

The Problem of Biological Destruction of Façades of Insulated Buildings - Causes and Effects

Elżbieta Stanaszek-Tomal¹

¹ Chair of Building Materials Technology and Structure Protection, Faculty of Civil Engineering, PK Cracow University of Technology, 24 Warszawska Street, 31-155 Cracow, Poland

estanaszek-tomal@pk.edu.pl

Abstract. The Regulation of the Minister of Infrastructure concerning the technical conditions of buildings and their location required new designed buildings to have reduced amount of heat that is transmitted through the barrier. This involves the use of thermal insulation, of adequate thickness to meet the relevant requirements. As the environment conditions are favourable, the façades may deteriorate. Major aggressors include algae fungi or lichens, i.e. the formation of symbiotic growth of algae and fungi. Their construction, metabolic processes are the basis of knowledge about action to prevent corrosion.

1. Introduction

Regulation of the Minister of Infrastructure on technical conditions of buildings and their location [1] necessitated that the newly designed buildings should have a reduced value of the thermal transmittance coefficient. Additionally, this coefficient is to be tightened gradually in the subsequent years. This implies the application of thermal insulation, which encapsulates the building envelope, with appropriate thickness to fulfil the relevant requirements. This has some positive implications in the form of reduced heat loss on account of the transfer through the building elements as well as reduced costs incurred on heating the building. However, more investigation into the hydrothermal issues is needed in order to enable elimination of the phenomenon of condensation, i.e. the places inside a barrier or on its surface where water vapour condenses. It is also necessary to provide an efficient ventilation in order to remove moisture from the building. This exposure risk concerns the interior of the building and must be absolutely prevented due to its adverse effect on human health. However, the phenomenon of moisture formation on surfaces, which is followed by invasion of microorganisms at the same places is not only limited to the interior. More and more frequently, coloured deposits are observed on façades. Research indicates [2] that approx. 85% of buildings with façades affected by biological corrosion are thermally insulated buildings. This problem, due to the compromised aesthetics and high refurbishing costs, is being treated with increasing seriousness nowadays. This is manifested in the marketing of agents and finishing products with biocidal additives.

2. Microorganisms causing biological corrosion

The occurrence of biological corrosion is dependent on the physicochemical properties of façade materials and the environmental impact, i.e. appropriate conditions for the growth of microorganisms in terms of moisture, heat and nutrients. The most dangerous of these is obviously excessive.



Particularly in our climate, façades are constantly exposed to the action of precipitation water. This is especially true of the west-facing façades as winds blow predominantly from that direction and the north-facing façades that are the least dried by the sun [3].

The occurrence of microorganisms on building materials has an adverse effect leading to progressive deterioration and decomposition. With regard to the character of biodeterioration and the properties of the materials, the following forms can be distinguished:

- mechanical – when the material gets damaged as a result of direct action of organisms, e.g. bumps in the road caused by tree roots;
- chemical assimilative biodeterioration – when the material is degraded due to the content of nutritious substances; it mainly affects organic products, e.g. fibres or wood;
- chemical dissimilative biodeterioration – occurs when metabolites from organisms damage the structure of the material leading to corrosion, e.g. crushing of stones overgrown with organisms;
- colonisation of material surfaces by organisms, the so-called ‘biofouling’ – occurs when the presence of organisms or their secretions become unwanted for the material. A common example is the fouling of ships’ hulls, right at the waterline, by organisms forming verdant overgrowth.

On the other hand, an example of deliberate action are deciduous plants climbing over façades and considered as a decorative element [4]. One of the phenomena related to biofouling is biofilm, a ‘network’ of organisms, which facilitates the functioning on materials.

The problem of deterioration of façades should be approached by first becoming acquainted with the organisms causing it. The chief aggressors are: algae (causing verdant overgrowth), moulds (grey-black mould spots) or lichens produced by the symbiotic growth of algae and fungi (green-black spots). Their structure, mode of reproduction, metabolic processes as well as the effect of metabolic waste products on building materials all constitute the knowledge base for actions aimed at preventing corrosion [5]. For the most part, façades are colonised by bacteria and aerophytic algae [6]. They initiate the process of biodeterioration due to their low requirements. At a later time, as a consequence of the biofilm microclimate that they form in the developed stage, they can provide favourable conditions for the development of other organisms. An example are lichens, i.e. fungi living in symbiosis with algae and readily colonising damper places. According to various expert reports [7], the most common algae belong to the three taxa of *Chlorophyceae* algae. The absolutely predominant algae species on residential building façades is the *Apatococcus vulgaris*. It belongs to a commonly occurring taxon. At the height of approximately 0.5 m, there developed green filamentous alga: *Chlorohormidium flaccidum* and *flaccidum*, and also, at distinct water stains, the typically aquatic species *Ulothrix oscillarina*, quite resistant to drying. They are typically found near gutter systems, downpipes and wall recesses, i.e. the dampest places. A seldom occurrence on façades is blue-green algae, which is often a component of aerophytic communities. The biomass of algae, blue-green algae and fungi facilitates the growth of mosses and lichens that can aggravate deterioration of the surface as a result of intervention of thalli in the structure of the material. As a result of metabolic transformations, lichens produce biogenic organic acids and other chelating agents, causing occurrence of cavities, cracks and corrosion pits on the surface. The most susceptible to their degrading action are carbonate minerals and iron-magnesium silicates, and the least feldspars [8].

3. Physical and technical factors that favour formation of biological corrosion

Environmental conditions have a decisive impact on colonisation of materials and development of microorganisms. Not all of them can be eliminated but if their causes and possible occurrences are known they can be efficiently prevented already at the stage designing. The most significant physical factors include:

- macroclimatic factors – precipitation and temperature; the amount of precipitation that favour development of microorganisms is more than 800 mm/year, and the average air temperature 6-8 °C. At higher rates of precipitation and higher temperatures, increased algae colonisation is not observed, which indicates greater impact of temperature than humidity;

- weather changes – the microclimate has been changing over the last years. The average annual temperature has increased by approx. 1 °C over 10 years, and winters are becoming warmer and damp. Higher temperature and absence of freezing winters favour development of organisms;
- air parameters – especially in urban agglomerations, CO₂ content in the air is increasing somewhat, which facilitates acquisition of carbon, which autotrophic plants need as a nutrient. Research proves that the rate of colonisation by microorganisms is also affected by the low quality of air [9];
- microclimate – neighbourhood of greeneries and water reservoirs creates favourable conditions for the development of algae through increased numbers of spores and higher humidity;
- location – walls exposed to the sun, i.e. south- and east-facing, are less frequently affected by biological corrosion due to the faster rate of drying than in the case of the north- and west-facing walls. The density of development and the height of the buildings also essentially determine the area exposed to sunlight and thus the humidity of barriers.

The technical factors include [10]:

- elements of the building – façade finishing or decorative elements, such as: cornices, corners, areas around plinths, under windowsills, at casings, over canopies, at balconies; also places where thermal bridges are created; any places where water can stay and accumulate – all of these places are subject to the threat of development of organisms.
- lack of efficient damp-proof insulation on basement walls and plinths;
- inadequate quality of finishing works, possibly due to inappropriate weather conditions during the works;
- the rate of permeability and water absorption of the façade coating;
- operation – water vapour escaping from the flats through tilted windows condenses on the cool surfaces of the façade just above the window openings. This phenomenon is particularly visible in the lower, insufficiently ventilated parts of the building;
- thermal bridges – the places where the dew point shift occurs towards the interior of the building. The external parts of the façade in these places have a higher temperature, which speeds up metabolic processes of the microorganisms. Such places are visible in the corners and on slab connections.
- the rate of permeability and water absorption of the façade coating;
- irregular manner of floating the plaster coating; surface texture – rough surface and incorrectly fitted flashings [11]

The observed increased activity of microorganisms within an urban agglomeration should be associated with industrial zones, thick development and climatic consequences. In order to be able to meaningfully consider all the processes taking place within the area of a city, particularly in the physical aspect, it is necessary to learn the specifics of the climate, which being influenced by human activity, differs significantly from rural or forest areas.

One of the resultant phenomena can be the phenomenon of urban heat island (UHI) [12] – sunlight falling and reflecting on the surfaces of buildings and streets causes that the air temperature gets higher than in the surrounding suburban areas. In large urban agglomerations with concentrations of buildings, this difference can be as large as 10 °C.

The isotherm shown in figure 1 depicts the characteristic increases in the area of the city, called the effect of urban heat island. They are unevenly distributed in the vertical cross-section of the city zone, reaching a maximum at the concentrations of buildings, streets and pavements, and lower values in the suburban or wooded areas and in the regions of water reservoirs. This may have specific implications:

- the proportion of long-wave thermal radiation, coming from different directions of the internal surface of the structures, increases as a result of emission and reflection into the street area with a reduction of losses into the atmosphere at the same time;
- the correlation of indicators of buildings being in proximity: the height, length and distance between them, contributes to the reduction of the speed of wind in the built-up area (reduced ventilation of the spaces) as well as on an overall increase of temperature;
- a high proportion of heat, accumulated in the façade materials, as well as large surfaces radiating reflected (long-wave) heat and materials used for the construction of the streets increase the temperature;
- reduction of the action of the wind (reduction of the speed) contributes to the reduced ventilation of the polluted streets;
- heat emitted to the atmosphere, generated in connection with burning, energy production, transport, etc. [12].

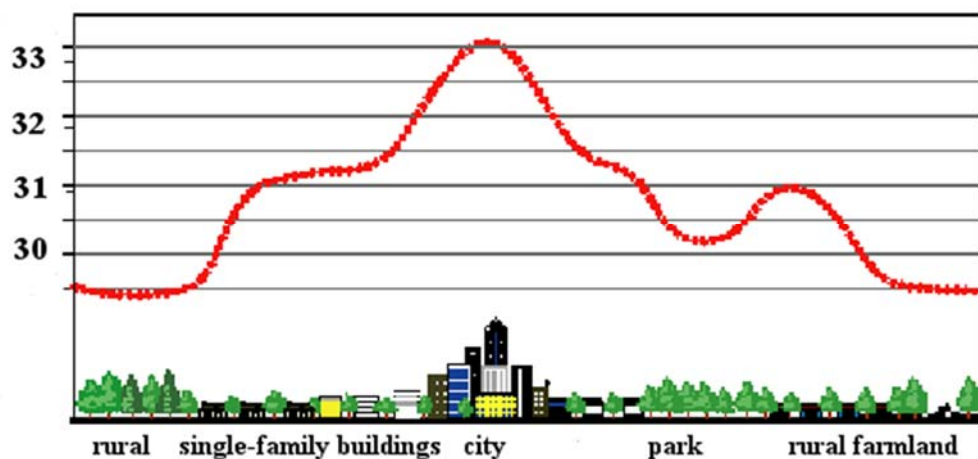


Figure 1. A representative vertical cross-section of air temperatures in a large city [13].

The correlation between the air quality and the intensity of façade soiling is also an essential factor that speeds up biological corrosion within cities. The correlation between volatile compounds that pollute the air and the rate of their deposition on selected coatings, and the subsequent colonisation by microorganisms has been presented in [9]. This correlation is essential because the dust compounds gathering in recesses within a façade are undoubtedly a breeding ground for microorganisms.

4. Designing envelope elements (construction barriers)

A reason for installing thermal insulation to existing buildings, apart from the environmental aspects, is a reduction of costs incurred on heating the building with maintained thermal comfort resulting from having warm rooms. At present, the degree of thermal insulation of walls is regulated by the Regulation of the Minister of Infrastructure of 5th July 2013 [1], which specifies the thermal transmittance coefficient for inter alia external walls. Over the years, it has been decreased, which implies that the external wall should be increasingly well insulated. As of this moment, it is 0.25 W/m²·K for heated rooms in residential buildings, and its value will continue to be reduced until 2021 down to 0.20 W/m²·K.

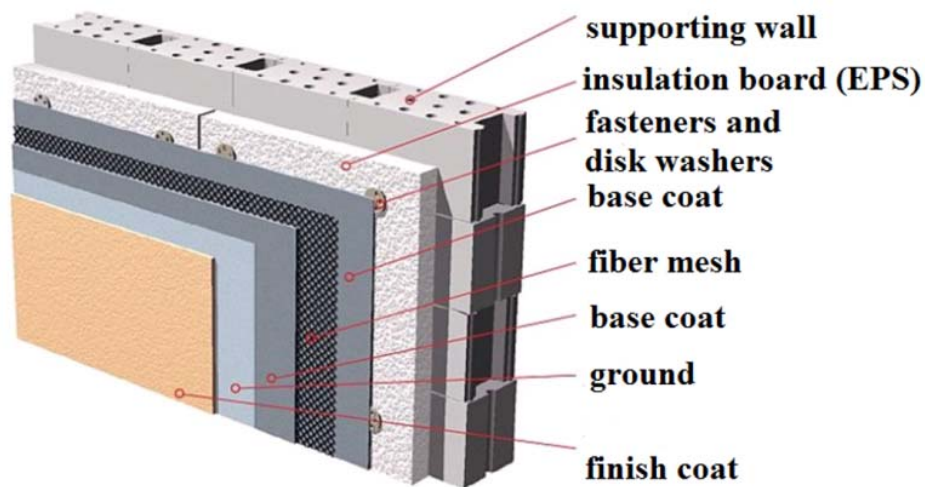


Figure 2. Layers of a barrier thermally insulated with a “light-wet” method [14]

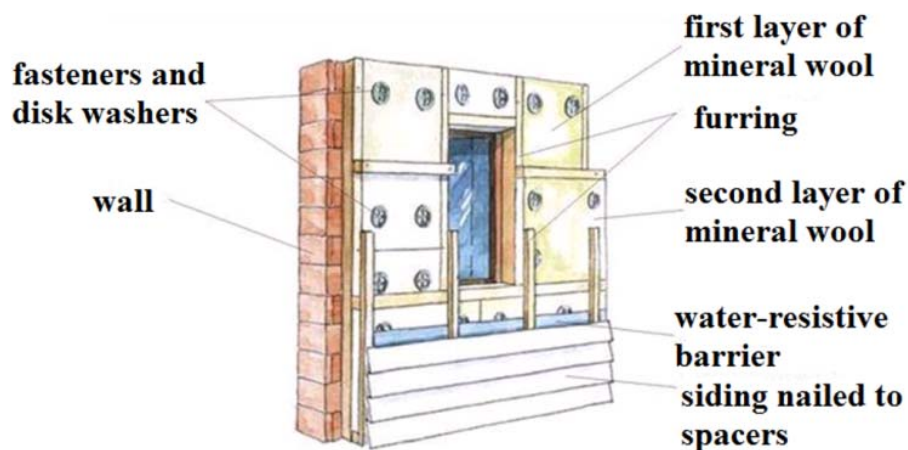


Figure 3. Layers of a barrier thermally insulated with a “light-dry” method [15]

The most popular methods of thermal insulation of external walls are the lightweight wet method (ETICS – External Thermal Insulation Composite Systems) and the lightweight dry method.

In the lightweight dry method (figure 2), the thermal insulation is fixed using a specially prepared steel, occasionally wooden grid fixed to the walls with wall plugs. This insulation system typically involves application of mineral wool. Such prepared insulation is covered with ready-made coating materials: a perforated membrane that is permeable for water vapour and an external façade cladding layer, which can be made up of metal sheets or plastic siding panels mounted on the grid. The materials are mounted without gluing or plastering, hence the name of the method. This way of solving the problem of insulation ensures that the wall barrier is well-ventilated and does not contain any technological moisture. The expected durability is 50 years.

The lightweight wet (figure 3) method is currently more preferred due to the low cost of using polystyrene, short fixing time and the high durability of the insulation (approximately 30 years). It consists in fixing polystyrene or mineral fibre panels to the external walls using glue and plugs and applying a layer of plaster. It is also referred to as Jointless Façade Thermal Insulation System.

Insulation made with this method consists of several layers: adhesive mortar, thermal insulation, reinforcing mesh of glass fabric, fasteners for mechanical fixing, plaster mass and finishing elements. It is advisable to use whole insulation systems, i.e. sets of materials, from one manufacturer. A prerequisite for ensuring adequate quality of thermal insulation is using materials with precisely specified technical parameters and adhering to the requirements defined in the installation method. There is a general principle concerning the design layered walls, which specifies each particular layer from the inside to the outside with decreasing thermal conductivity and diffusion resistance (and at the same time increasing vapour permeability). Therefore, it is not advisable to cover thermal insulation in the form of mineral wool of high vapour permeability with acrylic plaster, which would hinder moisture drying causing interlayer condensation [16,17].

Nowadays, providing buildings with thermal insulation is necessary in order to meet the conditions concerning the required insulating capacity of walls. Figure 4 shows temperature variation on the surface of a façade between the insulated and non-insulated areas. This involves reduction of heat transfer through walls. Especially during the autumn-spring period, the flow of heat from the interior of the building, i.e. of heated air, to the outside is inhibited. It can be thus expected that as a consequence, the external surface of the wall barrier will not be dried by the heat from the inside.

As temperatures on the façade are lower (on average by 0.5-2 °C), the drying of moisture occurring e.g. as a result of rainfalls is impeded [1]. On warm days, during the day the temperature on the wall surface is high because the heat is not transferred to the inside of the building. In the presence of moisture and at a favourable temperature, conditions promoting growth of microorganisms develop. In the night time, temperatures on façades are low because the heat accumulated in the solid part of the wall is not (or is to a small degree) transferred to the outside. Therefore, dew point can be attained when the temperature falls below the limit value below which water vapour condenses.

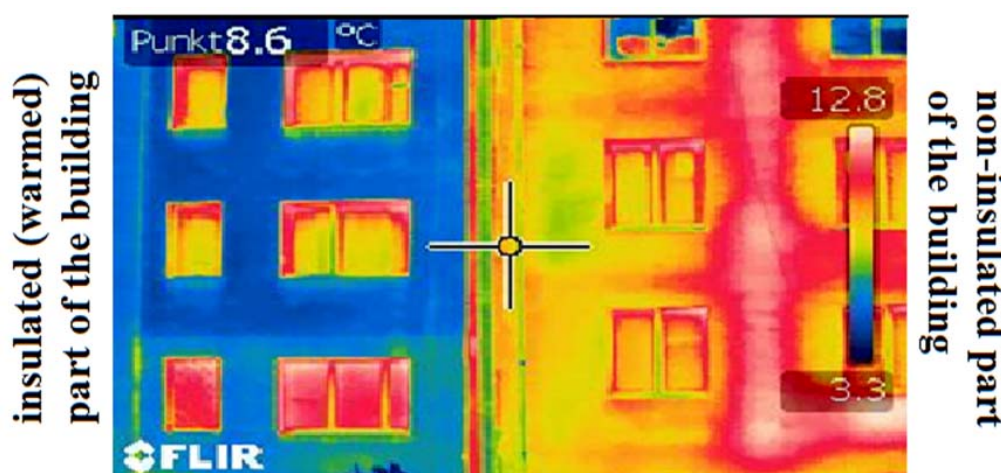


Figure 4. A thermal image showing temperature variation on the surface of a façade between the insulated and non-insulated areas [18].

Another factor that induces biological corrosion, which in itself is a result of bad design, are thermal bridges, i.e. spots of local thinning of the thermal insulation or spots where material of a higher thermal conductivity was applied. In such areas, an increase in the heat flux density and a local increase in temperature on the façade wall occur.

There is a method of forecasting the risk of colonisation of the surface by biological factors, which is related to correlation between the coefficient of water absorption of the wall surface (w) and the diffusion resistance (S_d). Both of these values should be low and should not exceed:

- $w < 0.5 \text{ kg} / (\text{m}^2 \cdot \text{h}^{1/2})$ and $S_d < 2.0 \text{ m}$,
- and also $(w) \cdot (S_d) < 0.2 \text{ kg} / (\text{m}^2 \cdot \text{h}^{1/2})$ [12].

For this reason, it is difficult to make a clear decision concerning the sort of insulation – application of foamed polystyrene causes high diffusion resistance in the near surface zone ($S_d > 2.0 \text{ m}$), which hinders migration of moisture. When mineral wool is used along with thinner layers of plaster, the insulation may become damp due to precipitation, which implies the risk of interlayer condensation. A guarantee of a well-designed barrier are hydrothermal calculations that will allow avoidance of moisture condensation inside the wall.

5. Façade plaster

The choice of façade plaster is one of the final stages of finishing a building. Apart from aesthetic qualities it should fulfil the technical requirements that ensure durability. Its composition, structure and properties are of crucial importance for the protection of the building against the harmful effects of the environment. There is no universal plaster. The choice of a plaster whose composition and properties will ensure the required durability should be preceded by an analysis of the surroundings of the building and the assumed risks related thereto.

Nowadays, so-called decorative thin-layer plasters (with a thickness of 2-3 mm) are used for insulated building walls. According to the sort of binder, they can be divided into:

- mineral, which include: mineral plasters based on cement-lime binders, silicate plasters – based on potassium water glass as a binder; silicate-silicone plasters, which are a variety of silicate plasters modified with silicone resins;
- polymer, which include: acrylic plasters based on dispersion, mainly of acrylic resin; silicone plasters based on various silicone (organosilicon) resins along with a range of various modifications; and mixtures of polymer plasters, e.g. acrylic and silicone plasters.

Table 1. Properties of decorative plasters [19].

Property	type of plaster			
	acrylic	cement	silicate	silicone
flexibility	***	*	**	**
diffusivity	*	***	***	**
water repellence	***	*	**	***
early strength	***	*	*	**
ultimate (long-term) strength	*	**	***	**
resistance to the substrate	***	*	*	**
resistance to biological corrosion	*	**	***	**
UV resistance	*	**	**	*
fire resistance	*	***	**	**

^a * - low; ** - average; *** - high

The binders used in plasters have an impact on a lot of physicochemical features, which is the reason why plasters have different properties (presented in Table 1).

In the case of mineral plasters, the binding takes place through a chemical reaction of the binder with the mixing water (hydration) and then with CO_2 from the atmosphere (carbonisation), which causes hardening of the mixture. In the group of silicate plasters, additionally, there take place long-lasting reactions of the binder with the fillers, pigments and mineral constituents of the substrate contained in the plaster (so-called silicification). The binding with dispersion in plasters takes place in

a mechanical manner, is relatively quick and consists actually in physical gluing, as a result of adhesion of the plaster layer with the substrate.

Plasters with cement-lime binders, due to their high porosity and sorptivity, require application of an additional coat of façade paint. Plaster coatings that have not been painted will fail to ensure long-lasting protection; the aesthetic values will deteriorate and the value of the building will be reduced. It is recommended that the plaster be coated with a silicate paint, which will fill the pores and thus prevent soiling and water penetration while the process of silicification will additionally reinforce the structure over the years. Application of cement-lime plasters is advantageous with regard to the price as well as the high resistance to biological corrosion (they are highly alkaline). An alternative for a silicate paint may be a silicone paint, which due to its water repellency will ensure resistance to dampening and dirt. Painting plasters with appropriate paints results in elimination of their weak points and makes this one of the most secure solutions [20].

Silicate plasters are characterised by: high diffusivity – this makes it possible to use them in the thermal insulation system (also with mineral wool), low susceptibility to dirt, high alkalinity and strength increasing with age. Standard plasters also have disadvantages, which include high sorptivity and sensitivity to weather conditions, also during application. The substrate for this plaster must be even and smooth, and the ambient temperature in the course of application should be between +8 °C and +25 °C. Furthermore, the wind must not be too strong, air humidity too high, and the plaster must not be exposed to direct sunlight. Fresh plaster should also be protected by a mesh. The restrictive application conditions cause difficulties that include trouble in finding a competent contractor, high costs and longer lead times which are also affected by weather conditions.

Silicate-silicone plasters have properties typical for silicate plasters, and the addition of silicone resin improves the binding properties and restricts their sorptivity. It also reduces sensitivity to the substrate, external conditions and improves initial strength.

Acrylic plasters are most popular among investors who are interested in a high pace of work, rich choice of colours and increased resistance to deformations and scratches. They are characterised by high flexibility and water repellency. They can be applied at temperatures above +5 °C, and the application is quick and easy. However, they have some disadvantages which restrict their scope of application. These include: low diffusivity – they cannot be used if mineral wool is used as thermal insulation; location of the building – in places with high ambient humidity; the manner of utilisation of the rooms – excessive water vapour accumulated in a wall barrier of the building may cause loosening of the plaster. The plaster is characterised by a higher susceptibility to biological corrosion. Nowadays, agents improving resistance of acrylic plasters to biological growth are applied; these agents – biocides – are already added at the stage of manufacturing; as an alternative, the plaster can be painted with a paint with this additive [21].

An improved variant of acrylic plaster is acrylic-silicone plaster. The addition of organosilicon compounds produces an increase in vapour permeability of the plaster. At the same time, it retains the advantages of acrylic plaster: water repellence, flexibility and a wide range of colours [22]. External plaster operates in a wide range of temperatures – in the summer season it is heated by the sun to temperatures above 50 °C and in the winter season it reaches as low as -20 °C. It must therefore combine in itself a number of features providing protection of the thermal insulation and the structure. Price as well as ease and time of application are the main factors that determine that choice of plaster [23]. In recent years, assessment of the resistance to microorganisms has started to be an equally important criterion. However, the choice of material is not easy. It is not at all facilitated by the standard – it is not found in any conditions to be met concerning biological protection. Requirements regarding plasters are contained in PN-EN 15824 *Specifications for external renders and internal*

plasters based on organic binders [24] and specify: adhesion, water absorption, water vapour permeability, thermal conductivity, reaction to fire and durability, which is determined by frost resistance testing. Requirements concerning microbiological protection are neither specified in ETAG 004. Assessment of biological resistance is made with application of PN-EN 15458 *Paints and varnishes. Laboratory method for testing the efficacy of film preservatives in a coating against algae* [25]. However, this is not a solution that reflects the actual conditions as it neglects the processes of aging that renders and plasters are exposed to, and which processes significantly reduce their resistance. Thus, the durability of the protection of plasters against algae cannot be assessed based on the current standard-based requirements. According to [11, 23, 26], a currently reliable assessment of durability can be based on application of the procedures provided for in PN-EN 15458 but they must be preceded by processes of leaching of the coats. Based on recommendations, manufacturers can declare an assessment of resistance to algae but due to the unclear regulations concerning the testing, it is not exactly known what is involved in the company process of assessing biological protection. For this reason, it is worthwhile to request such information from the manufacturer but not every entrepreneur is aware of that.

The choice of foamed polystyrene as the thermal insulation and then coating it with acrylic plaster, which is easy to use and the cheapest of the available plasters, is the most common way of providing thermal insulation. Just this configuration is found on most buildings, mainly in towns and cities. But after several years, some coloured growths appear on the façades announcing biological corrosion. It is not always so that the choice of foamed polystyrene and acrylic plaster involves colonisation by microorganisms at a later time; a lot depends on the environment and the climatic conditions. Therefore, the choice of thermal insulation and plaster mortar should always be well-thought-out. In general – at an early stage, the appearance of green growths is not an irreversible process but costly to eliminate. Biological corrosion can be prevented or significantly delayed at the stage of designing and by ensuring high quality of the finishing work [27].

At present, the most commonly applied thin-layer plasters have ‘stone’ or ‘rustic’ textures, which increases their flexibility and enables protection against cracking under high temperatures. These textures also facilitate capturing and retaining rainwater in the hollows, as well as dirt and traffic dust being a nutrient for organisms. The pH of plasters is higher than 10.5 (highly alkaline), which effectively prevents the growth of microorganisms (for which favourable pH value is in a range of 7-8.5). Fresh façades have a natural protection in the initial years of operation (approx. 2-3 years depending on the environment) due to their pH value. However, over the years, this effect vanishes. Durability of plasters is assessed to be 5 years. After the lapse of this time, some renovation measures may prove necessary such as cleaning and repainting [28].

Dark colours of plasters promote absorption of large quantities of heat and this leads to high temperatures on the surface; light colours have a reverse effect. The plaster coat should also be resistant to UV radiation and thus to ageing. Essential features include mechanical strength because while operating outdoors plaster may be exposed to impacts. The last risk that affects the durability of plaster is inadequate quality of the construction workmanship and carrying out work under adverse weather conditions [29].

6. The mechanism of biological corrosion on façades

Microorganisms colonising façades are primarily algae; later on, there may appear lichens, bacteria, fungi or mosses. For their development they need inter alia: moisture, access to the elements that they feed on e.g. carbon, nitrogen, phosphorus, moderate temperature and neutral or close-to-neutral pH.

According to available studies [2], the incidence of biological corrosion on façades is as shown in figure 5.

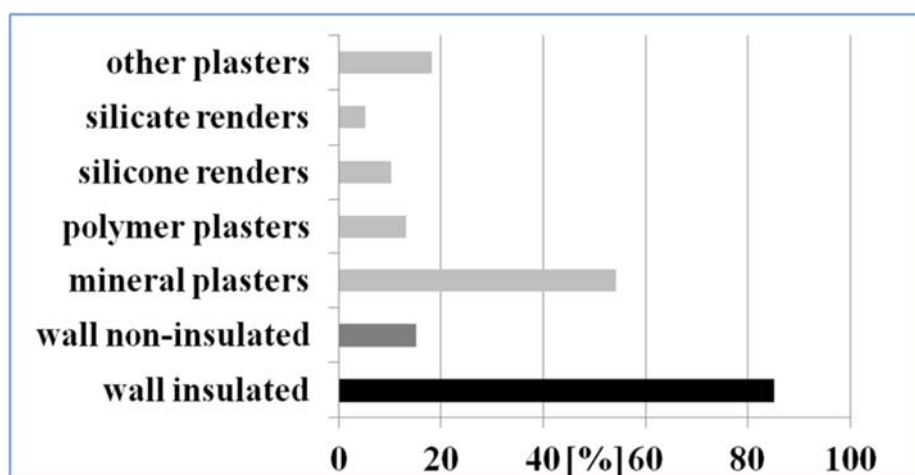


Figure 5. Incidence of biological corrosion on façades

Observations indicate that microorganisms are more common in buildings insulated with foamed polystyrene. The reason may be the high diffusion resistance and low water vapour permeability of the material. The effect of these properties is a virtually zero movement of moisture between the plaster coat and the construction wall. Excessive water cannot migrate through the walls of the building. Moisture is accumulated in the hollows of the external render. Application of thermal insulation also restricts heat transfer in the external wall. During the heating season in autumn and winter, the façade surfaces of insulated buildings remain cooler than is the case for non-insulated buildings. It cannot thus be expected that moisture will be dried by the heat from the inside [2]. Furthermore, renders and plasters are characterised by low thermal capacity – they can heat up quickly and cool down equally quickly.

This may contribute to the occurrence of the dew point, i.e. water vapour condensation on the surface. Thin-layer acrylic plasters do not have any natural protection against microorganisms, and the biocidal agents added to the composition lose their properties already after several years. Mineral and silicate plasters lose their protective alkaline reaction over the time. Furthermore, the system of application of plasters is likely to be affected by many errors in workmanship or design. A lot of ‘difficult’ spots, e.g. at plinths or joints between decorative elements of the building, are not drawn in detail by designers. Another factor that has adverse effect is the lack of an environmental analysis of the location of the building, which results in the wrong choice of plaster that cannot meet the conditions concerning durability. In order to maintain durable coating, it is recommended to check the technical condition of the building every 5 years and to clean the façade, especially in areas with heavy air pollution. Failure to remove dirt on an ongoing basis results in the ease of finding nourishment by microorganisms. Plasters in darker colours and rough texture with many hollows promote absorption of light energy, accelerate ageing and hold moisture and traffic dust. As a consequence, such a substrate is easily colonised by algae spores that spread in the air. Usually, biodeterioration begins on the north- and west-facing sides. Due to smaller exposure to sunlight, they find there a substrate with higher dampness and favourable temperature [30].

Organisms dwelling on façades often treat it as a foothold. Despite negligible nutritional value of plaster, they get organic compounds, e.g. carbon, from the air or pollution deposited on façades. Algae or lichens (fungi living in symbiosis with algae) are autotrophic organisms, often referred to as pioneer species. They easily adapt to the changing weather conditions and synthesize their own food. Visible signs of the presence of organisms on façades are: appearance of hard-to-remove green and dark stains; occurrence of greenish, brown, and in some cases black growths; local crumbling and cracking of plaster. Combined with occurrence of microorganisms – formation of bulges caused by gaseous products of metabolism and appearance of the smell of mould [31].

7. Results

The appearance of biological life on plastered façades is not a threat to the structure of the building; nevertheless, it should not be disregarded. In the early period, this is a significant aesthetic problem that decreases the value of the building and in the case of long-lasting dwelling on the façade it has an adverse effect on the technical condition. This involves producing harmful metabolites (products of metabolism) by organisms and increased moisture retention. As a consequence, this leads to a reduction in the thermal resistance of the wall barrier and falling off of fragments of the plaster, intensified by frost corrosion. The effects are permanent discolouration on the plaster, appearance of scratches and cracks, chemical decomposition of the material and impairment of the properties of the plasters.

The intensity of incidence of microorganisms on façade surfaces is primarily dependent on physical and environmental factors. External walls most affected by algae are those in insulated buildings, covered with plasters that are not fit for the environment or the structure of the wall barrier, with high roughness.

References

- [1] Regulation of the Minister of Transport, Construction and Maritime Economy of 5 July 2013., Dz.U. 926 dated 13.08.2013 r (in Polish)
- [2] A collective work edited by J. Karys, "Protection against moisture and biological corrosion in construction", *Guidance, MEDIUM Publishing House*, 2014.
- [3] S. Ilomets, T. Kalamees, J. Lahdensivu and P. Klõšeiko, "Impact of ETICS on Corrosion Propagation of Concrete Façade", *Energy Procedia (Sustainable Built Environment Tallinn and Helsinki Conference SBE16 — Build Green and Renovate Deep)*, vol. 96, pp. 67-76, 2016
- [4] E. Stanaszek, „Biodeterioration building materials for mineral binders”, 2007
- [5] B. Zyska and Z. Żakowska, (collective work.), "Microbiology materials", *Publishing Technical University of Lodz*, 2005.
- [6] M. Piontek and H. Lechów, "Aerophytic cyanobacteria as a factor in the biodegradation of technical materials on external building walls", *Civil and Environmental Engineering Reports*, vol. 13(2), pp. 109-119, 2014
- [7] M. Książek, „Biological corrosion of facades of buildings”, *Plasters*, vol. 1 (10), pp. 31-34, 2011 (in Polish)
- [8] B. Cwalina; „ The role of microorganisms in the deterioration of natural building stones.”, *Journal of Polish Mineral Engineering Society*, vol. 1, pp. 39-48, 2003 (in Polish)
- [9] J. Kobus, „ Characteristics of pulverized air pollutants”, *Corrosion protection*, vol. 7, pp. 269-274, 2008
- [10] J. Karyś, Ch. Richter, „ Biological factors on the facades of residential buildings - causes of occurrence and removal.”, *Corrosion protection*, vol. 10s/A/2003, pp. 91-101, 2003. (in Polish)
- [11] A. Wiejak, „Resistance of polymer plasters to algae growth as a feature of their durability”, *Building materials*, vol. 9, pp.21-22, 2016 (in Polish)
- [12] A. Dylla, „Practical thermal physics of buildings”, *Publisher University College of Technology and Life Sciences in Bydgoszcz*, 2009
- [13] <http://eetd.lbl.gov/heatisland/>, 23.02.2017
- [14] <http://www.ladnydom.pl>, 23.02.2017 r.
- [15] <http://cte.fea.pl/Centrum-Transferu-Technologii/Baza-wiedzy/Efektywnosc-energetyczna-w-budownictwie/Izolacje/Jak-docieplac-sciany>, 23.02.2017
- [16] Cz. Byrdy, „ Heat-insulating structures of external walls of residential buildings”, *PK Publishing Technical University of Cracow*, 2009 (in Polish)

- [17] E. Radziszewska-Zielina, „Methods of performing thermal insulation of external walls”, *Publishing Technical University of Cracow*, 2003 (in Polish)
- [18] <http://www.badaniatermowizyjne.info/>, 23.02.2017
- [19] S. Chładzyński, „Plaster on facades”, *Building materials*, vol. 9, pp. 2-5, 2011 (in Polish)
- [20] W. Brachaczek and W. Siemiński, „Comparison of the facade properties of coatings”, *Building materials*, vol. 9, pp.49-51, 2013 (in Polish)
- [21] M. Niziurska and M. Wieczorek, „Durability of finishing layers on thermal insulation systems”, *Building materials*, vol. 9, pp. 16-19, 2012 (in Polish)
- [22] T. Rybarczyk, „Plasters - an important element of masonry construction”, *Building materials*, vol 9, 2012 (in Polish)
- [23] J.W. Kulig, „Impact of environmental factors on mechanical and biological erosion of façade coatings”, *Building materials*, vol. 9, pp.6-7, 2007 (in Polish)
- [24] PN-EN 15824:2010 *Requirements for external and internal plasters on organic binders* 2010 (in Polish)
- [25] PN-EN 15458 2014-09 *Paints and varnishes. Laboratory method of effectiveness test in a coating of a coating agent against algae*, 2014 (in Polish)
- [26] M. Piontek, „Efficiency of biocides for exterior applications in construction.”, *Corrosion protection*, vol. 1, pp. 2-7, 2012 (in Polish)
- [27] B. Zyska, „Disasters, accidents and microbiological risks in industry and in construction”, *Publishing Technical University of Lodz*, 2001 (in Polish)
- [28] J. Miklaszewska and A. Wiejak, „Resistance to algae thin plaster for exterior objects”, *Building materials*, vol. 9, pp.28-29, 2012 (in Polish)
- [29] M. Wiwatowski, „Performing thin-layer plasters”, *Plasters*, vol. 1, 2008 (in Polish)
- [30] M. Książek, „Research on algae on building facades. Part 1”, *Corrosion protection*, vol. 3, pp. 19-22, 2013 (in Polish)
- [31] M. Książek, „Research on algae on building facades. Part 2”, *Corrosion protection*, vol.6, pp. 269-272, 2013 (in Polish)