Frontiers of Architectural Research (2016) 5, 101–110

HOSTED BY

Available online at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/foar

Frontiers of Architectural Research

RESEARCH ARTICLE

The physical, chemical, and microscopic properties of masonry mortars from Alhambra Palace (Spain) in reference to their earthquake resistance

Hanifi Binici[a,*], Selim Kapur[b]

[a]Department of Civil Engineering, Kahramanmaraş Sütçü İmam University, Kahramanmaraş 46100, Turkey
[b]Departments of Soil Science and Archaeometry, Çukurova University, Adana 01330, Turkey

Received 12 January 2015; received in revised form 16 October 2015; accepted 27 October 2015

KEYWORDS
Al-Andalus mortars;
Alhambra Palace;
Microscopic properties

Abstract
Al-Andalus mortar is an ancient binding material (lime mortar) that was used for centuries in numerous historical buildings in Al-Andalus, Granada (Spain). The physico-chemical and microscopic properties of Al-Andalus mortars in Granada were studied as part of an investigation into the mineral raw materials present in the territory of Spain. Scanning electron microscope and X-ray diffraction analyses of eight main types of mortars were performed to show the presence of calcite, gypsum, quartz, and muscovite minerals with organic fibers. Chemical analyses of the specimens showed that high $SiO_2+Al_2O_3+Fe_2O_3$ contents yielded high values of hydraulicity and cementation indices. A significant result of this study was that mortars with high hydraulicity and cementation indices have high mechanical strengths. This characteristic may be the main reason for the earthquake resistance of the historical Alhambra Palace.

1. Introduction

The Alhambra Palace was first constructed in 1236 by the last Muslim emirs (kings) in Spain and the Nasrid Dynasty. Later, in the 16th century, the Palace was renovated and modified for King Charles V (Figures 1 and 2). Consequently, European features intermingle with some of the finest

*Corresponding author. Tel.: +90 344 2801660; fax: +90 344 2801602.
E-mail address: hbinici@ksu.edu.tr (H. Binici).
Peer review under responsibility of Southeast University.

http://dx.doi.org/10.1016/j.foar.2015.10.003

Figure 1 Map of the Andalusian state and location of Cordoba in Spain.

Figure 2 General view of Alhambra Palace.

examples of Moorish architecture in the world. Alhambra Palace incorporates many traditional Islamic details, such as column arcades, fountains, reflecting pools, geometrical patterns, Arabic inscriptions, and painted tiles. For many centuries, the maintenance of Alhambra Palace was neglected. Scholars and archeologists began restorations in the 19th century, and today, the Palace is a major touristic attraction and a UNESCO World Heritage site since 2007 (Jones, 2014; Mojtaba, 2009; Suarez and Bravo, 2014). Although the urbanization of Granada and the immense pressure of mass tourism raise the concerns of preventive conservators, the atmospheric risks related to the conservation of the Palace have yet to be sufficiently evaluated. In one of the few studies conducted to determine the indoor and outdoor air quality of the Alhambra monument, the application of complementary analytical chemical techniques was carried out to formulate a strategy for the preventive conservation of the monument (López et al., 1996; Horemans et al., 2011; Sarró et al., 2006). Some studies were recently conducted on pilot applications with compatible restoration mortars, which avoids the common practice of cement mortar mixtures (Cultrone et al., 2007; Binici et al., 2010; Boynton, 1980). The aim of the present study is to draw attention to the general