



# BUILDING CHEMISTRY

## LAB 5

### CORROSION OF BUILDING MATERIALS

#### THEORETICAL BACKGROUND

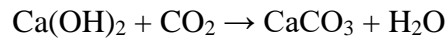
Portland cement is a hydraulic binder that sets due to hydration, so it can set under water as well as in the air. Products of hydration are solid in both environments. The main oxides of cement are: CaO, SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub> i SO<sub>3</sub>. The oxides form anhydrous chemical compounds which prove hydraulic properties are: calcium silicate, calcium aluminate and calcium aluminoferrite.

Anhydrous chemical compounds: alite (C<sub>3</sub>S), belite (C<sub>2</sub>S), tricalcium aluminate (C<sub>3</sub>A) and calcium aluminoferrite (C<sub>4</sub>AF), undergo hydration combined with hydrolysis after the addition of water. As a result of those chemical reactions, hydrated calcium silicate (C-S-H phase), hydrated calcium aluminate and calcium ferrite, and calcium hydroxide are formed. As a result of the presence of the gel phase of C-S-H, the evaporation of the redundant water and the presence of air cavities, the cement based materials are porous. Highest porosity characterizes the cement paste, as it does not contain any aggregate.

Susceptibility to corrosion of the cement materials is caused by their porosity and the presence of calcium hydroxide – Ca(OH)<sub>2</sub> which comes from alite and belite. Only around 1% to 2% of calcium hydroxide comes from hydration of free calcium – unbound with C<sub>3</sub>S, C<sub>2</sub>S, C<sub>3</sub>A and C<sub>4</sub>AF. Furthermore, the corrosion resistance of the cement materials in sulfate environment (with SO<sub>4</sub><sup>2-</sup> ions) depends on the C<sub>3</sub>A content. After hydration, C<sub>3</sub>A reacts with SO<sub>4</sub><sup>2-</sup> ions and builds salts which splits the material apart.

#### Carbonatation

Over time, calcium hydroxide located in the top layer of concrete bonds with CO<sub>2</sub> from the air. The higher the porosity and the less dampened the concrete is, the more accelerated is the process. This phenomenon is called carbonatation and it is expressed with the following chemical equation:



Carbonatation slows down over time. Sealing of the structure of concrete is an advantage of this process.

Material corrosion is the damage of the material during its exploitation caused by external factors such as environment or the human factor. The physical factors of concrete corrosion include:

- external forces and deformation of the material,
- differences in temperature of the elements caused by irregular exposure to sunlight,
- variable dampness of the material (shrinkage and swelling of concrete),
- water freezing in the cavities present in the building and the concrete pores, and leaching from its components,
- mechanical damage to buildings due to running water, ice or wind.

The biological factors of concrete corrosion are: the presence of living organisms, bacteria, algae or fungus, plant roots.

The chemical factors are:

- leaching of water resulting from atmospheric precipitation or water-vapor condensation in cooling towers in industry,
- effect of the presence of chemical compounds in ground water, underground water, sewage, soil and atmosphere.

### Chemical corrosion

The development of chemical corrosion of concrete depends on various material and environmental factors:

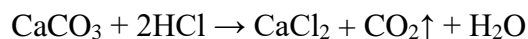
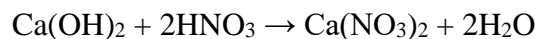
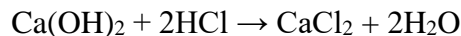
- chemical composition of the binder – cement (Portland cement, blastfurnace cement, calcium aluminate cement) and aggregate (quartz aggregate, calcium aggregate, solid or porous aggregate),
- structure of concrete (solid, porous, dispersed),
- age of concrete – there is an optimum age for concrete when it comes to corrosion resistance



- fresh concrete is very susceptible to leaching corrosion caused by the incomplete hardening process of the binder and high content of calcium hydroxide. Old concrete is susceptible to corrosion due to high porosity. However, due to the effect of carbonatation, old concrete is less susceptible to leaching corrosion,
- chemical composition and aggressive environmental concentration (gas, liquid, aggressive soil).

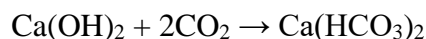
Depending on the type of the aggressive environment, the following types of corrosion can be distinguished:

- leaching – caused by soft water deprived of  $\text{Ca}^{2+}$  ions, based on leaching of  $\text{Ca}(\text{OH})_2$ . Low temperature, water pressure and water flow promote leaching.
- acid corrosion – caused by the solutions of strong mineral acids such as  $\text{HCl}$ ,  $\text{HNO}_3$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{H}_3\text{PO}_4$ , weak acid  $\text{H}_2\text{S}$ , organic acids – acetic and lactic, as well as the humic substance from the soil. Acid corrosion results from the formation of freely soluble calcium salts, decomposition of the C-S-H phase, or the decomposition of calcium carbonate in the carbonatated areas.

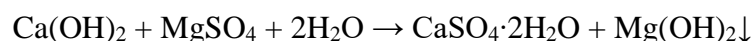


The solution of  $\text{H}_2\text{S}$  acid also causes sulfuric corrosion which is the formation of hydrated sulfate with bigger volume. That phenomenon causes the material to expand and split apart.

- carbonate corrosion – caused by water aggression and free  $\text{CO}_2$ . Excessive amount of aggressive  $\text{CO}_2$  contained in mineral water causes material corrosion due to freely soluble calcium bicarbonate formation:

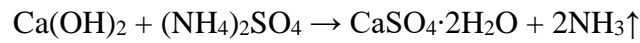


- magnesium corrosion – due to  $\text{Mg}^{2+}$  salts, greasy  $\text{Mg}(\text{OH})_2$  without binding properties is formed.

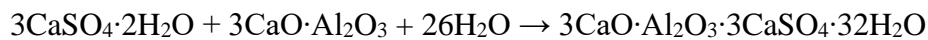
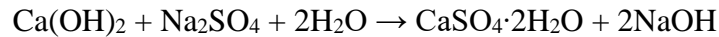




- ammonium corrosion – caused by  $\text{NH}_4^+$  salts that react with the ammonia splitting the material apart.



- sulfuric corrosion – caused by  $\text{SO}_4^{2-}$  salts that react resulting in the secretion of hydrated salts such as gypsum or Candlot's salt.



Cyclic dampening and drying out of the material is particularly dangerous.

- base corrosion – caused by the solutions of highly concentrated bases (sodium or potassium).

Corrosion is also caused by fats and vegetable or animal oils. Internal corrosion caused by the reaction between an aggregate containing active silica (e.g. opal) and alkali (e.g.  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ) from cement can also occur.

Highly corrosive effect on the cement material is exerted by acid flue gases:

- $\text{SO}_2$  – contained in flue gases, after oxidizing with the oxygen in the air and connecting with water forms sulfuric acid,
- $\text{CO}_2$  – contained in flue gases, forms freely soluble calcium bicarbonate, just like in mineral water,
- $\text{H}_2\text{S}$  – hydrogen sulfide (from natural sulfur sources, putrefactive gases, technological gases) forms calcium sulfide or, after oxidizing, sulfur acid,
- $\text{HF}$  – hydrogen fluoride reacts with  $\text{SiO}_2$  contained in aggregate, and also with calcium hydroxide.

The corrosion of concrete can be avoided by using:

- appropriate to the environmental conditions type of cement, e.g. blastfurnace cement, calcium aluminate cement, Portland cement with pozzolan additions,
- appropriate aggregates,
- suitable granulometric composition of the aggregate and low water/cement ratio (with superplasticizers),
- technologies that increase the air tightness, e.g. vibration, shaking, hydrothermal treatment,



- organic and inorganic protective coatings.

Knowing the level of environmental aggression according to PN-80/B-01800 enables us to select appropriate preservative methods.

#### Methods for the evaluation of corrosion of concrete materials

Depending on the aim of the corrosion test, more and less precise methods exist. If they are only to be of diagnostic nature, the physico-mechanical properties shall be tested, e.g. compressive strength, depth of neutralization, and the chemical composition of concrete and the products of corrosion. Additionally, in reinforced concrete structures, the ability of concrete to passivate steel is also determined. In more scientific research, elongation, loss of mass or the deterioration of the mechanical strength of the material exposed to aggressive factors compared to a material not exposed to aggressive factors are also determined.



## PRACTICAL SESSION

### CORROSION OF BUILDING MATERIALS CORROSION OF CONCRETE MATERIALS

Equipment: beaker (800 ml), balance with a limit of performance of  $\pm 0.01$  g

Reagents: concrete samples,  $\text{CH}_3\text{COOH}$  and  $\text{HCl}$  solution (with concentration of 2%, 4% and 6%), lignin

### PROCEDURE

1. Dry (using lignin) and weigh the 6 samples of concrete initially stored in water.
2. Put the samples in separate beakers and cover them with acid solutions.
3. Samples should be fully covered and the acid solutions should reach 1 cm above the upper edge of each sample.
4. Cover the beakers with watch glasses.
5. After 1 hour, take the samples out of the acid solutions, dry them and weigh.
6. Calculate the loss of mass for each sample. The loss of mass is the measurement for the corrosion progress that occurred.