Construction and Building Materials 49 (2013) 575–582

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

The hydrophobicity of renovation plaster in manufacturing technology optimized by statistical methods

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HIGHLIGHTS

- Hydrophobicity of renovation plaster.
- Manufacturing technology optimized by statistical methods.
- ANOVA double classification.

ARTICLE INFO

Article history:
Received 29 May 2013
Received in revised form 7 August 2013
Accepted 29 August 2013
Available online 23 September 2013

Keywords:
Renovation plaster
Salt transport
Plaster
Modified mortar
Hydrophobicity
Water penetration
Multiple regression

ABSTRACT

In this paper, the influence of cement and some selected admixtures: redispersible polymer powder, air-entraining and hydrophobing agents, on the hydrophobicity of cured renovation plaster was analysed. The results were obtained experimentally. The result of capillary action (*H*) over a given period of time was used to evaluate the hydrophobicity of these materials. Statistical methods based on multiple regressions were employed to evaluate the influence of particular factors on this parameter. The analysis of the results showed that the suggested statistical models can be considered as very useful tools in optimizing the plaster composition thereby allowing for considerably shortening the time of preparation of production formulas for renovation plasters, thus lowering the costs of production. The analysis of the research results showed that the hydrophobicity of renovation plaster is mostly influenced by the weight amount of such ingredients as: cement, redispersible polymer powder, air-entraining and hydrophobing agents known also as water repellents. As expected, water repellent admixtures based on silicone show the greatest influence on the hydrophobicity of renovation plasters. An addition of only 0.6% of that admixture, at a relatively low content of cement in the mix design, accounted for a ca. 10% reduction in the capillary rise. Such a ratio ensures meeting the requirements of EN-998-1: 2012 [EN-998-1: 2012 Specification for mortar for masonry – Part 1: Rendering and plastering mortar] as for CS II resistance category.

1. Introduction

During use, the external walls of buildings are exposed to different chemical, mechanical and physical loads contributing to the walls losing their functional properties. Destruction caused by chemical and biological factors, as well as alternate swelling and shrinking (frost or thermal–humidity destruction), is the main cause of the loss of the functional characteristics of these elements [1,4]. The most aggressive destructive factors include salts and water. In historic buildings in particular, walls are exposed to the destructive impact of salts, both from the walls themselves and from the ground, as groundwater penetrates into the walls as a result of capillary rise, through damaged damp proof courses or insulation losing its tightness with time [2,5–7].

The destructive impact mechanism is related to the process of solving and washing out soluble ingredients, followed by a chemical reaction leading to a formation of sparingly soluble salts that increase their volume at crystallization. Considerable damage may be also caused by changes of relative humidity which directly influences the wall humidity and concentration of salt therein. At low air humidity, salt equilibrium concentration is exceeded and crystallization begins[1]. During crystallization, depending on the type, salt crystals increase their volume five to seven times. This results in generating high stress values (from 100 to 200 (MPa)), which leads to the walls bursting from inside. The corrosion resistance of building materials is strictly related to their chemical composition of the substrate/plaster combination and structure, in particular porosity [6,7,10].

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[1] Every solvent-solute system has certain critical concentration at which the crystallization starts. This concentration decreases together with temperature [25].

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http://dx.doi.org/10.1016/j.conbuildmat.2013.08.051

Despite significant technological advancement in building engineering, a simple yet efficient and long-lasting method of preventing the impact of water and destructive salts has not been developed. Renovation works in such cases mainly involve interfering in the building substance, which results in such nuisances as noise, dust and the limited use of the building under renovation.

1.1. Renovation plaster

The functions of renovation plaster are mainly related to its porosity and hydrophobic properties. In the case of renovation plaster, in humidified walls, liquid moisture does not reach the external coat of plaster, but mainly stops at the thickness of 5 mm. Moisture is further removed as a result of evaporation and diffusion. Then the surface of renovation plaster remains dry and free of blooming. Salt crystallizes within the area of physical transformation of water into vapour and the formed crystallized salts are stored in the pores of the renovation plaster. This protects the walls of buildings from damage on the saline walls for many years [11,12].

Depending on the degree of salinity of walls, salts may break the hydrophobic barrier with time and appear on the plaster surface. Therefore, to ensure proper functioning, it is necessary to use renovation plaster in a system with other materials, such as a rendering coat and porous priming plaster, also called a storing plaster, with hydrophilic properties [5,10].

Water movement in mineral materials with a porous structure is subject to the general laws of liquid dynamics, where the flow density is proportional to the water potential/pressure gradient. Its special nature results from a complex construction of such material, its variability in time, as well as the presence of admixtures influencing the surface tension [13]. In the simplest case, pores are modelled by a set of cylindrical capillaries, also called a "capillary bundle model" [14]. Real porous structure is more complex as presented in Fig. 1. The material absorbs water, since the surface tension in the capillary pores "sucks" water due to the capillary pressure defined as:

$$p = 2 \cdot \sigma \cdot \cos\theta / r \tag{1}$$

where p is the capillary pressure, σ represents the liquid surface tension, r is the capillary pore radius, and θ is the contact angle [5,11].

The action of hydrophobing admixtures mainly involves increasing the angle between the walls of capillary pores and water, leading to a change in the capillary pressure [15]. The application of such admixtures in the production of mineral materials based on a cement binder with a porous structure is a common practice to reduce the transport of moisture being a carrier of salt ions and having a corrosive impact on building constructions [13]. Contrary to sealing, hydrophobing actions help the penetration of water vapours and all gases in general, which leads to a reduction of the construction humidity. In practice it is hard to cover the entire surface of capillaries and complete water tightness is impossible to achieve. Some admixtures increase water tightness, in addition to their hydrophobing action also causing blocking of pores [13,16]. The literature provides little knowledge explaining and classifying actions in this respect.

1.2. Requirements for renovation plaster

The basic parameters and requirements for renovation plaster were described in EN 998-1:2012 [8]. Since the aforementioned standard contains requirements only for renovation plaster, but not for the entire plaster system, one should refer to the more detailed requirements for a system of renovation plaster included in the WTA guidelines No. 2-9-04/D [9], developed by the. WTA International Association for Science and Technology of Building Maintenance and Monuments Preservation Contrary to the standard, the WTA guidelines present a detailed description of the requirements for a complete system of renovation plaster and they also contain essential information for contractors.

1.3. Factors for the modelling of the technical characteristics of renovation plaster

Renovation mortars are provided with relevant properties by selection of appropriate aggregate, binder and admixtures [6,9]. Commonly available admixtures impact the characteristics of mortars based on different mechanisms. From the point of view of changing the technical characteristics of renovation plaster, e.g. porosity, mechanical strength or hydrophobicity, air-entraining and hydrophobizing admixtures are of great importance. A favourable effect can also be obtained by using several admixtures at a time. If the mortar characteristics are not sufficiently modified as a result of using the admixtures, modifying the aggregates or the binder by an addition or partial replacement of a cement binder with polymer binder can provide further benefits. Polymer resins, mainly vinyl and acrylic ones, in the form of redispersible powders are used for binder modification [17,18].

Being familiar with the characteristics of aggregates and admixtures, one can programme the technical properties of renovation plaster. However, one should remember that the mechanism of admixtures' action is varied and depends on their chemical construction. One admixture can impact on several technical properties of mortars.

As for hydrophobicity and porosity, as well as mechanical strength, the following groups of admixtures can be mentioned:

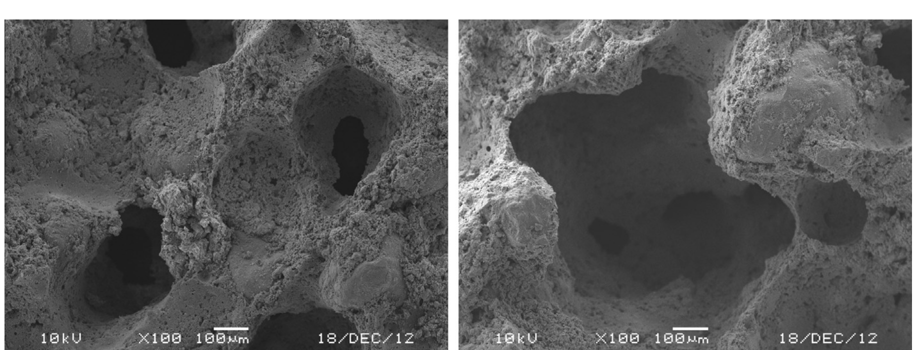

Fig. 1. SEM images of the structure of renovation plaster containing combined pores with different diameters.