CONSERVATION OF ANCIENT MORTARS AT SAGALASSOS - TURKEY

Prepared by J. Elsen, G. Mertens, P. Degryse and M. Waelkens,
Katholieke Universiteit Leuven, Belgium.

1. Introduction

Since 1990 regular archeological excavations have been carried out in the city of Sagalassos by the Catholic University of Leuven (Belgium), directed by M. Waelkens. Sagalassos is situated in southwestern Asia Minor, at an altitude between 1300 m and 1600 m in the western Taurus mountain range (Figure 1). The city rose in importance during the Hellenistic period and it became the wealthiest city of Pisidia in Roman Imperial Times [1]. After a systematic survey of the city and its mapping, the enormous scientific potential of the virtually untouched site became clear and it was decided to carry out an interdisciplinary research approach involving a systematic study of the whole territory of classical Sagalassos, involving inter alia geomorphologists, palaeobotanists and archeozoologists. One of the research topics of this interdisciplinary approach is the mineralogical and petrographical study of the ancient mortars. A great number of mortar samples used for different building purposes and dating from the late-Hellenistic to the early-Byzantine period were collected for analysis and characterised following the methodology as described in Middendorf et al [2]. Detailed results of these studies can be found in [3] together with the results of experimental mixtures of restoration mortar that have been tested for strength and frost resistance using the same or similar raw materials as in ancient time.

Figure 1: The location of Sagalassos in modern Turkey, +/- 120 km from Antalya.
2. Description of ancient mortars

With respect to their function, the mortars can be divided into two main groups. The first group consists of mortars used in architectural structures and tombs from the beginning of the Imperial period to the 6th - early 7th century AD. This group includes masonry mortars used to bind building blocks (mostly bricks and limestones), mortars used in rendering and mortars from fills and foundations. The second group consists of mortars used in various water-related structures and includes mortars from casings of water conduits, jointing compounds from terracotta pipes and mortars used in the rendering of reservoirs and aqueducts.

At Sagalassos three different types of aggregates were used. The first type of aggregate is a pure limestone and originated, as the lime itself, from the local limestones of the Lycian nappes, omnipresent in the vicinity of the city and composed of Mesozoic to early Tertiary marine sediments. The limestone aggregate fragments show the same characteristics as the limestones identified in the building stones of Sagalassos. The limestone around Sagalassos is rather pure and it is logical that the inhabitants of the Roman period should have chosen it as a raw material. Because lime lumps can be found in the mortars dry slaking is assumed [4]. Crushed ceramics as an aggregate are found from early Hellenistic to early Byzantine times in mortars related to water-bearing constructions, but no signs of puzzolanic properties were identified. Samples taken in a context of water-related constructions containing no ceramics belong to load-bearing parts of the construction or surround terracotta water pipes, keeping the pipes in place rather than making the construction watertight. At Sagalassos, crushed ceramics also occur in mortars not directly related to water-bearing constructions but for example to protect the inside of the wall from moisture. The third type of aggregate used at Sagalassos is volcanics, which were added to the lime mortars by both Greeks and Romans probably because of their puzzolanic properties. Mortars with volcanic aggregates were used for construction purposes where strength in compression was necessary, for instance in the masonry of the Roman Baths in Sagalassos. Petrographically, the aggregates in these mortars are very similar to volcanic deposits from the region of Gölcük, NW of Sagalassos. Both lava and pumice fragments and zoned augites and plagioclases are observed in the mortars as in the rocks from the volcanic region. The fragments in the mortars often have broken rims, indicating that the hard tuff and lava layers have been crushed. A detailed study of samples from the volcanic deposits of the region of Gölcük region, mainly consisting of tuff layers, observed as cliffs and as loose sandy material, has shown that the volcanic rocks of this area have been used as aggregates in the mortars of Sagalassos.

3. Conservation of ancient mortars

Several buildings at Sagalassos have been subjected to conservation studies and a first experimental study has been carried out to design a suitable mortar for restoration and conservation purposes with the durability against frost resistance as one of the central issues. The frost regime at Sagalassos is high with high amounts of rainfall (885mm per
year), long periods of frost (7 months) and a very high number of freeze/thaw cycles (100 cycles or more per year). For this first experimental study, mortar test objects were prepared with the different raw materials and compared with the Roman mortars from Sagalassos. For the production of quicklime, local limestone was taken from the Lycian nappes north of the city of Sagalassos. Lime was prepared in the laboratory by burning fragments <4.75 mm of the limestone samples for five hours at 900°C with a heating and cooling rate of 5°C per minute. Slaking was done by immersing the CaO in a linen bag under water until no more reaction was observed. The aggregate/lime ratios used for the mixes were obtained from the ratios that were estimated from the results of the image analysis measurements on thin sections from the ancient mortars. The ratios used, given as weight %, were: lime-grog 65-35; lime-volcanics 45-55; lime - grog - volcanics 40-40-20. A measure of the mortar strength was obtained by Grindosonic E-modulus measurements and a uni-directional freezing test (TNO-test) was carried out to determine the frost resistance of the prepared mortar objects. The detailed results can be found in Degryse et al [3].

Mortars with only grog (of building ceramics or common wares) as an aggregate were not suitable for building purposes as it was clear that the mortars containing grog are not frost resistant to a high frost regime. The mortar strength can be enhanced by adding local limestone as an aggregate to the mix. Also the addition of grog to a volcanics/limestone mix enhances the mortar strength. However, the best results for mortar frost resistance strength was obtained by using limestone and volcanics from Gölcük. Mortars with volcanic aggregates, with or without limestone fragments, were used for most building purposes or on exterior surfaces. The mortars with the addition of grog are suitable for circumstances where frost resistance has no interest.

4. Mix design on restauration mortar

The last decade different conservation teams have been working during the summer campaigns on several buildings at Sagalassos. The conservation of the ancient walls using restoration mortars is one of the main issues. The results are rather moderate especially those from the first conservation campaigns. The reason for these sometimes poor results are the following. Firstly, as discussed before, winters at Sagalassos involve a high frost regime with high amounts of rainfall, long periods of frost and a high number of freeze/thaw cycles. Secondly, due to organizational and technical reasons, the conservation team can only operate from July on till end of August, while the first longer raining periods are already starting during the months of September and October. Third difficulty is that the conservation mortars are applied in very hot and sometimes windy conditions. These environmental conditions can result in rapid shrinkage, drying cracks and debonding problems. Prevention measures against rapid shrinkage are the covering of the masonry work with jute bags and by water sprinkling during several days. Another preventive measure against drying shrinkage during the last campaign (2004) was the use of wood ash as water retention admixture.
The composition of the restoration mortars applied during the summer campaign of 2004 is the following (vol. parts):
- 1 part pumice sand,
- 1 part river sand,
- ½ part wood ash,
- 1 part lime,
- small amount of fibers.

A new experimental research programme is foreseen with the objective to comply the following requirements:
- compatible with the historic materials,
- durable in severe winter climatic conditions,
- suitable to be prepared and to be applied in hot and windy conditions,
- use of locally available materials.

Three different types of lime binders will be evaluated (white cement is no alternative); two different natural hydraulic lime types and one locally available non-hydraulic lime. As a result of the first research programme [3], a combination of local limestone and volcanic sand will be used as aggregate. The lime/aggregate ratio will be varied and different admixtures will be evaluated (air entrainer, wood ash, fibers...). A great number of masonry samples will be prepared at Sagalassos during the 2005 summer campaign. The masonry elements will be exposed at Sagalassos under different conditions and evaluated in 2006. Part of the samples will be tested for frost resistance in Leuven using an accelerated freeze-thaw test.

Figure 2: Part of a wall from the Roman Baths at Sagalassos, which has been restored by the conservation team with moderate success.
5. References


