Construction and Building Materials 48 (2013) 35–44

Contents lists available at SciVerse ScienceDirect

Construction and Building Materials

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

Effect of coatings on moisture and salt transfer phenomena of plasters

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HIGHLIGHTS

- Effect of coatings on water vapour transmission rate of plasters.
- Study of a brick–plaster-coating system at a capillary rise test.
- Use of infrared thermography technique for monitoring.

ARTICLE INFO

Article history:
Received 10 October 2012
Received in revised form 18 May 2013
Accepted 17 June 2013

Keywords:
Coating
Plaster
Infrared thermography
Water vapour flow rate
Sodium sulphate
Ageing test

ABSTRACT

For the protection of masonries against salt dampness various plasters and coatings are proposed. In many cases the application of inappropriate materials accelerates the degradation process. In this work the performance of different types of premixed plasters, suitable for confronting rising damp problems, along with different coatings (silane–siloxane coating and potassium silicate paint) were evaluated. For this purpose water vapour transmission rate experiments for uncoated and coated plaster were performed. Moreover, in order to investigate the durability to salt decay, an ageing test, through repeated cycles of capillary absorption of sodium sulphate solution, on brick–plaster-coating systems was carried out. The ageing test was monitored with the aid of infrared thermography. The results showed that the applied coatings seem not to influence moisture and salt transfer phenomena. Moreover, the plasters which presented the ability to transport the salt solution from the brick substrate, assuring the brick durability, are preferable in respect to salt transport blocking plasters.

1. Introduction

Buildings moisture content determines decisively their overall energy performance and durability [1]. Water can enter building materials through rain, condensation, or capillary rise. Damage caused by the presence of moisture is of physical, chemical and biological nature, based on decay mechanisms such as hydrolysis, dissolution, hydration, oxidation, capillary rise, salt transfer and crystallization, hygroscopicity, and cycles of wetting/drying [2]. Salt crystallization is considered among the most destructive phenomena, and is determined by the equilibrium established between water evaporation rate and solution transfer rate [3]. Frequently treatments that are used for masonries suffering by salt damp problems intensify, instead of eliminate the salt crystallization problem [4]. In particular plasters and coatings applied as final layers influence the water solution transfer rate and in many cases accelerate the degradation process [5,6].

Generally, coatings and plasters are used for the protection of masonries. The use of term coating is generic and includes paints, but also water repellent coating [6]. In the passage of years main categories of paint coatings used for damp buildings are silicone paints (with polysiloxane resins and, in addition, an acrylic or styrene-acrylic resin), silicate (usually potassium or sodium silicate), hydro-pliolite systems (with a hydro-pliolite resin) and lime-based paints [7]. Furthermore, water repellent coatings often applied are silicones and fluoropolymers, stearate, siliconate and silane–siloxane products [8,9].

On the other hand repair plasters quality and performance is determined by the kind of the binder and the composition of the plaster mixture [10]. Plasters of controlled microstructure (in some cases called as macroporous plasters or dehumidifying), are proposed for the treatment of masonries with rising damp problems, facilitating water transfer (both in liquid or water state) [11,12]. Their action is based on the moisture evaporation rate increase, facilitating drying of walls, due to their high porosity values. However, in practice for the final finish of the masonries with salt damp problems are used inappropriate coatings of impermeable nature, which inhibit the water vapour flow leading to decrease of plasters permeability. Coatings used for the final finishing of masonries must also be permeable to water vapour, without sealing the pores of the plaster, in order to permit water vapour transfer [13]. Water vapour flow rate is a crucial parameter for the assessment of the ability of plasters and coatings to allow the movement of water va-

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0950-0618/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.conbuildmat.2013.06.050

pour from the inner part of the masonry to the outer. In the literature, there is a great deal of interest in measurement of water vapour flow and there are a wide variety of methods applied [14,15]. Besides the need of high permeability values, in most cases, there is a need also for waterproofing of the masonry surface, which would allow the water to evaporate, but at the same time would prevent rain from penetrating the structure. In consequently, coatings used for the protection of masonries with damp problems along with high permeability values, should also present water repellence characteristics [6].

Additionally, selection criteria of repair plaster for salt loaded substrates includes parameters like history, type, location, extent and severity of damage, moisture-salt load and origin, properties of plasters and substrate, environmental conditions and application technique [16,17]. Two different working 'principles' of salt resistant mortars are proposed; salt accumulation and salt transport mechanisms [18]. The largest group or restoration plasters produced for salt loaded substrates tries to keep the crystallization of salts within the plaster, based on the first principle. In this case a specific composition of the salt accumulating layer is necessary and specific requirements have to be fulfilled. The application of the second principle, where crystallization takes place on the surface, may therefore seem more desirable. But since plasters are usually covered with a coating, the question remains whether the coating impair the moisture and salt transport [18,19].

For the evaluation of building materials durability to salt crystallization various ageing tests are used. Sodium sulphate is a salt commonly used, due to its destructive action when crystallising. Sodium sulphate crystals in a porous material may precipitate originally either as thenardite, or as mirabilite plus thenardite mixtures, depending on the environmental conditions and the porous system characteristics. Mirabilite may undergo dehydration, resulting in the formation of thenardite. With the presence of water, thenardite may dissolve, forming a saturated solution following evaporation, and finally precipitating alone or together with mirabilite. In any case, crystallization pressure seems to be responsible for building material damage [20].

Different studies show that damage depends on the quantity of salt in the material, the characteristics of the porous network, materials mechanical strength, as well as on the environmental conditions (e.g. temperature and relative humidity) [20–22].

The objective of this research was to study the water vapour transfer rate of repair coated and uncoated plasters, used for masonries suffering by rising damp phenomena. Moreover in order to investigate the durability to salt decay, an ageing test, through repeated cycles of capillary absorption of sodium sulphate solution, on brick–plaster-coating systems was performed.

2. Materials and methods

2.1. Materials

Two series of specimens were prepared:

- Plasters coated and uncoated for measurements of water vapour flow rate.
- Systems of brick and plaster coated and uncoated, for the ageing test with the capillary rise of sodium sulphate solution.

The plasters and coatings used in both cases were the same. More specifically, four commercial premixed plasters (*EM*, *TR*, *MP*, *RL*) were selected for testing. Main criterion for the selection of these plasters was the fact that all plasters were used for treatment of masonries with rising damp problems.

According to the manufacture's data sheets for each product:

- *EM* is a natural hydraulic lime based plaster, with sand and artificial aggregates, air-entraining additives, polypropylene fibres and hydrophobic compounds.
- *MP* is a natural hydraulic lime based plaster, with natural sand, air-entraining additives and polypropylene fibres.
- *RL* is a grey cement based plaster, with natural sand and air-entraining additives and polypropylene fibres.
- *TR* is a white cement based plaster, with natural and artificial lightweight aggregates, air-entraining additives and hydrophobic compounds.

The preparation of the samples was carried out according to the manufacturer's recommendations, regarding the water/solid ratio and time of mixing. The curing period of plaster was six months, in a room with temperature of 20 °C and relative humidity of 55%.

Considerable attention was paid to the time of mixing, which determines the action of air-entraining agent and consequently the final microstructure of plasters. The specimens' thickness selected to be 3 cm in order to comply with the manufacturer's suggested thickness of plasters when applied on the masonry. The area of each plaster selected to be 20 × 20 cm, larger than the suggested by the standard for the measurements of water vapour transfer in building materials [23]. The above dimensions were selected in order to simulate the application of representative plasters in real scale. For each product 9 specimens were prepared.

Concerning the coatings two commercial protective agents were evaluated: *S*, an inorganic paint, based on potassium silicate and *As*, a colourless coating, containing silane–siloxane in organic solvent. The coatings were applied after the hardening of plasters. Both products were selected because of their high water vapour permeability values, as their manufactures claim to be.

Potassium silicate coatings are widely used in restoration works. Their name derives of the use of potassium polysilicate as binder, combined with inorganic, alkaline-resistant pigments [24]. According to *S* data sheet, the specific product is sodium silicate paint, water repellent, water-based paint.

On the other hand silane–siloxane coatings compared to other water repellent coatings are permeable at water vapour. These compounds can be viewed as hybrid of both organic and inorganic compounds [25,13]. Siloxane bonds, which are created are stable, with thermal and oxidative stability. Their light stability, which contrasts with many organic solvents, makes them a good choice for outdoor applications [8].

The two coatings were applied on plasters surface (20 × 20 cm), with a roller paintbrush in two applications, at three specimens of each plaster (Fig. 1, left sample) with consumptions for *S* 0.4 l/m^2 and for *As* 0.8 l/m^2. Both coatings presented water repellent characteristics, as it was evaluated with water drop adsorption test [26].

Each plaster surface, before and after the application of coating, was observed using a portable fibre optics microscope (i-scope – Moritex). The aforementioned digital images (×50) acquired with the fibre optics microscope, and were processed with the aid of Image Pro Plus v.4.5 software, in order to evaluate the eventual change of plasters surface texture before and after the application of coatings. The parameters determined with the aid of digital image analysis where "porosity" *P*(%) (defined as the ratio of the area of the pores to the total area of the image (%)), average pore diameter d_{mean} and pore roundness *R* (a size that characterises pore shape).

Furthermore for the ageing test with sodium sulphate solution capillary rise test, systems of brick–plaster coated and uncoated, were prepared (Fig. 1, sample on the right). The brick used was a traditional clay brick (*B*), with dimensions of 18 × 8 × 4 cm. The plasters dimensions were 13 × 8 × 3 cm. At the surface of the plasters the same coatings were applied, with identical application procedure as before.

The microstructural characteristics (cumulative volume, bulk density, corrected bulk density, porosity, average pore radius and specific surface area) of the plasters, as well as of the brick substrate were examined by the use of mercury intrusion porosimetry (Macropores Unit 120 & Porosimeter 2000, Fisons instruments). For each material 3 measurements were performed. Samples were cylindrical in shape,

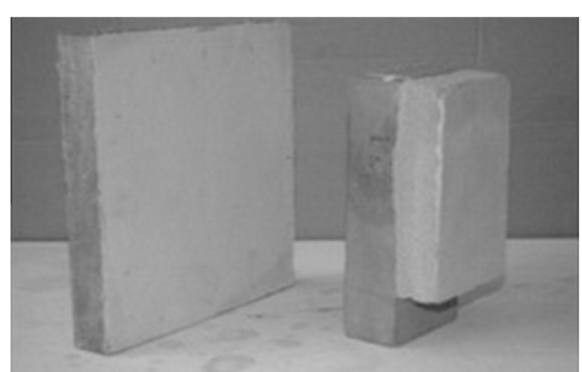

Fig. 1. In the left is shown the plaster-coating system for water vapour transmission rate measurements and in the right the brick–plaster-coating system used for the ageing test.