Biodegradation and its impact on durability of building construction

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Abstract. The durability of building elements is influenced by a number of different factors. Among the most complicated, biocorrosion can be included without exaggeration. From practical experience, we know that biodegradation manifests itself in all kinds of materials and structural elements. Although both primary and secondary protection of a particular building structure is realized, if appropriate living conditions are created for the existence of a particular species of biodeteriogen, this kind of degradation will be initiated. The paper deals with the issue of biocorrosion, which was studied at selected parts of the technical extension in Campus of the Technical University in Košice. Undesirable bio-corrosive symptoms due to the presence of algae and fungi are often visually observed on the surfaces, but their effects also have a negative impact on the internal structure. In practical terms, a solution to identification of these symptoms are required which needs to develop methods of monitoring the state of the surface over time and removing them. Diagnostic methods will be presented to check the technical state condition of construction parts as support in identification bio-corrosion symptoms.

1. Introduction

Most of the degradation processes require the presence of water. On the one hand, water is necessary for the performance of technological procedures, but on the other hand, causes disorders construction. Humidity is one of the basic technical parameters which are observed continually from production of building materials up to demolition of building objects. With higher humidity goes plenty of processes which lead to decreasing durability and reliability of construction. Practical determination of humidity of each other materials therefore becomes an important tool of quality control, technological processes while realizing up to diagnostic of corrosion. The determination of presence of water is the basic of diagnostics procedures. There is a particular correlation of humidity and related chemical changes and corrosion processes of building materials [1]. Water within its natural circulation in environment is never chemically pure. When we take this into consideration, the logical conclusion is that because of the presence of water pollutants, in the structure of building materials appears chemical and chemical – physical processes. Polluted water also causes salinity of elements and structures, which is a significantly interconnected degradation processes. The most important physical aspects are phase changes of water (gaseous - liquid - solid state) which are associated with a change in their physical parameters. [2] The main types of such processes in building are soaking, damping and drying. Upon penetration of contaminated water into the structure, the dissolved salts are transported to the whole structure of the elements. If the aqueous phase is evaporated under suitable thermodynamic conditions, the salts may be precipitated. After evaporation of liquid phase are formed new products on the surface or inside of the construction [2]. Their presence is manifested in the form of both crystalline
and amorphous new products. Production of new products can be connected with volume changes, which are linked with mechanical consequences (increasing tension, decreasing of strength parameters or even destruction) [2]. In diagnostics the technical state of building elements, salts are very important phenomena and their concentrations are used as assessment criteria of damaged parts of construction. Humidity related degradation processes as well as effect lies in the formation of available conditions to grow of biodeteriogens [3]. Biocorrosion of building materials - stone, concrete, mortar, etc. can be caused by such microorganisms as bacteria, fungi, lichens, algae, and plants [3]. Biofilms are complex communities of microorganisms attached to surfaces of materials generally, or associated with interfaces. Bacterial biofilm formation on inert surfaces is a significant technical and economic problem in a wide range of environmental, industrial, and other areas. Bacterial adhesion is generally a prerequisite for this colonization process and thus, at the same time represents suitable live conditions for another biodeteriogens mostly different types of mosses, moulds, algae’s and plants. Multidiscipline methods are available for the study of biodeterioration building materials. Almost of them is bearing to biological part of problem e.g. identification of biodeteriorates, evaluating of birth biofilm or studies of metabolites. An investigation of the effects of humidity and salt crystallization on masonry has been undertaken at chosen part of technical extension of building and its roofing. Masonry has been contaminated with chloride salts above all, which are undergoing cycles of crystallization - dissolution in response to fluctuations in relative humidity. Assessment of degradation masonry consisted of determination of moisture and salinity combination of gravimetric and chemical analysis of samples. Biocorrosion of masonry was also studied by using spectral analysis method.

2. Methods

2.1 In situ determination
In this case study was provided diagnostics of selected building in Campus area of Technical University Košice specially its exterior finish roofing basement. As can be seen from photo documentation, the outer above-ground part of the basement is solved by a combined masonry; from two sides is provided by a concrete fence (Fig. 1), from the north side by a brick wall (Fig. 2). The western part of the fence is directly connected to the facade of building. From a material point of view it can be stated that at this relatively small area has been realized combination of various structural components and materials. In situ was done visual confirmed cracking patterns, efflorescence, and spalling parts. All this knowledge’s provide useful information regarding the structure and current situation. To the purpose of biocorrosion study (chemical, physical and structural changes) is important to obtain the representative sample from damaged part. Also, the dimensions and condition of the damaged elements must be taken into account in order to avoid deterioration of their technical condition.

2.2 Methods of sample processing
Samples were taken at atmospheric conditions: relative humidity of air was 65% , air temperature was 15°C. Sampling of external parts of concrete parts was carried out at a height 0.5m, 1.0m and 1.5m measured from the floor of the basement. Sampling of external parts of bricks and mortars (north part) were carried out at a height 0.5 m. All samples were taken carefully from damaged parts - the depth was up to 20-35mm, material was stored in plastic sealable containers, labelled and then processing in laboratory. In the case of a significant crack in the south-oriented part of the structure, the sampling was also carried out from the inside from a depth of approx. 200-300mm.

2.3 Determination of humidity
Humidity of samples was provided by gravimetric method. The samples were weighed in Laboratory using electronic scales Mettler Toledo, to an accuracy of 0.0001g, then dried up to 105-110°C (Laboratory dryer Matest, ITALY) until constant weight. The mass humidity \( \omega_{\text{m}} \) was calculated according to formula (1).
w_{mh} = \frac{m_w - m_d}{m_d} \times 100\%  \quad (1)

where:  \quad m_w = \text{mass of wet sample},
\quad m_d = \text{mass of dry sample},
\quad W_{mh} = \text{mass humidity of sample}.

Follow to the standard CSN 73 0610 \(\text{(informative Annex A)}\) \[4\] masonry mass humidity is classified by percentage mass humidity, follow to criteria in Table1.

**Table 1. Criteria for assessment of silicate materials humidity \[4\].**

| \(w_{hm} [\%]\) | humidity     |
|-----------------|-------------|
| < 3             | low         |
| 3 \leq W_{hm} < 5 | very low    |
| 5 \leq W_{hm} < 7.5 | increased  |
| 7.5 < W_{hm} < 10 | high       |
| W_{hm} > 10     | very high   |

The obtained values \(w_{mh}\) (see Table 2) were different for the individual parts of masonry, partly linked to the fact, that sampling of material was realised after raining weather.

2.4 Chemical processing

For chemical analysis were used a representative parts of samples after their particular homogenization follow to methodical recommendations \[5\]. Determination of c(Cl) concentration (as selected representative salts), was provided by potentiometric method using selective chloride electrode. Alkality changes of samples were expressed as pH values, the potentiometric method was chosen for their estimation. Table 2 shows the comparison of the average results of silicate samples taken from above mentioned height from the ground. Selected samples of silicates were also subjected to spectral FTIR analysis.

3. Results and discussion

The results of diagnostic assays show (see Table 2), that the samples have followed to criteria \[4\] higher degrees of humidity. The samples taken from the brick are able to absorb humidity and consequently salts are deposited into pores, their technical state was insufficient.

The presence of salts has also been observed at the surface of the sampling points as efflorescence’s. Increased salt concentrations are related to the location of sampling and also in close vicinity of the driveway with parking and their maintenance in the winter months. According to the results in Table 2, it is evident that chloride salts are accumulated at a height of 0.5 m from the basement, with a high degree of salinity according to criteria of WTA directive \[6\].

Increased concentrations of chlorides which have been determined, indicate degradation processes. At the same time, decreased pH values of silicate samples were observed, indicating the carbonation process \[5\]. In addition to above mentioned method was made FTIR spectral analysis of sample by ATR FTIR spectrometer Alpha Brucker, in range 4000-360 cm\(^{-1}\), with 24 scans. The results of 2 samples taken from the south part - surface and inner part from crack, are shown in Fig. 5.
Table 2. Results of analytical determination of mass humidity and salinity.

| Orientation of sampling | Type / high of sampling | w_{mh} ±0.01% | pH ± 0.01 [-] | c(Cl)± 0.01% | degree of salinity [6] |
|-------------------------|-------------------------|----------------|-------------|-------------|------------------------|
| north                   | plaster 0.5m            | 5.64           | 8.21        | 0.03        | low                    |
|                         | mortar 0.5m             | 8.65           | 8.45        | 0.27        | high                   |
|                         | brick 0.5m              | 10.64          | 8.65        | 0.56        | very high              |
| east                    | concrete 0.5m           | 8.32           | 8.90        | 1.30        | very high              |
|                         | concrete 1.0m           | 8.67           | 9.10        | 1.70        | very high              |
|                         | concrete 1.5m           | 8.25           | 9.35        | 1.40        | very high              |
| south                   | concrete 0.5m           | 16.20          | 8.85        | 1.72        | very high              |
|                         | concrete 1.0m           | 14.30          | 9.15        | 1.50        | very high              |
|                         | concrete 1.5m           | 10.15          | 9.14        | 1.67        | very high              |

Figure 1. General view of the southern part of the enclosure (concrete support wall).

Figure 2. General view of the northern part of the enclosure (brick masonry with sheet metal overlap).
Figure 3 also shows a significant failure of the crack, which was located along the entire height of the southern part of the roof (its location is also highlighted in Fig. 1). After measuring its depth, it was found to be up to 300mm. The presence of ants as a further source of biodegradation of silicates was found in the interior of the crack during its measurements. A representative sample of the damaged concrete was also selected from this site and subjected to spectral FTIR analysis, spectra recording are at Fig. 5. A significant occurrence of algae from the surface parts is documented in Figure 4. As we can see, there were also cracks and leaching of the coating layers due to biocorrosion. Method FTIR is a powerful aid in identifying corrosive changes in building materials. In Fig. 5 are characteristic FTIR transmittance spectra of 2 concrete samples obtained from surface and inner part of crack (approximately from 200mm of depth). In both spectra a weak broad band of approximately 1100 cm$^{-1}$ is an indication of silicate (-Si-O) vibrations, which are overlapped the peak of the anion -SO$_4^{2-}$. The characteristic peak of calcite (1410 cm$^{-1}$) is in inner part stronger as in surface parts. The characteristic peaks about 1650cm$^{-1}$, 1064cm$^{-1}$ respectively at 620cm$^{-1}$ which are an indication of sulphates [2], [3] guiding us to conclude that the samples contain products of biocorrosion processes.

Vibration of $\text{-OH}$ groups (1610-1628cm$^{-1}$) was also partially reflected in both spectra. Surface part has at 3570 cm$^{-1}$ resp. 3398 cm$^{-1}$ stronger OH stretch vibrations, of which we expect to be of the metabolites of present algae. Conversely, at 2920cm$^{-1}$ and 2850 cm$^{-1}$ vibration of CH groups are more pronounced in the interior of the concrete, which could be corresponded to organic acids as a manifestation of biodegradation in the interior of the concrete structure.

Figure 3. Determination of wide cracks of damaged concrete parts.  
Figure 4. Detail of biocorrosion of masonry due to algae.
4. Conclusion
Determinations of humidity, corrosion and salinity of silicate materials is from durability and reliability aspects very important, taking into account the need for proper selection of sanitation materials.

The obtained results logically complement and confirm fact, that all parts of the structure under consideration are damaged by bio-corrosion and require reconstruction. Protection against atmospheric conditions would be appropriate, including repair of downpipes of rainwater, revision or addition of waterproofing and surface treatment, etc. A specific assessment of the samples has unfortunately confirmed the expected state of urgency for repairs.

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