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INVESTIGATION OF TECHNICAL CONDITION OF EXTERNAL THERMAL INSULATION COMPOSITE SYSTEM WITH MICROBIAL ATTACK

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Abstract

The paper is focused on analysis, demonstrating and improving methods for evaluation the condition of the insulation construction colonized by micro-organisms. The results of the laboratory investigations and measurements in situ are examined in relation to the optimization of the choice of technological measures for the elimination of colonization. In addition to taxonomical classification of identified micro-organisms, the guide was created for visual determination of quantity of micro-organisms on External thermal insulation composite system (ETICS) and evaluation of technical condition of ETICS with bio-corrosion as a non-destructive tool. Destructive tests are applied when non-destructive methods are not sufficient. Permanent treatment of elimination of "green façades" is not currently known. The main research methods are indirect methods, or even prevention. Bio-corrosion needs to be treated immediately. Immediate operative intervention and efficient technologies for elimination of micro-organisms are required while long-term secondary prevention against colonization of ETICS is used. Intervention technologies that are used: conservative (technology with minimal intervention to the original layers of ETICS) and radical (technology with mechanical modifications of original layers of ETICS). Case study of investigation of bio-corrosion of façade with ETICS has shown a combination of destructive and non-destructive methods as an efficient tool for optimum choice of recovery of the façade. The main benefit of presented diagnostics is detailed bio-corrosion identification and quantification of micro-organisms on the façade. Diagnostics allows us to determine the seriousness and possible consequences of the failure with sufficient precision.

Key words

bio-corrosion, diagnostics, external thermal insulation, façade, micro-organisms

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1 INTRODUCTION

It is known that life processes of microbiological organisms change the characteristics of the substrate, in particular the stability, permeability, colour, hygroscopicity, hydrophobicity or density. Micro-organisms form a crust and slime on the surface of the building material and by the action of chemical compounds produced by the process of photosynthesis and chemosynthesis can penetrate into the substrate. The main requirements include performance, safety, durability and adequate service life, efficiency (operating costs) and architectural design. Evaluation of the data collected gives the condition for the real technical assessment of external insulation construction and helps to decide on the protection, maintenance, repair, decontamination, and not least on prevention. There are various works and studies on the impact of micro-organisms and their chemical and photosynthetic processes on a surface [1-4] and works on the decontamination technology of constructions [5, 6]. According to [1-4] the bio-corrosion and bio-erosion of construction materials are primarily caused by water, changes in temperature and the chemical solutions produced by micro-organisms during chemosynthesis and photosynthesis. As a result of deep study a review on colonization and deterioration of building materials by organisms was made by [7, 8]. The importance of multidisciplinary approach is stressed by most of researchers. Researchers [5] consider the principles of the creation of algae but also analyse possible repairs and maintenance. They have presented their 20 years of experience dealing with ETICS damaged by micro-organisms. Damage and changes in the characteristics of various construction materials caused by micro-organisms have been shown through chemical analysis, scanning electron microscope devices (SEM), microbiological analysis and other specific diagnostic methods (as in [9], microscopic investigation of samples from block of flats in Bratislava is shown in Figure 9). Recent microbiological techniques were identified and compared in [8]. Deep study on rendered façades based on surface relative humidity and surface temperature [10] showed the impact of render thickness, colour and orientation of the wall on potential for mould growth. Study and examination the role of the drying process in the surface water content and biological growth was conducted by [11]. Research on quantification the activity of a moss as a function of temperature was done in [12]. Durability data of buildings and their parts can be gathered either through laboratorial testing (analytical methods) or through fieldwork (empirical methods). Empirical methods including visual assessment, interviews and questionnaires to end users and facility managers were used in [13]. Research on assessing the risks of biologically contaminated external walls and on creating maps of high-risk areas was introduced in [14]. Various authors have proposed a qualitative ranking based on various degradation levels defined by the condition found in situ [15-17]. Mathematical formula that could contemplate the mechanisms of degradation is being developed by [18]. The method is based on field work, which consists of the visual inspection of samples under normal exposure conditions. The data obtained in the field survey are processed and converted into numeric indicators to allow identification of the degradation patterns and estimation of a reference service life for ETICS. According to [19] it is need to elaborate a scale of bio receptivity index values for building materials.

2 METHOD OF INVESTIGATION OF ETICS WITH MICROBIAL DEGRADATION

Diagnosis of building construction is carried out by visual, basic, preliminary or detailed surveys, at which the procedure and extent is not mandatory, is not known, and it depends on the binding environment, requirements for building construction. The method of investigation the functionality of external insulation is explained at Figure 1. According to the type of intervention during investigation of ETICS (Fig. 1) following methods are used:

• non-destructive (indirect) - in which the strata is not broken or is minimally broken. This includes visual survey, a collection of biological material by means of smear, laboratory culturing of biological material, measuring the size of tears, moisture measurements, measurement of surface temperatures, temperature field imaging, testing the acidity of the environment, setting the area of bio-corrosion [2].

• destructive (direct) - these methods require structural failure due to sampling the entire strata of thermal insulation composite system. The most common way is to perform a probe to investigate the layers of strata, technology of construction, laboratory verification of physical properties of particularly plasters and also penetration of biological material in the strata [2]. The method is used when non-destructive method does not lead to the required determination of the extent of damage, followed by proposals for treatment. Microbiological samples from thermal insulation surface are due to environmental exposure covered by a number of inorganic and organic materials (pollen, dust, soot and even soil.). Their laboratory studies cannot be done without laboratory cultivation that results in isolation of pure culture of micro-organisms, usually micromycetes. This process is very specific, time consuming and technically challenging.

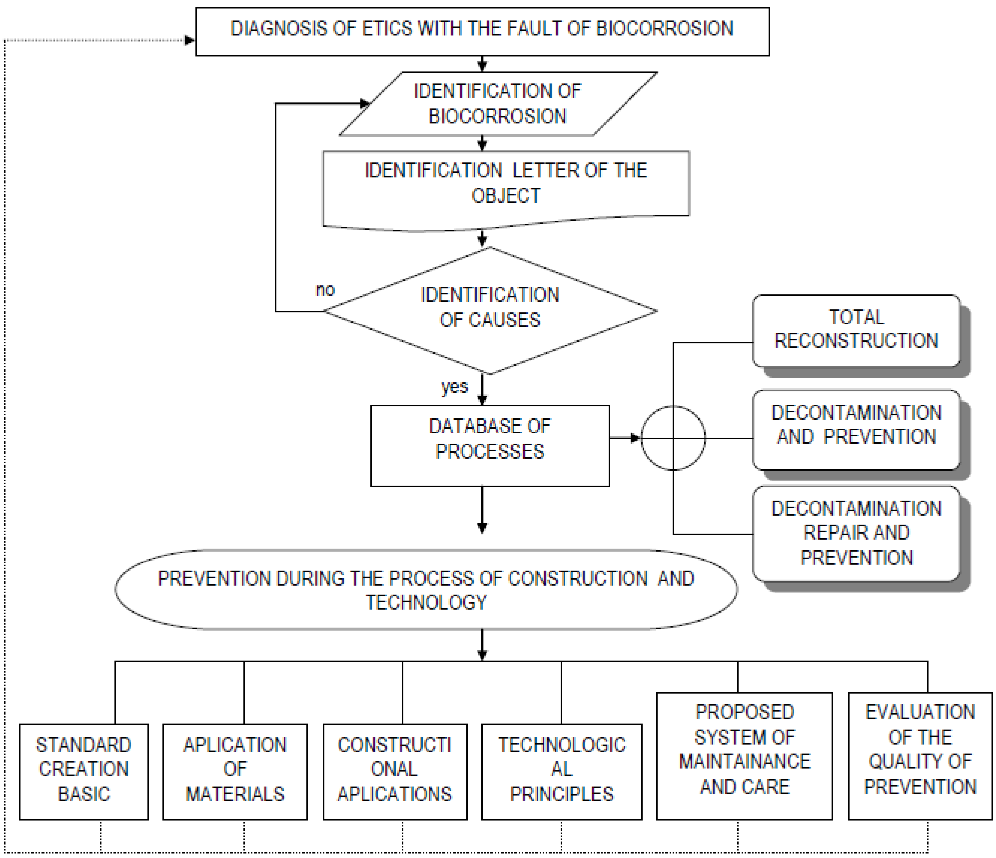

Fig. 1: Method of investigation of ETICS with microbial degradation and use of diagnosis [16].

3 INVESTIGATION OF TECHNICAL CONDITION OF ETICS

Research in the field of ETICS colonization by micro-organisms is also oriented to assess the significance of colonization. In addition to taxonomical classification of identified micro-organisms, the guide was created [14] for visual determination of quantity of micro-organisms on ETICS and to determine the significance of colonization. To evaluate the number of acceptable amount of micro-organisms they used the procedure for determination the quantity of micro-organisms on the façade based on laboratory observed samples of size 30x30 cm and a rating scale was specified in the range between 0 and 10. As a tipping point is considered the phase between 3 and 4 of rating scale when microorganisms on the surface are perceivable, while the age of insulation is in the range 3-6 years. Recommendation for the assessment of the status of ETICS bio-corrosion in Slovakia is based on the Commercial and Civil Code SR. Therefore it was introduced a three-step model (in range: aesthetic deficiency, usual defect and significant defect) [17] as it is seen in Table 1.

Tab. 1: Quantifying the seriousness of consequences [17] using the scale for evaluation of growth according to scale introduced in [16].

Index	Category	Evaluation of seriousness of the consequences according to ETICS surface covered with micro-organisms
1	minimal	**Aesthetic defect,** colonisation only on the surface of ETICS, mainly with single-cell micro-organisms, without the protection of slime and there are no breaks or defects in ETICS. **Colonisation in the interval of 0% to 25% (evaluation scale 0 - none, 2 – minor contamination, 3-moderate a 4 – medium contamination).**
2	significant	**Usual defect**, colonisation on the surface of ETICS. Micro-organisms have penetrated the layers of ETICS, without the protection of slime. Existence of higher organisms (e.g. moss) is not diagnosed and the required characteristics of ETICS in terms of protection of the interior of buildings are preserved. **Colonisation higher than 25% up to 62.5%, there are breaks or defects in ETICS (evaluation scale 5 – marked contamination, 6 – significant, 7 – very significant).**
3	hazardous	**Significant defect**, colonisation on the surface of ETICS. Micro-organisms have penetrated the layers of ETICS, microorganisms are protected by slime and existence of higher organisms (e.g. moss) is diagnosed. The required characteristics of ETICS in terms of protection of the interior of buildings are lower than the standard requires; the functionality and safety of ETICS is lowered. **Colonisation higher than 62.5% up to 87.5% or even constant layer, there are breaks and defects in ETICS (evaluation scale 8 – strong contamination, 9 – very strong, 10 – extremely strong).**

Sampling and subsequent mycological analysis of the external environment of a block of flats in Bratislava (Fig. 2), was conducted within the local examination (Fig. 5-6). When sampling, the relative air humidity was 67.9% and outside air temperature was 7.8 ° C. An air sample was obtained (airborne fungus with the possibility of deposition on the examined surfaces - the façade) and samples from the external surfaces of buildings [7].

Taking of samples was carried out with piece of tape at specific places:

- examined façade with different coloured finish with no visible fungal increase,
- examined façade with grey, black and green spots possible fungal to algae growths (fig 3, 4),
- holes by destructive probe from ETICS plasters (fig. 7),

- samples from control buildings opposite the examined façade with no visible colour change, green or black deposits (fig. 8), one plaster was of the same type on the insulation construction and another plaster based on lime.

Fig.2: North facade – local contamination show process of water run-off from sill or thermal bridges in window to sill joints. (Antošová)

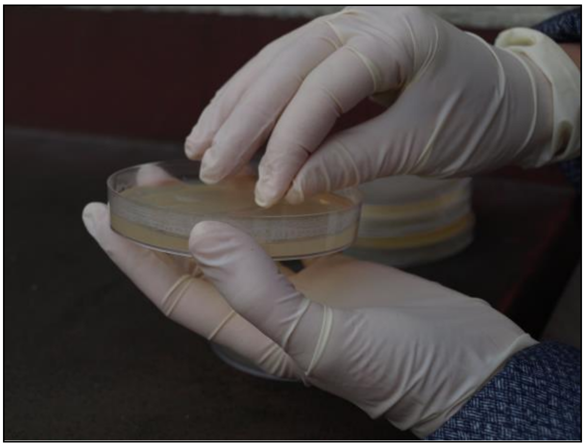

Fig.3, 4: Taking of samples with sampling tape (Fungitape) from the surface of contaminated plaster. (Antošová, Piecková)

Fig. 5, 6: Localization of sampling.

Fig. 7: Sampling by tape from the strata under the plaster. Fig. 8: Sampling of surrounding façades- without insulation- for comparison.

Isolation of pure cultures of micro-organisms on the surfaces of building materials is not easy. Given the fact that the laboratory provides the most provable analysis of bio deterioration (microbial corrosion) of building materials by eukaryotic micro-organisms (microscopic fungi - “fungi" and algae) includes just mycological tests [7]. Façade with insulation and the surrounding exterior have been studied by comprehensive qualitative and quantitative mycological examination (Fig. 8). The relevant microbial findings were then tested for their biodegradation potential on the components of the construction materials (Fig. 9).

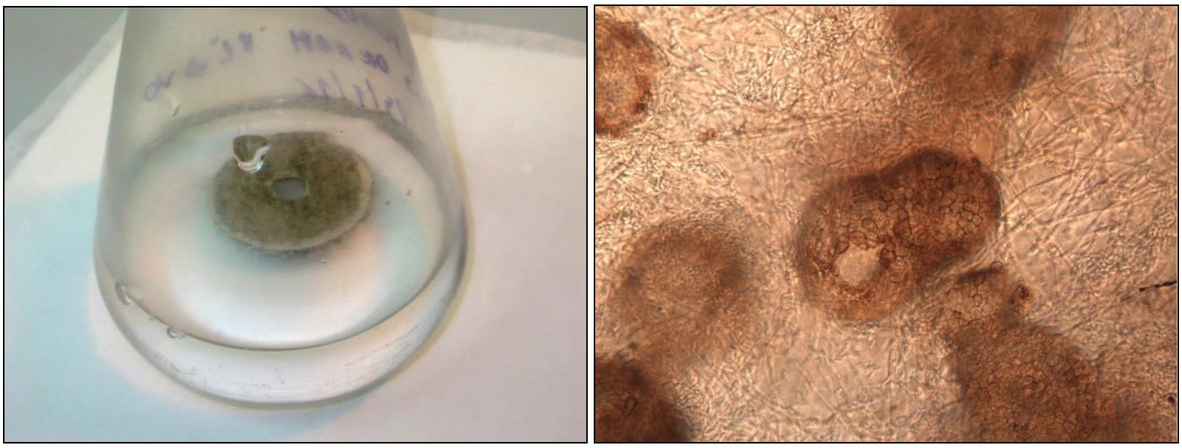

Fig. 9: Isolation of microorganisms from the sample. Microscopic examination (Phoma, magnified 400x) - detection of biological material on bottom surface of the sample (polystyrene) [7].

4 RESULTS

All isolated microscopic filamentous fungi belonged to the normal outer mycoflora in colder times of the year (the incidence is similar in all tested surfaces - "dirty, clean" and also in the air). There was found a predominance of melanised fungi that are in term of colonization of surfaces considered as secondary colonizers, requiring increased humidity of growth medium. Furthermore, Alternaria sp. and C.cladosporioides were present from dead plant material (fallen leaves, etc.). Penicillium sp. and Trichoderma sp. are typical ubiquitous airborne fungi. Mucorrhoea indicate the presence of an organic substrate (component plasters, paints, as well as an organic powder on its surface). They are able to decompose organic substrate through the rich enzymic feature. Identified tertiary colonizers (acremonium, phoma) are able to colonize environment with very high content of use humidity [5]. From the assessment of the biodegradation activity of tested representatives of fungal isolates was found that neither of them was capable to dissolve or mineralize the lime substrate (CaCO3). All present isobaths were decomposing the cellulose (sacharolytic activity) [7, 15].

5 DISCUSSION

Initial superficial evaluation of thermal insulation with bio-corrosion that was based on visual exploration, resulted in the assessment as aesthetic deficiency, without finding surface breaking cracks, peeling off and other deformation of the structure. Colonization of the investigated surface area exceeded the value of 25%, and local colour soiling has been detected. Protection of micro-organisms with slime was not observed. Destructive method has been performed to verify the penetration of micro-organisms into the strata. The results confirmed the doubts about the severity of the technical condition of ETICS.

According to the results of the investigation, it is possible to assess the identified condition in 3stage rating scale as normal, common defect. There are not recorded cracks and other defects on ETICS surface, colonization of an area is in the range of 25% and more, that is considered as level 5 Severity classification rating scale -as major pollution. Recorded consequences however, can be corrected or repaired by routine repair and subsequent maintenance.

The basic conceptual design of disposal of micro-organisms and their prevention is based on laboratory examination of types of micro-organisms and their degradation effects. Disposal technology is therefore considered as operational technology, with direct mechanical and chemical intervention to minimize further colonization of surfaces. In terms of affecting the original layers of ETICS the disposal technology may be:

- conservative (technology with minimal intervention to the original strata of ETICS)
- radical (technology with mechanical intervention to the original strata of ETICS).

Conservative technology means decontamination and repair or maintenance, as part of secondary prevention. Conservative technology enables disposal of symptoms, suppress the aesthetic drawbacks while eliminating further development of bio-corrosion. The principle of this technology is the removal and extermination of whole live microflora by combination of mechanical and chemical action, which is in other words a targeted way of cleaning. In terms of use of the active chemical substance we consider this type of technology as a barrier protection of ETICS surface against colonization by micro-organisms. The technology requires periodicity over the life cycle of ETICS. However, if the result of such attack of micro-organisms is failure of adhesion of strata, reduction of mechanical or physical properties of ETICS, decrease of plaster hydrophobicity, or lack of thermal properties of ETICS or proving penetration of micro-organisms into the layers of insulation- then it is appropriate to consider radical technologies such as reconstruction - replacement and completion of insulation layers (finishing or insulation with new plaster) or total replacement of insulation. By combining several techniques, it is possible to achieve the desired effect in all of stages of bio-corrosion severity.

The growth of vegetation and algae is at a specified time being restored while the plaster surface is covered with new vegetation. It is therefore very important to use decontamination technologies with combination of preventive measures that are aimed at preserving their longer lifetime. Regular cleaning, sealing of joints and cracks, and regular monitoring of the ETICS condition are the most important measures for biodegradation prevention.

6 CONCLUSION

ETICS construction requires the application of the disposal of micro-organisms, the application of normal periodical maintenance and other preventive measures (conservative method of technological measures, where necessary, additional method - sealing joints and cracks). Regular monitoring in at least 3 year cycles is also recommended. A permanent solution for disposal of green coatings on thermal insulation of façades is not currently known. Technology of all over volumetric protection rouse risks of insufficient proof of service life, increased cost of insulation. To resolve current problems there are efficient technologies that are operational, with direct mechanical and chemical intervention to achieve the elimination of micro-organisms on ETICS and to minimize further colonization of surfaces. Technology with volume protection is effective in local use in treating cracks and defects of ETICS. Selection of basic technology (conservative or radical, barrier or volume) depends, among other conditions, on the location of buildings, requirements on environmental protection, age of ETICS and on the return on investment in insulation and in particular is related to the assessment of the state of ETICS.

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