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"PAST AND PRESENT USE OF LIME AS A BINDER IN MASONRY AND POINTING MORTAR" A PUBLICATION BY THE DUTCH MONUMENT SERVICE WITHIN A DUTCH-FLEMISH COLLABORATION*

K. Van Balen[1]

Abstract

In the fall of 2003, the Dutch Monument service (Rijksdienst voor de Monumentenzorg) published a book entitled "Past and Present Use of Lime as a Binder in Masonry and Pointing Mortar" (Van Balen et al. 2003b). The book resulted from a Dutch-Flemish collaboration. Its purpose was to disseminate knowledge on lime mortar to professionals in the field of architectural preservation. This paper presents an overview of the content of the publication, focussing on preservation issues.

Keywords

dissemination, preservation, lime mortar, high calcium, damage evaluation

[1] K. Van Balen, engineer-architect, PhD in engineering, Associate Professor, K.U. Leuven, Civil Engineering department and R. Lemaire International Centre for Conservation, Belgium, koenraad.vanbalen@bwk.kuleuven.ac.be. President of the publication's editing group.

1 Introduction

The lime book deals with lime-based mortars that are often considered to be a special and separate group of masonry mortars and pointing mortars. Although attention is paid to historical construction practices, the principal subject is contemporary restoration practices. In that context, the question is not only what the role of these mortars is now, but also what their role could be.

Contemporary bricklaying and pointing is done mainly with mortar in which portland cement is the principal or even the only binder. As a result, much of the knowledge of lime mortars has been lost. Since the end of the 19^{th} century, lime mortars have been replaced more and more by cement mortars. There are several different reasons for this phenomenon. The most important may be that a cement mortar achieves its final strength much more rapidly.

Construction practice had to adapt to an ever-greater need for buildings, such as houses, factories, schools, and civil engineering constructions. This was mainly the result of population growth and industrialisation. A milestone in this process was the explosive growth of construction activities immediately after the Second World War, when the restoration of wartime damage and alleviation of the substantial housing shortage had to be dealt with simultaneously. In Western Europe, there was a great need for many new buildings. The mainstream thinking was that this could only be achieved with cement mortars. While portland cement mortar is still being used abundantly, a rediscovery of lime mortars is presently taking place, especially for use in restoration and renovation. This development is influenced by the search for compatibility--mortars used for restoration must be highly compatible with historical materials. In restoration projects, mortars that are insufficiently compatible are sometimes used. This leads to less durable construction and can cause damage in the long term. In many cases, lime mortars are compatible with historical brickwork, or at least more compatible than the cement mortars used in new construction. The examples of historical lime mortar that are still in good condition today demonstrate that when lime mortar has the proper composition and was applied competently, it can be extremely durable. This publication deals with the application of lime mortars for bricklaying and pointing and was motivated, in part, by an appreciation of this material.

2 Overview

2.1 Lime, ethics, and ecology

The book begins with a general description about the nature of lime mortar. The authors also introduce building conservation, which is the context in which lime is often considered. Included is a discussion of how conservation deals with preservation of values, how those values can be defined, and how they relate to the use of lime. Preservation activities are based on the concept of minimum intervention, compatibility, and retreatability, which are closely related to the concept of sustainability. Despite the more theoretical introduction, the book recognizes that practitioners are challenged to carry out the right “job” and should be properly informed about the practical use of lime in mortars.

The sustainability of construction made with lime is compared to that of other types of binder. Life cycle analysis (LCA), in itself, is not sufficient to define the impact of different mortar types on the environment. A study was carried out in which the LCA method was integrated in the “TWIN-model” that includes some non-quantifiable factors. From this analysis, the greatest apparent difference between lime-based mortars and others was the possibility to reuse the bricks in new construction after demolition (not advisable in case of monuments!).

2.2 History of mortar binders

Chapter 2 reviews the tradition of lime mortar use. The use of building lime has a long and rich history. This is reviewed in detail in Section 2: 'The use of lime over the centuries'. Section 2 is preceded by a section on the other binding agents that were and are used for the manufacture of mortar. From ancient times to the recent past, mortars based on lime have been commonly used. Historical sources are referenced in order to explain changes in the lime types and procedures. An English summary of this history can be found in Van Balen (2003).

2.3 From raw materials to mortar

2.3.1 Raw materials for lime production

Mortar is obtained by mixing a binder with aggregates. Mortar is usually composed mainly of aggregates. In the case of mortar for bricklaying or pointing, the aggregate is usually quartz sand. The binder adheres to aggregate and brick. Sometimes, additives are also used. The nature and relative amounts of all these constituents determine the hardening process and the properties during use and after setting.

In lime mortars, the binder is either air-hardening lime (calcium hydroxide, [$Ca(OH)_2$]) or hydraulic lime. Hydraulic lime consists partly of calcium hydroxide, and, in greater quantity, calcium silicate, which reacts with water and then hardens.

Slaking quicklime with water produces calcium hydroxide. Quicklime (CaO) is obtained by burning limestone or seashells (the raw materials for lime) in lime kilns. An important constituent of limestone and seashells is calcium carbonate ($CaCO_3$).

The formation of limestones, their nature, and the most important types used for lime production are explained. In the Netherlands, the use of shell lime has long been a primary source of $CaCO_3$n.

2.3.2 Mortar constituents

The constituents of lime mortars are discussed in Chapter 3 (Section 2: 'The raw materials for lime mortar'). However, the properties of a mortar are not determined purely by the properties of its constituents, but also by their relative amounts. The choice of a mix design for mortar must be made on the basis of the specific application for which the mortar is intended. This is discussed in Chapter 3, Section 6: 'The constituents and their proportions'. However, this publication is not a book of recipes! Putting together a mortar is work for specialists and must, therefore, be left in the hands of such mortar technologists.

2.3.3 Hardening

Following the discussion of the composition of mortar, attention is given in Chapter 3 Section 7 to 'The hardening of lime mortar'. The hardening of air-hardening lime mortars can be summarised in the lime cycle--the process from stone or seashell to hardened binder: Pieces of limestone or seashells (calcium carbonate) are transformed into calcium oxide by burning; After slaking with water, this calcium oxide becomes calcium hydroxide; The use of such mortar again results in a petrified lime--by reacting with carbon dioxide from the air, calcium hydroxide is transformed into calcium carbonate and the cycle is complete.

Depending on the mineral composition of the raw material, lime that is made from limestone (lump lime) sometimes contains not only lime but also so-called hydraulic secondary constituents. They react with water and lime to form hardening gels. These gels are responsible for the primary hardening of the binder. If there is still free lime (calcium hydroxide) present in the mortar after this primary hardening, then the primary hardening is followed by hardening due to the reaction between calcium hydroxide and carbon dioxide (provided of course that air is not excluded from the construction, for example, because the construction is under water). The last reaction is, thus, the same as during the hardening of air-hardening lime. This lump lime may, therefore, be looked upon as a mixture of a hydraulic constituent and air-hardening lime. The first hardens relatively rapidly, even under water, while the second hardens relatively slowly and only if carbon dioxide from the air can reach the lime. The degree to which the two constituents are present determines whether the lime is strongly or weakly hydraulic.

In the absence of (sufficient) hydraulic constituents, pozzolanic components may be added to the lime mortar in order to increase its hydraulicity and final strength. Together with these pozzolanic components, lime can harden more or less in the same way as hydraulic lime. The pozzolanic components may be either ground natural materials, such as trass, or artificial products such as crushed roofing tiles or other weakly-burned ceramic materials.

2.4 Sustainability and degradation

Chapter 4 deals with environmental influences and provides an insight into weathering, degradation, and related properties, such as durability. This chapter constitutes an important basis for the last part of Chapter 5, which deals with the use and composition of lime mortars (Section 3.2) and discusses some examples from daily practice (Section 4).

Based on scientific research and methodologies developed within European research programs (Franke et al. 1998; Van Balen et al. 1999; Van Balen et al. 2003a), an overview of damage types and damage causes to historic brickwork and pointing is given. For a variety of examples, advice for repair and preservation are presented.

2.5 Lime in preservation practice

Chapter 5 begins with a section on research methods that helps identify the circumstances in which lime can be used. This is based on the information given in the previous chapter. When investigating historical lime mortars, one can see that a great diversity of lime mortars were used in the past. The principal differences are in the proportions of binder and sand, the type of lime used (air-hardening lime or hydraulic lime), and the presence or absence of additives, such as trass. These differences can be explained, on the one hand, by exploitation of local and regional sites for obtaining the raw materials (limestone, seashells). On the other hand, a role is played by progress in technical expertise over time. Thanks to the expertise gained, the composition of mortars could be increasingly fine-tuned to the circumstances in which and for which the mortar was used (brickwork walls, dams and dikes, etc.).

The use of lime mortars in restoration or renovation work requires an understanding of the stone and the historical mortar to which it must adhere. Weather, wind, and other environmental influences are also important. The chapter ends with answers to eighteen questions collected from practitioners in the field of restoration. Finally, a few case studies of preservation, in which lime has been used, are presented in detail.

2.6 Postscript

The aim of the lime book is to describe the state of the art. Based on their own expertise, from both old and recent publications and from the contributions from the working group, the authors have attempted to draw as complete a picture as possible of lime-based mortars for pointing and bricklaying. The incentive behind this was not only the insight that equally good, if not better, mortars can often be made with lime as with the portland cement that is often used, but also sprang from the important conviction that conservation of monuments would benefit from the re-introduction of this material in the spectrum of products that are available for restoration work. If one gets to know the material better again, it will also be used more often.

A number of annexes have been added to increase the information, thus avoiding over-burdening the reader. The inheritance of property of Adriaan Bommenee from the eighteenth century and a publication of W.C. Brade from 1827 show interesting first-hand information on the use of lime at that time. A glossary, an extensive bibliography and translations of a summary in English, French, and German complete the annexes.

3 Conclusions

The book was released in September 2003 at a one–day conference in Breda (The Netherlands) to an audience of more than 300. The response from the audience at the conference and the interest that the book has received since, suggest that the Lime book fills a need for professionals and authorities in the fields of conservation and construction more widely. Translations of the Lime book are expected to become available in English and French. Even though the examples and historical references often refer to the Belgian-Dutch context, the information is expected to be valuable for professionals from other countries.

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