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SPECIAL ISSUE

Mineralogical and chemical characterization of historical mortars from military fortifications in Lisbon harbour (Portugal)

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Abstract Historical mortars from sixteenth to seventeenth century military forts located at the mouth of the Tagus River in Lisbon have been characterized by polarized light microscopy (PLM), thermal analysis (TG/DTA), X-ray diffractometry (XRD) and scanning electron microscopy + energy dispersive spectroscopy (SEM + EDS). The results indicate that the mortars used were all hydraulic lime-based. The presence of well-rounded lime lumps indicates a limited use of water during the lime hydration process. The detection of hydrated calcium chloroaluminate and carboaluminate compounds mostly at binder-aggregate interfaces provides evidence for the onset of pozzolanic reactions during mortar production as further confirmed by the presence of ceramic fragments in the aggregate fractions intentionally added by the fort builders to increase the hydraulic properties of the mortars. The higher mechanical strength and greater resistance to degradation processes imparted by these pozzolanic compounds could explain why, despite the extreme proximity of the investigated sites to the sea, salt weathering processes do not appear to have significantly affected the studied mortars.

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Introduction

The study and characterization of historical mortars has received remarkable attention in recent years from conservators, restorers and other professionals involved in the safeguard of European architectural heritage (Baronio et al. 1997; Riccardi et al. 1998; Sabbioni et al. 2001, 2002; Maravelaki-Kalaitzaki et al. 2003; Elsen et al. 2004; Moropoulou et al. 2000, 2002, 2005; Veiga et al. 2001; Candeias et al. 2005; Elsen 2006; Schiavon and Mazzocchin 2009; Silva et al. 2010). Historical mortars are composite materials consisting of an aerial (air hardening) or an hydraulic (water-hardening) binder (gypsum or lime based and, in the oldest cases, also mud) combined with an aggregate fraction commonly made up of sand-to-gravel sized mineral grains, rock and/or fossil fragments (Sabbioni et al. 2001; Elsen 2006). Aggregate material is usually derived from local beach or fluvial sand deposits available nearby the building/site under consideration (Schiavon and Mazzocchin 2009; Silva et al. 2010), although more unusual materials such as, for example, finely crushed pottery, tiles or bricks (the "cocciopesto" mortar for instance, widely produced during Roman times) have also been used. Hydraulic binders are characterized by two main properties: (a) they harden in the presence of water and (b) they produce a mortar with water-resistant properties (Baronio and Binda 1997).

The textural, mineralogical and chemical characterization of historical mortars provides useful information regarding the history of buildings, particularly as far as age, social context, construction techniques, past restoration