Available online at ScienceDirect
www.sciencedirect.com
Elsevier Masson France
EM|consulte
www.em-consulte.com
Journal of Cultural Heritage
Journal of Cultural Heritage 11 (2010) 185–195

Original article

# Study on some sorption properties of treated bentonites for their potential use as a moisture regulating system for the preservation of historical wooden elements

Marco D'Orazio [1], Enrico Quagliarini *

*Department of Architecture, Constructions and Structures, Marche Polytechnical University, Via Brecce Bianche, 60131 Ancona, Italy*

Received 7 November 2008; accepted 8 September 2009
Available online 29 December 2009

**Abstract**

We report the first results of a research study aimed at developing a new strategy for the conservation of wooden structural elements present in historical buildings, based on moisture regulating systems. As has been happening for artefact preservation in museums, the idea is to develop systems based on the ability of some highly hygroscopic materials to moderate variations in relative humidity. These materials could adsorb and release moisture to reduce the extreme values of humidity in the micro-climate, for example between wooden beams and masonry. In order to experimentally verify this possibility using current, low cost and easy handling building materials, 5 bentonite samples were laboratory processed to improve their adsorbing properties by means of treatment with sodium carbonate at 3 concentrations: 2, 3 and 4% by weight. The effectiveness of ion exchange between sodium carbonate and bentonite was controlled by measuring the swelling volume of the bentonites. All the samples ($n = 15$) were tested for their hygroscopic properties. Adsorption isotherms were measured at 25 °C, using desiccators with silica gel, saturated salt solutions and bi-distilled water. A comparison between isotherms of one of the lower hygroscopic treated sample of bentonite and of a sample of wood and of a sample of brick and some numerical analyses with the Delphin code were made in order to evaluate the potential use of this bentonite as a moisture regulating system for the preservation of historical wooden elements. Results show that it seems to be possible to use bentonites as a moisture buffering material in order to reduce moisture content in wooden beams at least during their adsorption phase. It remains to investigate their desorption phase and their behaviour if they be in a saturation condition. Further studies are currently under way.


*Keywords:* Bentonite; Moisture buffering; Historical wooden structures; Conservation; Moisture

## 1. Aims

During the service life of buildings, natural aging of materials due to different chemical, physical, and biological processes may take place. These processes are influenced by abiotic factors like relative humidity (RH), temperature and quality of substrate. These factors can also influence the growth of organisms that can lead to bio-deterioration (i.e. mould, fungi and insects damage) that may be a critical factor for durability and usage of different historical building materials, such as wood. In reference to the boundary conditions that may accelerate these last processes it turns out from literature that the decisive parameters of influence like RH [1] and temperature [2] as well as the substrate [3] have to be available over a certain period of time simultaneously [4].

In particular, the effect of RH, temperature and the exposure time on bio-deterioration development has been studied and modelled, especially on wood material [5].

In this way, moisture appears as one of the most important parameter that cause harmful processes especially on historical wooden elements, having a great impact on the working efficiency of wooden bearing structures, like trusses or beams and traditional remedies to protect timber from humidity, especially where the timber is in contact with masonry, such as the ventilation of the environment to keep the timber dry, or encasing the timber in copper sheaths or in bituminous membranes to prevent infection, do not seem to have solved the problem, and the latter has often accelerated the decay process.

* Corresponding author. Tel.: +39 071 2204248.
*E-mail addresses:* m.dorazio@univpm.it (M. D'Orazio), e.quagliarini@univpm.it (E. Quagliarini).
[1] Tel.: +39 071 2204587.

1296-2074/$ – see front matter © 2009 Elsevier Masson SAS. All rights reserved.
doi:10.1016/j.culher.2009.11.005

**Nomenclature**

*Notation*

| | |
|---|---|
| $m_b$ | mass of the dry buffering material (kg) |
| $m_{bm}$ | mass of the moisture content into the buffering material (kg) |
| $m_v$ | mass of the vapour of the environment (kg) |
| $dm_{wm}$ | mass of the moisture content into the wooden material (kg) |
| $dm_{mm}$ | mass of the moisture content into the masonry material (kg) |
| $M$ | moisture content (kg water/kg dry matter) in a porous body |
| $p_v$ | water vapour pressure (Pa) |
| $p_{vsat}$ | saturation vapour pressure (Pa) |
| RH | relative humidity (%) |
| $R_v$ | Gas constant for water vapour 462 J kg$^{-1}$ K$^{-1}$ |
| $T$ | temperature (°C or K) |
| $u$ | moisture content (m$^3$ water/m$^3$ dry matter) in a porous body |
| $u_b$ | moisture buffering material moisture content (m$^3$ water/ m$^3$ dry matter) |
| $u_m$ | masonry moisture content (m$^3$ water/ m$^3$ dry matter) |
| $u_w$ | wood moisture content (m$^3$ water/ m$^3$ dry matter) |
| $\mu_{dry}$ | dry matter vapour diffusion resistance factor (-) |
| $\phi$ | relative humidity in fraction (-) |
| $\rho_{H2O}$ | water density (kg/m$^3$) |
| $\rho_b$ | buffering material density (kg/m$^3$) |

For this reason it is essential to find new approaches to reach a more effective conservation of historical wooden structures from a hygrometric standpoint.

In particular, the aim of the present work is the evaluation of some adsorbing properties of current, low cost and easy handling building materials, such as bentonite, to preserve historical wooden elements, such as the head of historical wooden beams in contact with masonry.

## 2. Introduction

This research paper is the first approach to a more general study, which involves the use of bentonites as a moisture regulating system in building applications (e.g. inert for plasters, hygrostatic system for kitchens and baths).

Recent research studies, in fact, have shown that RH control is an important environmental factor not only for humans but also for artefact preservation and that passive systems (mostly hygroscopic materials) have some potential to assist in controlling indoor RH [6].

Thus materials that adsorb and release moisture could be used positively to reduce the extreme values of humidity in the microclimate, for example between wooden elements and masonry (Fig. 1). This moisture buffer performance will obviously depend on the moisture buffer capacities of each combination of materials together with the moisture production and air exchange rate and the ratio between the surface area of the material and the air volume.

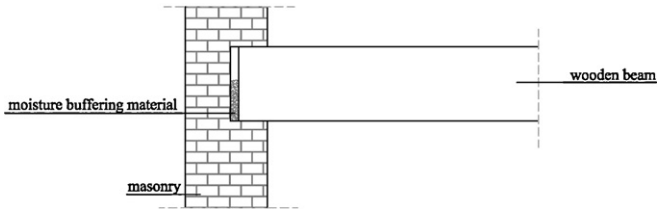


Fig. 1. Example of insertion of moisture buffering material in the cavity between the masonry and the wooden elements.

Bentonite is a mineral material with a defined crystalline clay-like structure. The mineral is composed of silica and alumina sheet-like units, tied together; water can enter between the sheets separating them and hence bentonites can be readily dispersed in water into extremely small particles [7]. A generic bentonite is always unbalanced, with a net negative charge, which can be balanced with adsorbed cations such as sodium or calcium; these cations determine the ease of separation and to some extent, the quantity of adsorbed water [8]. In fact, raw bentonitic materials are industrially treated under appropriate conditions with sodium carbonate in order to obtain products at different degree of ion substitution, hence enhancing their adsorbing capacity [9]. Bentonite shows some interesting properties, such as thixotropic behaviour, adsorbing and flocculation capacity. As a consequence, bentonite is used in civil engineering, for oil drilling, for some pharmaceutical and cosmetic applications and also in the food industry [10]. No applications of bentonite as an adsorbent of water vapour in preserving artefacts are known.

Hence, it is our opinion that bentonite could be used for its adsorbing capacity, or more generally as a moisture regulating system, to preserve historical wooden elements.

## 3. Materials and methods

### 3.1. Phases

In order to experimentally verify the use of bentonite as a moisture regulating system, 5 bentonite samples were laboratory processed to improve their adsorbing properties by means of treatment with sodium carbonate at 3 concentrations: 2, 3 and 4% by weight. The effectiveness of ion exchange between sodium carbonate and bentonite was controlled through the measurement of the swelling volume of the bentonites.

All the samples ($n = 15$) were firstly tested for their hygroscopic properties. Adsorption isotherms were measured at 25 °C, using desiccators with silica gel, saturated salt solutions and bi-distilled water. These experimental data were compared with those of some historical materials such as spruce and brick.

Later they were used in order to conduct some numerical simulations with the Delphin code to evaluate the potential use of bentonite as a moisture regulating system for the preservation of historical wooden elements taking into account not only the moisture buffer capacities of each combination of materials but