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Climatic and Air Pollution Effects on Building Facades

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The paper provides the basic characterization of the principal agents that affect the durability of building materials and the description of the degradation mechanisms. The degradation factors are classified according to their nature (mechanical, electromagnetic, thermal, chemical and biological agents) as well as to their origin (atmosphere, ground etc.). The interactions between materials and climatic factors with pollutants are very complex and many variables are involved. Deposition of pollutants onto surfaces depends on concentrations of the atmospheric pollutants as well as the climate including the microclimate next to a surface. In case the pollutants are on the surface, interactions will vary depending on the amount of exposure, the reactivity of different materials and the amount of moisture. General effects and their causes include surface material cracking, splitting, spalling, softening and staining, due to salt or water crystallizations and acid-base chemical dissolution reactions. The article focuses on the specific problems connected with the atmospheric pollution and climatic effects on building materials, new accelerated ageing tests, including the simulation of atmospheric acidic precipitations.

Keywords: weathering of building materials, acid rain, degradation, corrosion, accelerated weathering tests methods.

INTRODUCTION

An external surface of building enclosures, more precisely, its protective coating, is directly affected by climate. Atmosphere is the basic factor causing deterioration of building envelope and coatings. Atmospheric factors are divided into natural (precipitation, wind, high and low temperatures, solar radiation) and complex chemical and biological processes, issued by air pollution.

The durability of external walls is determined by the following properties [1]:

- frost resistance, i.e. the capability of a moisture-saturated material to resist temperature fluctuation through freezing and thawing cycles;
- moisture resistance, i.e. the capability of a material to resist the periodical moisturizing and drying cycles under positive temperature;
- corrosion (chemical impact) resistance, i.e. the resistance to solutions of dissolved aggressive destructive chemical agents (UV radiation, causing photochemical reactions on surfaces, can also be considered as a chemical impact).

It is useful to consider the mechanisms (climatic and of airborne pollution) that contribute to deterioration and hence to identify the specific deposition phenomenon that is likely to be most important. The mechanisms are as follows [2]:

Physical mechanisms. The presence of water at the surface is known to be a key factor in promoting the fracturing and erosion of building envelope and coating. Water penetrates the pores and cracks and causes mechanical stresses both by freezing and by the hydration and subsequent crystallization of salts.

Chemical mechanisms. Some deposited chemical agents react with surfaces. Sulphur compounds have been indicted as the most critical factors in this regard, mainly because they are often acidic and can have high concentrations in city and suburban air; however, nitrogen compounds should be considered as well. Fluxes of trace gases (e.g., sulphur dioxide) can be high, especially when promoted by biological activity. Dissolution by chemical reactions with contaminants contained in precipitation is one of the most familiar eroding processes, particularly in the case of carbonaceous stone.

Biological mechanisms. Many different biological factors have been found to be important. Growths of lichens, mosses, algae, mold, fungi and bacteria are capable of promoting surface deterioration. Some bacteria can synthesize sulphuric (or nitric) acid from airborne sulfur dioxide (or nitrogen oxides).

During the last decades acidic rains created by sulphur and nitrate oxides (since air pollutants constantly emit to atmosphere) became one of the most important ecological problems. When emitted to the atmosphere, the sulphur and nitrate oxide air pollutants are active up to a few days and migrate for hundreds of kilometers from an emission source [3, 4, 5]. Affected by solar radiation and other airborne chemicals (oxidants and accelerants) as well as humidity, they turn into sulphuric and nitric acids.

Deterioration and decay of materials of building enclosures besides an ordinary climatic factor is also stimulated by chemically active impurities and unstable water-soluble formations migrating and chemically or/and physically reacting with the structural skeleton of the material. Mineralized water additionally dissolves the unstable formations of a material through further mineralization. Various chemical materials make new, weaker and easily washable products, which after the evaporation of water form deposit crystals of various volume, form and origin. These crystals, similarly to ice, stress on the walls of pores and capillaries, destroy the surface of enclosures and spoil its appearance.

Material degradation and loss of characteristic properties, as described by the performance of function, in the course of time in most cases occur due to chemical or physical deterioration or corrosion.

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Natural weathering is essentially a cyclic phenomenon also involving the wetting and drying of the surface. The detrimental effect of an air pollutant on building materials has been recognized for a long time and still causes major concern [6 – 9]. It appears desirable to focus present attention on the deposition of sulphur dioxide and small (potentially acidic) particles, on the condensation of water at the surface and at already deposited particles, as well as on the characteristics of pollutants delivered during precipitation.

A sufficient amount of studies have been performed aiming to find the corrosive effect of the air pollutants and to establish the relationship between material decay and the environmental degradation factors. Although it is generated a lot of useful data about the effects, there is still lack of the homogeneous approach in terms of measurements, time frames and data-analytical procedures.

The aim of this work is to evaluate the deterioration and weather resistance of paint coatings of building facades. Also we present a new approach establishing a new test method, which would allow to evaluate a durability of building facades in more reliable way.

EXPERIMENTAL AND RESULTS

A vapor permeability and water absorption process of different coatings is quite well investigated and known. Values of physical parameters are found out with neglect to the interaction with the basis on which paints are coated. For our investigations as a basis of coatings silicate brick was chosen. The choice was based on relatively homogeneous capillary structure of silicate brick and its surface in order to get as less as possible scattering of results related with irregularity of homogeneity of the material. The vapor permeability of the coating-basis system was measured in laboratory conditions at the temperature of 20 °C, creating a water vapor pressure difference between surfaces of sample and measuring water vapor flow density penetrating the sample through some established time period. Air humidity values have an impact to the value of measured water vapor permeability.

Vapor resistance values Z calculated from measurement results are shown in Fig. 1.

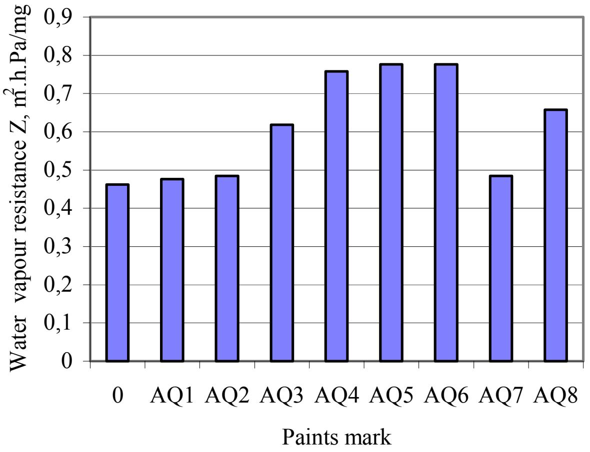

Fig. 1. Vapour resistances of surface layer of silicate brick coated with aqueous polymeric dispersion paints

Fig. 1 shows that it is difficult to say anything positive about paints durability considering just vapour permeability values. We think that it is important to pay an attention to the water sorption coefficient values too.

Analyses of compositions of the paints indicate that vapor permeability depends on the paint used, on the polarity of film-makers, and on the bonding agents used. During investigation the changes showing decrease in adhesion between paint and brick, were fixed.

An areal water absorption content W, [kg/m^2] shows an amount of absorbed water (kg) driven by capillary suction forces by 1 m^2 of surface in contact with water surface. Afterwards water absorption content is established by measurements, the water sorption coefficient w, [kg/(m^{2}h$^{0.5}$)], is calculated according to EN ISO 12572:2001 [10].

Water sorption coefficient w values of silicate brick samples painted with 8 different aqueous polymeric dispersion paints are shown in Fig.2.

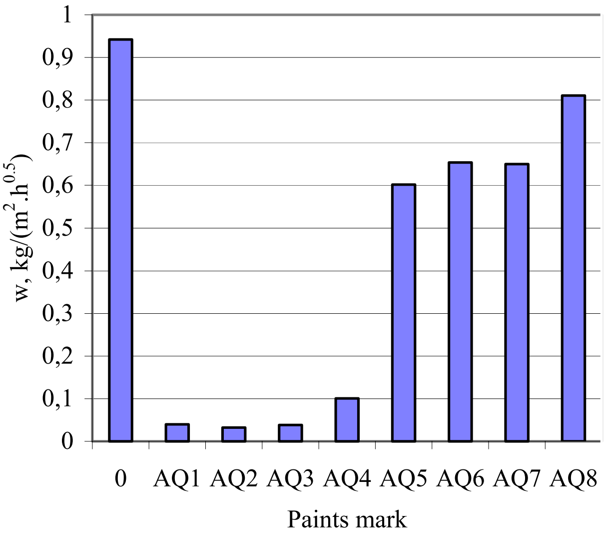

Fig. 2. Water sorption coefficients of surface layer of silicate brick coated with aqueous polymeric dispersion paints

As it is seen from Fig. 2, aqueous polymeric dispersion paint coatings are polarised regarding to water sorption coefficient into:

- coatings restricting for basis to absorb water: AQ1, AQ2, AQ3, AQ4, AQ5 [$w \leq 0.1$ kg/(m^{2}h$^{0.5}$)];
- coatings enabling for basis to absorb water: AQ6, AQ7, AQ8 [$w = 0.60 – 0.80$ kg/(m^{2}h$^{0.5}$)].

Water sorption coefficient determined for materials covered by all tested facing coatings in order to establish dependences between obtained water sorption coefficient values and analogical weather resistance values of facing coatings to complex conditioning in climatic chamber. Graphic views of resistance on complex effects of climatic chamber weathering tests are given in Fig. 3.

Resistance of different paints on complex effects test was carried out in a climatic chamber [11, 12] in which the complex weathering climatic test consists of such weathering factors:

- freezing and thawing,
- showering and drying,
- UV radiation.

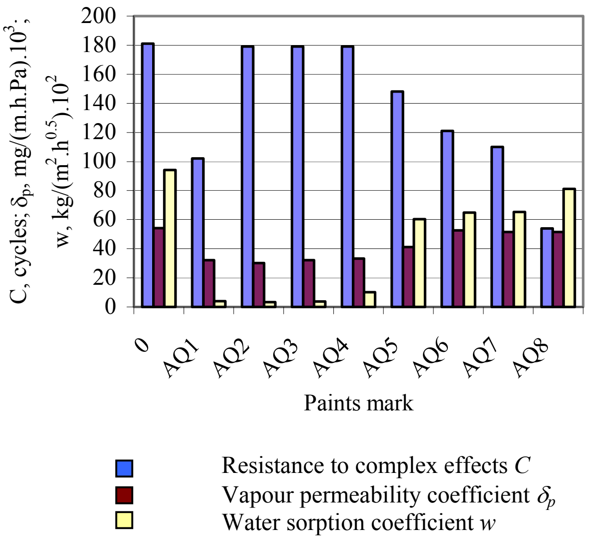

Fig. 3. Resistance to climate effects of aqueous dispersion paints on silicate brick walls considering water sorption coefficient and vapour permeability

Our climatic test does not evaluate the impact of acid rains, but even so the weathering results show a substantial influence to the durability of paint coatings.

The foreign experience turns to introduce of acid rain imitation to the complex weathering climatic test, especially for localities with frequent acid rains. It would imitate an impact of local environment to coatings of building facades in more reliable way. Such enhanced weathering tests would allow making better prognosis of real durability of paint coatings in real field conditions.

DISCUSSION

The earlier research studies on deterioration and corrosion (related with air pollution) have mostly been concerned with the SO_2 effects on painted metals [7, 8, 9, 13]. The influence of acid rains as a catalyst of metal corrosion is well known. However the durability of facing building materials due to the impact of acid rains is much less analyzed field. It was also determined that the joint action of UV radiation and deposits of acids result in the acceleration of decay of materials. The impact of corrosion can be measured as the loss of the mass of material (g/m^2), surface recession (µm), depth of leached layer (nm) or increase of weight (µg/cm^2) [2, 6].

Laboratory accelerated test methods always have played an important role in the assessment of material's performance, but in general, they have not been applied by virtue of their ability to simulate and enhance natural weathering. A lot of research works have been executed when investigating the durability of the building materials, however during the investigation tests natural acidic rain water was not used, and samples were exposed to etching with acids and salts whose effect was too strong for the determination of real ageing. Emphasis has often been made on the speed with which results may be obtained, rather than the relevance of the chosen experimental conditions compared with the actual conditions in service.

Though accelerated laboratory-weathering tests play a significant role in the estimation of the exploiting features of building materials, in fact, at present they offer an ineffective model by intensifying the action of the natural climate. Therefore the standard tests should be improved as well as research methods of weathering tests that should be elaborated by inclusion of solutions very much similar to natural rainwater and other climatic conditions.

Under such circumstances there is a possibility for a realistic test meant for the general assessment of the complex atmospheric corrosion and climatic resistance of materials, which over a longer period, could provide more accurate indicator of material performance and durability in a natural and real conditions of some specific locality. This will allow us to create more reliable prognostic methods on durability of different paints and coatings to be used for painting of building enclosures. The impact of airborne pollution up to now is not investigated in our Country, especially considering specific locality conditions.

CONCLUSIONS

1. The durability of aqueous polymeric dispersion paint coatings is enlarging with the significant reduction of water sorption coefficient values comparing with the relatively small reduction rates of water vapour permeability values.
2. Up to now degradation of the building materials due to air pollution was insignificantly investigated in our Country and research of weather resistance of building facades was made with neglect of air pollution.
3. According to foreign experience, acid depositions on surface of building materials depending on its nature can accelerate or slow the degradation process down (i.e., creation of protective coats).
4. As a rule for environmental simulation ordinary standardized test methods are used. In most cases such tests are based on a set of extreme conditions that imitate the type of the so-called 'universal environment' and because of that they are far from the conditions of specific cases. It leads to the simulation of unrealistic parameters and, as a consequence, the reaction of the investigated object does not too much correlate with reality. Therefore, when simulating the environmental conditions, it is necessary to create realistic and adapted test methods for each specific locality.
5. In order to determine a weather resistance of facing building materials in localities with frequent acid precipitations, the impact of acid rains also should be involved into laboratory-climatic weathering tests.

BASIC TERMS AND DEFINITIONS

Degradation **-** changes over time in the composition, microstructure and properties of a component or material, which reduce its performance [15].

Durability - capability of a building or its parts to perform its required function over a specified period of time under the influence of the agents anticipated in service [15].

Degradation agent - whatever acts on a building or its parts to adversely affect its performance [15].

Corrosion resistance - resistance of material to moisture solutions of dissolved aggressive and destructive chemical agents.

Moisture resistance - the capability of a moisture-saturated material to resist the periodical moisturizing and drying cycles under positive temperature.

Frost resistance – the capability of a moisture-saturated material to resist temperature fluctuation through freezing and thawing cycles.

Weather resistance - the ability of a material to withstand a complex of main destructive factors – frost, moisture, UV radiation and corrosion, up to allowable degree of material degradation.

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