defined periods, slices are split from the prisms and the freshly split surface is sprayed with a phenolphthalein solution or rainbow indicator. The mean depth of the reacted surface layer is calculated and called the depth of carbonation.



Chloride ingress

Chloride ingress is one of the main causes of reinforcement corrosion. The main parameter of concrete resistance to chloride penetration is the diffusion coefficient.

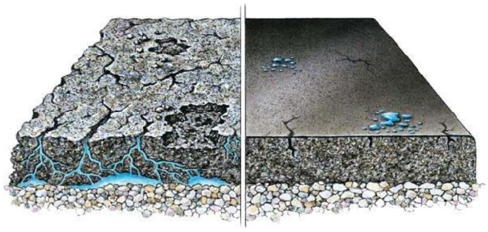
1. Rapid chloride migration test
   - DC current range 0-60V
   - Vacuum saturation
   - Temperature control
   - Output: chloride migration coefficient D_{nssm} (m^2/s)
   - Silver-nitrate solution
   - Testing is performed according to NT Build 492

2. Chloride diffusion test
   - collecting concrete powder from thin concrete layers
   - Output: effective chloride diffusion coefficient De (m^2/s)
   - Potentiometric titration method
   - Testing is performed according to EN12390-11, NT Build 443

3. Electrical resistivity (durability indicator)
   - DC current range 0-60V
   - Output: specific electrical resistivity ρ (kΩcm)

Chloride migration coefficient is tested according to standard NT Build 492. A specimen is a concrete cylinder with a diameter of 100 mm and a thickness of 50 mm, sliced from cast cylinders or drilled cores with a minimum length of 100 mm. An external electrical potential is applied axially across the specimen and forces the chloride ions outside to migrate into the specimen. After a certain test duration, the specimen is axially split and a silver nitrate solution is sprayed on to one of the freshly split sections. The chloride penetration depth can then be measured from the visible white silver chloride precipitation, after which the chloride migration coefficient can be calculated from this penetration depth.

Chloride diffusion coefficient is tested according to standard EN 12390-11 or NT Build 443. The profile specimen is coated on all sides but one and then the uncoated face is exposed to a chloride exposure solution. The exposure is achieved by complete immersion, ponding the uncoated face or inverting the specimen and having the uncoated face immersed in the chloride exposure solution. After 90 days of exposure, at least eight parallel layers of the chloride exposed surface are ground off the profile specimen. The acid-soluble chloride content of each layer and the average depth of the layer from the surface of the concrete exposed to the chloride solution are determined. By non-linear regression analysis by least squares curve fitting, the nonsteady state chloride diffusion coefficient (Dnss) is determined.



Freeze/thaw

Low temperatures lead to a reduction of concrete durability. Cycles of freezing with or without de-icing salts lead to degradation of the internal structure and the concrete surface.

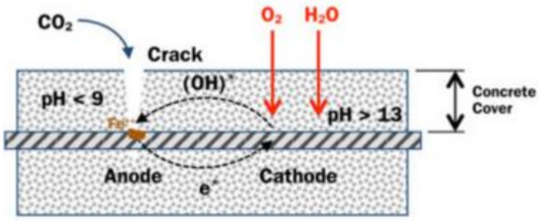
Climatic chamber

- Volume 54x67x140cm
- Temperature range -25 ÷ 70^{o}C
- Humidity control
- Testing is performed according to SRPS U.M1.016, SRPS U.M1.055, SRPS U.M8.002, EN 196-1, EN 12390-2, EN 12390-9, EN 1338, EN 1339, EN 1340, EN 1367-1, EN 1367-6, EN 12371, EN 1348, EN ISO 10545-12, EN 12091, EN 539-2, CEN/TR 15177, ASTM C666-03, ASTM C672

1. Freeze/thaw resistance
   - Output: Relative Dynamic Modulus of Elasticity
2. Frost salt scaling
   - Output: Loss of mass (g/cm^2)

Concrete structures exposed to the effects of freezing and thawing need to be durable, to have an adequate resistance to this action and, in cases such as road construction, to freezing and thawing in the presence of deicing agents. It is desirable, especially in the case of new constituents or new concrete compositions, to test for such properties. If the concrete has inadequate resistance then the freeze-thaw attack can lead to two different types of damage, namely to scaling (surface weathering) and to internal structural damage. Freeze-thaw resistance will be tested according to standard EN 12390-9. According to the standard, there are three methods for testing freeze-thaw resistance of concrete. A specimen is a concrete cube with dimensions 150 mm.

Cracks



Concrete cover is the main protection from external influences that can cause reinforcement corrosion. The occurrence of cracks leads to the destruction of concrete cover and concrete permeability increase.

Crack width measurement

1. Digital camera
   - Magnification: 260
   - Crack width measurement software

2. Microscope
   - Magnification: 40, 50, 60 times
   - Ruler precision: 0.01 mm