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WATER IN CONSTRUCTION ELEMENTS OF OLD BUILDINGS. DEGRADATION MECHANISMS

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Abstract: *The main cause of ancient buildings degradation is the presence of moisture in the construction elements. No matter which the source is, the degradation mechanism is a complex phenomenon, being influenced both by the structure of materials, as well as external factors, to which the construction elements are exposed. This article aims to describe the processes of degradation caused by moisture, common in old buildings and to present the main factors that contribute to the decay of construction materials.*

Key words: *decay, old buildings, capillary action, freeze-thaw, salt crystallization.*

1. Introduction

Since ancient times it is known that water plays an important role in the development and exploitation of buildings. When referring to the water necessary in the process of formation of materials, chemically bound water, which participates in the formation of materials and the water of hydration, with a role in the crystallization of chemical compounds, in these circumstances, the water has a beneficial role. On the other hand, the hygroscopic water, absorbed or adsorbed by capillaries [11] and the free water held mechanically, can have a negative impact on the construction elements.

Due to the fact that most of the construction materials have a porous structure, the water enters the pores and leads to the degradation of the structure of these materials. Liquid water can get into the capillary structure by land or infiltration of rain water due to poor uptake. Water in the gaseous state, present in the buildings due to the processes of exploitation increases the relative humidity of the indoor air, transiting through the layers of the construction elements, in order to achieve a balance. Water in the solid state is a fraction of the liquid state water, absorbed and not evaporated from the pores in the warm season and that freezes afterwards, destroying the material structure, due to volume variations.

In the wetting - drying processes, the physically bound and the free water vary. However, in whichever phase, liquid, solid or gaseous, water can cause severe damage in the construction elements.

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2. Degradation Mechanisms

In the case of building materials with open porosity, the mechanisms of accumulation of moisture in their mass are the absorption of water vapor from the outside environment, condensation produced after reaching the water vapor saturation pressure and the ascent of water from the soil through capillaries.

Material moisture is determined as the report between the mass of free water contained and the mass of material in the dry state. In the case of permeable to vapor materials, there is an interdependence between the humidity and the relative external environment, to maintain a balance.

The material wetting phenomenon, by absorption and adsorption, occurs when the partial pressure of water vapor in the exterior environment is greater than the pressure of saturation, otherwise, the material being the one that gives moisture, in the form of vapor [11]. This phenomenon occurs in the case of hygroscopic materials and is called hygroscopic moisture balance.

Factors influencing the amount of water present in the construction materials are: the nature of their constituents, their density, the size and organization of the pores in the material structure, the physicochemical interactions between the liquid, solid, gaseous phases and the conditions to which these materials are exposed [11].

Mass transfer is the transport of moisture from the areas in which the concentration is high, to those with a low concentration, to achieve a balance [10]. Mass transfer can be achieved by two mechanisms, molecular diffusion, due to the trend of reduction of the difference of concentration in a fluid and turbulent diffusion, dependent on the transport properties of the fluid [10].

The phenomenon of mass transfer is influenced by the partial pressure of water vapor in the air, the amount of water deposited by condensation, by the coefficients of conductivity and diffusion of the vapor, the absolute temperature and the resistance of the material to vapor diffusion. In addition to the physical phenomena of mass transfer, a number of different degradation mechanisms are also present in construction elements. They are caused by the interaction between the characteristics of the material and the action of external factors. These phenomena are the capillary rise of water from the soil, freeze-thaw, soluble salts crystallization and the aggressive action of micro-organisms and fungus.

2.1. Rising - damp

In some cases, infrastructure elements are in direct contact with groundwater, due to accidental causes or the modification of hydrostatic levels of groundwater, but most often, the water reaches the structural elements through the action of capillary forces, which are inversely proportional to the pore diameter.

According to the literature, the main cause of moisture presence in construction elements is the rise of water from the soil, through the material capillaries. Due to the porosity of construction materials, the water climbs up through the pores and moistens the areas in the immediate vicinity of the land, changing their physical and mechanical characteristics.

A hypothesis related to the maintenance of moisture in masonry is that, due to the difference of electric potential of masonry and soil, the amount of water that can evaporate from the wall, through various processes of drying is the same as the amount that can penetrate from the soil, therefore the walls remaining always moist [3].

In the case of the church of San Bernardo in Rome, where the walls were 4 m thick, the moisture of the capillary reaches 5.3 m height, and in the construction of the church of San Marco in Venice, with the thickness of the walls ranging between 0.7 m and 2 m, the water penetrates through the capillaries up to 6 m in height [8].

Experimental studies have demonstrated the linear growth of the capillary absorption coefficient with increasing temperature [4].

2.2. Freeze - thaw

Freeze - thaw is the property of some materials to degrade or destroy under the action of frost or thaw. Most of the traditional materials of construction are freeze-thaw, but the effects of this phenomenon manifests itself in different ways, depending on the characteristics of each material. For example, experimental tests conducted on specimens of masonry have shown that, after numerous cycles of freeze – thaw to which they were subjected, the ceramic elements have increased permeability to vapor, due to the increase in pore diameter and the appearance of new micro-cracks [5]. In the case of natural stone, the repeated action of this phenomenon has not produced significant changes on the vapor permeability.

The interaction of the phenomenon of freeze – thaw with the capillary rise water has a fundamental role in the ceramic masonry elements degradation [10] and mortar based plaster, causing exfoliation, dislocations, milling.

2.3. Soluble Salts Crystallization

Soluble salts can be found in the structure of construction materials due to water from the soil that carries them through the capillary pores, due to the presence of different chemical compounds in the mineralogical composition of the material or due to environmental pollution.

Degradations caused by the presence of salts are determined by the crystallization pressure, as they produce important volume variations in the pores of materials, which lead to the destruction of the material structure and the occurrence of efflorescences (Fig. 2). These are deposits powdery, which appear in the form of spots or strips, visible on the surface of the construction elements, due to the migration of salts from their structure, under the action of dissolution phenomena, transport and evaporation of water [6]. The cause of the appearance of efflorescences is the moisture migrating upward, carrying the magnesium sulphates (which are the most soluble in the water), calcium or sodium sulphates.

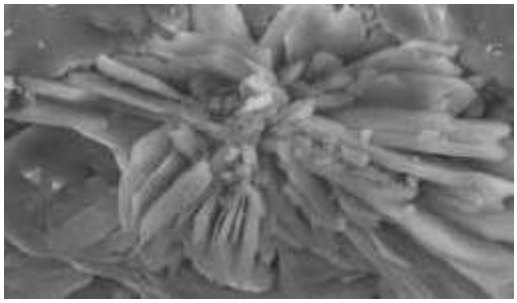

Fig. 2. *Efflorescence microstructure* [10]

In addition to the appearance of efflorescence on the walls of old buildings, the content of soluble salts has a negative influence on the mechanical performance of construction elements [2].

Chlorides (Fig. 3) affect the buildings located in the marine environment, where sodium chloride precipitates in a saturated solution, which occupies a larger volume in the pores of the material and, after numerous cycles of exposure, it produces the detachment of the plaster or of the material exposed [3].

Fig. 3. *Sodium chloride crystals* [2]

2.4. Biological Degradation

The presence of moisture in the walls of old buildings has a significant role in the degradation of a biological nature, thus creating the environment conducive to the development of micro-organisms and fungi (Fig. 4).

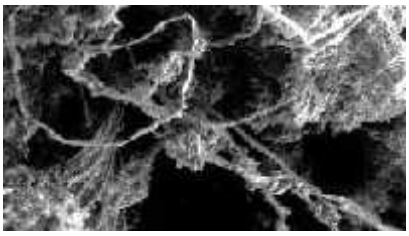

Fig. 4. *Micro-organisms on the surface of the material* [10]

Common manifestations of biological attack are represented by the appearance of black color crusts, on the face exposed to the exterior environment. Research has shown that these films are due to the content of organic materials in the aggregates or cement. This type of degradation is common in old buildings, affecting both the aesthetic character and the structural integrity of the building materials, producing their deterioration and the peeling off of the outer layers.

3. Structural Characteristics of Building Materials

Both in new and older constructions, the moisture can have negative effects on construction elements. Old buildings, due to long exposure to weather conditions and to material aging process, are more sensitive to the action of water, than new buildings.

Old buildings are made, mostly, of natural stone masonry, ceramic elements masonry or mixed masonry: natural stone – ceramic elements, secured with lime mortar. All of these materials are highly afftected by moisture and suffer damage, depending on the intrinsic physical properties, the mineralogical composition and the weather conditions to which they are exposed [7].

3.1. Ceramic Elements for Masonry

In the case of the masonry ceramic elements, the factors influencing the degradation process determined by the action of water are porosity, water absorption capacity, permeability to vapor and the presence of soluble salts [8].

The structure of ceramic elements, mainly the size and distribution of pores in the mass of material, is determined both by the type of clay used and the temperature and time of burning.

Due to the open porosity of the ceramic elements, the water absorbed stagnates in the pores and, after numerous cycles of freeze – thaw, they produce degradations in the mass of the material (Fig. 5).

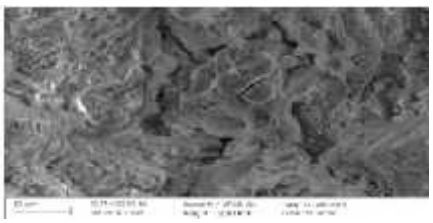

Fig. 5. *Damaged ceramic element microstructure* [10]

The presence of soluble salts is due to either the mineralogical composition of the clay from which the ceramic elements are

made, to the mortar type, or to the action of capillaries carrying water loaded with soil salts. The crystallization thereof produces high voltages in the structure of the material, leading to its degradation.

An important degradation of masonry bricks is the emergence of efflorescences, due to salts crystallization at the surface of the element and the appearance subfflorescences, the phenomenon of crystallization occurring in its mass [1].

3.2. Natural Stone

Natural stone masonry is frequently encountered, due to the fact that this material was easly found locally, by craftsmen bricklayers. The most used types of natural stone for the realization of construction elements are: silicates, granite and sandstone. As a rule, materials with high porosity, being energy efficient, are encountered in superstructure levels, and compact materials, less permeable, can be found in the infrastructure level [8]. In the case of natural stone, the degradations are caused by physical and biological actions, having as main cause the presence of moisture in the material mass. The intrinsic factors which determine the deterioration of the structure are the porosity and mineralogical composition of the stone.

Another cause of natural stone masonry decay is long exposure to weather conditions. The freeze – thaw phenomenon can produce cracks in the structure of the material, which contributes to the increased permeability. So, the degradation phenomenon becomes continuous, the damage being more severe with each freeze – thaw cycle.

The occurrence of efflorescences on the natural stone masonry surfaces is due to the action of the water carrying soluble salts through the capillaries, from the soil [8].

3.3. The Mortar for Masonry and the Plaster

The most widely used type of mortar in old buildings is the mortar of lime and sand. The physical properties of lime mortar are determined by the amount of binder and the amount of mixing water, vapor permeability being directly proportional with these [8]. In the case of mortars used for exterior plastering, the permeability has a beneficial aspect, due to the fact that it allows the construction elements to release the moisture absorbed in the atmosphere, thereby facilitating the drying of the masonry.

The absorption capacity of the natural stone masonry is determined by the porosity of the mortar [5], since it allows the soil water to penetrate into the masonry through capillary structure.

The degradation of the mortar (Fig. 9) is caused by physicochemical actions, such as freeze - thaw, salts crystallization by water evaporation in the surface layers and biological actions. The effects produced by these actions are the emergence of cracks and the dislocation of the plasters, the occurrence of efflorescences and the staining of the walls, due to aggressive biological agents.

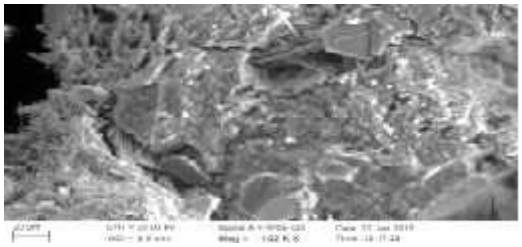

Fig. 9. *Damaged mortar microstructure* [10]

4. Conclusions

According to the research, the degradation mechanisms generated by the presence of

moisture in the case of old buildings, are extremely varied. They depend both on the physicochemical material characteristics, and the external factors, physical, chemical or biological. Regardless of its nature, the degradation of construction elements has a negative impact on the aesthetic and structural requirements.

In order to establish a correct diagnosis, in relation to the nature of building degradation, we have investigated the peculiarities of multiple degradation mechanisms, since there is no general behavior valid for all buildings of a certain type. Each building is unique, so its degradations have a particular character and require a thorough investigation of the phenomena that generated them, in order to establish the intervention measures.

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