Construction and Building Materials 24 (2010) 2572–2578

Contents lists available at ScienceDirect

Construction and Building Materials

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

Methods for porosity measurement in lime-based mortars

Stefanidou Maria *

Aristotle University of Thessaloniki, Civil Engineering Department, Laboratory of Building Materials, Greece

ARTICLE INFO

Article history:
Received 14 July 2009
Received in revised form 4 May 2010
Accepted 24 May 2010
Available online 17 June 2010

Keywords:
Porosity
Problems
Lime-based mortars

ABSTRACT

Porosity is one of the most common determined physical properties of building materials mainly because of its influence on important properties such as strength and durability. Porosity especially in lime-based mortars occupies an important volume. The heterogeneity as well as ageing effect often found in these mortars that have been used for the construction of monuments and historic buildings, make porosity a difficult property to measure. In the paper the porosity of old lime-based mortars is estimated using four well-known techniques. The advantages and restrictions of each method are discussed. The porosity values differ according to the methodology followed. The type of information gained by each method could give valuable data for the material's quality.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

Mortar is counted among the oldest building materials and their main role was to connect masonry elements such as stones and bricks. They were also used to render surfaces for protective and aesthetic purposes, as substratum for frescoes, floors, roofs, mosaics. Based on the study of old mortars it seems that for each of those applications, mortars had different technological characteristics in terms of binder combination, aggregate type and size, different compaction degree and binder/aggregate ratio in order to meet the specific construction demands [1]. According to the technological aspect of each historic period, clay, lime, natural pozzolans, brick dust or combination of them were used. In certain cases gypsum was also used as binder especially for mortars for internal usages or places protected from moisture [2]. By this mixed binding systems the old technicians tried to give strength and durability to the mortars [3]. Apart from the binders, aggregates mainly of natural (river) origin were also used usually in gradation of 0–4 mm. Not rarely, pebbles of 16–32 mm of crushed stones (gneiss, schist, chert) or brick fragments were added to the structure. Also finer sand was used in the case of renderings and plasters [4].

In comparison to modern cement based mortars, the old lime-based ones differ significantly. The binder matrix is softer and strength capacity is below 10 MPa, often 1.5–2.5 MPa. The apparent specific density is below 2.0, usually between 1.5 and 1.8. Ageing effects have resulted in creating a net of micro and macro cracks. In order to measure the porosity of old lime-based mortars, which is an important physical property that gives an idea about the strength level and pathology status of the material, different parameters should be taken into account [5]. Porosity occupies a great volume of this type of mortars, it is influenced by many parameters both from the mortar's technological point of view (type of binders used, the binder/aggregate ratio, the type and size of aggregates, the compaction applied during their application) and from the influence of the environment, it does not have a static form but it is easily altered mainly due to the action of time and additionally the size of pores cover a wide range from nano meters to few mm [6]. Also the available measuring techniques are various with different capabilities and restrictions [7]. Porosity in the mortar structure is found in two main forms that of rounded (or almost rounded) pores of different size and elongated cracks. There are many classification systems of pore sizes. According to IUPAC (1972) pores are classified as micropores, mesopores, and macropores. Macropores seem to have a direct influence on strength, mesopores are related to transfer properties and micropores are responsible for sorption properties [8]. Spherical pores usually in the order of above 100 μm to few mm are primary formed due to the entrapped air during mixing and insufficient compaction. These pores can be met in contact with aggregates or inside the binder matrix. In some of them cracks have been developed on the pore walls allowing the air or liquid to escape (Fig. 1). These pores with cracks seem to have a greater influence on mortar strength and durability [9].

Capillary pores the diameter of which range from 0.1 to 100 μm are formed in the binder matrix and in the transition zones during hydration/and setting process or due to the removal of water during hardening. The water/binder ratio and the carbonation/hydration rate influence the percent of capillary pores. These pores are reduced by time unless secondary alterations (shrinkage phenom-

* Tel./fax: +30 2310995635.
E-mail address: stefan@civil.auth.gr

0950-0618/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.conbuildmat.2010.05.019

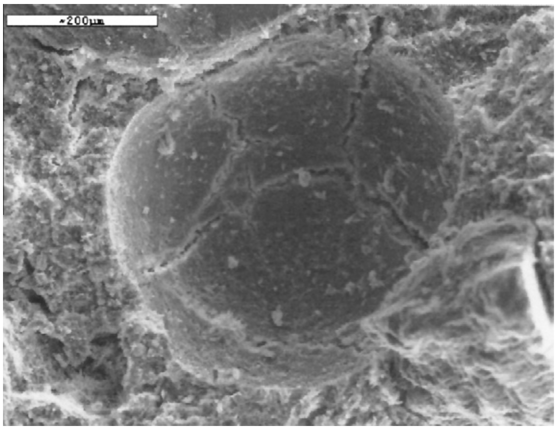

Fig. 1. Large pore inside the binder matrix (SEM, mortar from Panagia Acheropiitos Church 7th century AD, author's archives).

ena, chemical and mechanical processes due to the environment) occur. Capillary pores represent the greatest part of the mortars porosity and their role to permeability is considerable (Fig. 2) [10].

In lime-based mortars the pores smaller than 0.1 μm are in limited amount. These pores are formed inside the crystal lattice. Crystals which constitute the solid mass, contain pores of small diameter and different shape. The amount and arrangement of these pores make the crystals vulnerable to dissolution and they also have an important role in creep and shrinkage phenomena [10]. According to their interconnectivity, pores are characterized as "open" when they are allowing liquids or gases to penetrate and they are permeable. Usually open pores have access to material's surface. "Closed" pores are isolated into the structure and they have no role to permeability. The combination of open and close porosity is the total porosity of the material.

Cracks are the result of shrinkage phenomena or due to the differential movement of the mortar constituents during the setting stage of the material. They are randomly oriented into the mortar structure and their geometry varies according to the technological characteristics of the mortar and the pathology degree (Fig. 3).

In order to scan the different pore sizes of mortars, different techniques have been employed. As it is not possible to gain all these information by one measuring technique different instrumental methods have been developed. The data can be obtained by direct measurements such as microscopes assisted by image analysis techniques and by indirect measurements which are

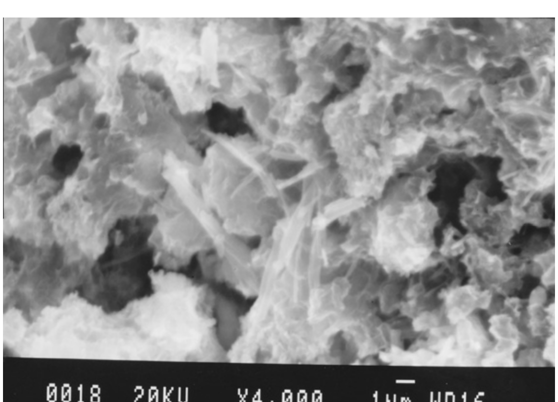

Fig. 2. Capillary pores in mortar from the medieval city of Rhodes, 14th century AD (author's archives).

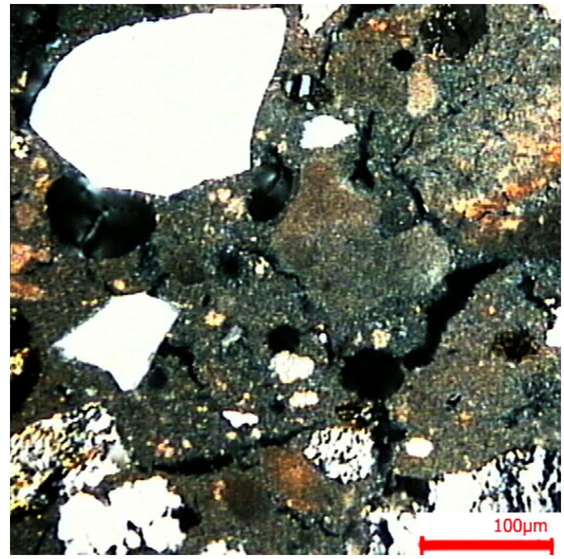

Fig. 3. Cracks and pores in the structure of a lime mortar from Bezesteni in Thessaloniki 15th century AD) (polarized microscope, author's archives).

based on the properties of the materials which are connected to porosity [11]. Nowadays, the technological evolution permits the application of techniques such as neutron scattering and nano-indentation for investigating nano-porosity [12].

2. Porosity measuring techniques

In the present paper four well-known techniques for recording porosity are discussed in respect to the information gained and the restrictions of their usage when their application is related to soft lime-based mortars. In order to proceed in measuring the porosity by instrumental methods the tested samples should be free of water (dry). The technique usually used is oven dry. For the drying process it must be noted that an inadequate temperature can lead to scattered results up to 30% due to excess or insufficient drying [13]. Excessive drying temperature can affect the microstructure by tightening the pore structure, initiating cracks and dehydrating the hydrate products such as gypsum. On the other hand, insufficient drying temperature restricts the access to the whole porous network. Proposed temperature for drying is 40 °C (in order to avoid dehydration of components or thermal shock) and the duration is sufficient when two successive weight measurements do not have difference more than 1%.

For the analysis performed in this paper direct observation has been performed using stereo microscope Leica Wild M10, optical microscope Leica Laborlux 12 POLS. For the image analysis system the camera is ProgRes and the software is dhs image database. SEM instrument is JSM 840A. For the indirect measurement techniques the method of distilled water absorption was according to RILEM CPC11.3, nitrogen absorption by Quantachrome NOVA 2000, mercury intrusion porosimetry was performed using Quantachrome Autoscan 60 and Quantachrome Poremaster Macro.

2.1. Direct methods

2.1.1. Microscopy

Microscopes are tools among a range of other techniques which can be used to understand the complex nature of mortars having the major advantage that the pore structure has an image and the exact position of the pore can be located. In this way pores and cracks occurring inside the matrix or in the transition zone

دریافت فوری ← متن کامل مقاله

ISIArticles
مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات