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# Cement Mortar Restorations and Disorders in the Archaeological Site of Chellah

Meriem Benharbit

Institut National des Sciences de l'Archéologie et du Patrimoine

***Abstract—*** *The restoration works undertaken in the archaeological site of Chellah in the Sixties used cement for the consolidation of the Roman structures undercovered. They're mainly consisting of calcareous rocks, which density, porosity, and hardness are lower then cement, and they're clearely weakened. Indeed, the capillary increase to which are subjected the structures allowed to convey salts whose advance is blocked by the introduced cement mortar. Trapped in the calcareous rock, the salts contribute to the acceleration of its degradation.*

***Keywords—Chellah, restoration, incompatibility, stone, cement.***

## I. INTRODUCTION

In the 1960s, Chellah's archaeological site saw the consolidation of masonry and structures following the discovery of buildings dating back to Roman times. As a result of this work, where the cement mortar was massively used to reinforce the masonry, important disorders appeared in the calcareous stone. The purpose of this article is to underline the incompatibility of the mortars used with the stone used for the construction of the Roman buildings and to identify the disorders and saline phases involved in the deterioration of the cut stone.

## II. PRESENTATION OF THE ARCHAEOLOGICAL SITE OF CHELLAH

The archaeological site of Chellah, located 4 km away from the Atlantic coastline overlooks the Bou Regreg valley and occupies an intramural area of about 7 hectares. The site had a Phoenician occupation in the 6th century BC and Carthaginian in the 12th century BC. Later, the Romans settled there and founded a city mentioned by the Greek astrologer and astronomer Ptolemy under the name of Sala, and a river port serving as a Mediterranean counter (Basset H., and Levi-Provençal E., 1929, Basset H., and Terrasse H., 1932, Boube J., 1966). This prosperous Roman city surpassed the site of the Merinid precinct, which still encircles it in the direction of the river. Chellah was then deserted and abandoned before being occupied again by the Merinid sultans who built a necropolis named Al-Ribat Al Mubarak. An inscription in kufic script on the front door indicates that the work was completed in 739 AD / 1339 AD. The surrounding walls of the Merinides encircle the remains of the Roman cities, including the capitol, the forum, the thermal baths, a nymphaeum and a triumphal arch. A mosque, a medersa, a mausoleum, rooms for ablutions and several funerary rooms remain. The site, property of the state, is protected since November 19, 1920 by the royal decree, which defines as national historical monument the whole complex of Chellah. Since 2012, Chellah is part of the the sites of Rabat inscribed on the list of World Heritage of UNESCO as cultural property.


*Fig. 1: Localization of the archaeological site of Chellah in the town of Rabat – Morocco*

*Fig. 2: Panoramic view of the archaeological site of Chellah*

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## III. CHARACTERIZATION OF MATERIALS USED IN CHELLAH

The cut stone used in the construction of the Roman structures, of plio-quaternary age, is outlined in the form of a system of elongated dune cords juxtaposed parallel to the line of the Atlantic coast from El Jadida to Larache. It corresponds to the local appellation of calcarenite of Salé.
The rock, of beige color, shows stratification levels (So). The grain is predominantly millimetric. The petrographic study of the calcarenite shows a detrital fraction composed of rock debris and quartz grains and a bioclastic fraction (Lamellibranchiata, brachiopods and echinoderms shell fragments). These elements, which may present specific variations in terms of content and particle size, are linked by a mainly calcareous phase.
The mechanical strength of the salt stone is about 50 MPa (Asebriy L., 2010). It is in fact sufficient to allow its use as a building stone but remains relatively weak, making its extraction, size and sculpture quite easy compared to other massive rocks of the region.
The rock has an important porosity ranging from 25 to 35% (Rahmouni A., et al., 2013) releasing cavities of varying shape and size. This porosity conditions the sustainability of the rock in the long term: it regulates fluid transfers, gives the material a surface roughness for fixing pollutants, and also opens the way to biological colonization.

*Fig. 3: Macroscopic aspect of the calcarenite of Salé*

## IV. STATEMENT OF THE DESORDS

The archaeological site of Chellah is an excellent exemple of natural site.The materials are exposed there to the severe weather, with the animal and vegetable biological breakdown, and the action of the man (Benharbit, 2017) . To these factors, the consequences of defective restoration works undertaken in the Sixties in order to consolidate the structures of the buildings, are added. There are also various figures of deterioration such as illustrated in glossary ICOMOS (2008) going, from the least harmful, of simple efflorescences saltworks to more or less dense saline encrustings “fig. 4 and 5”. However, other figures witnessing of more advanced disorders are also present: sandy disintegration “Fig.6”, alveolation “Fig.7” and gullying “Fig.8”.

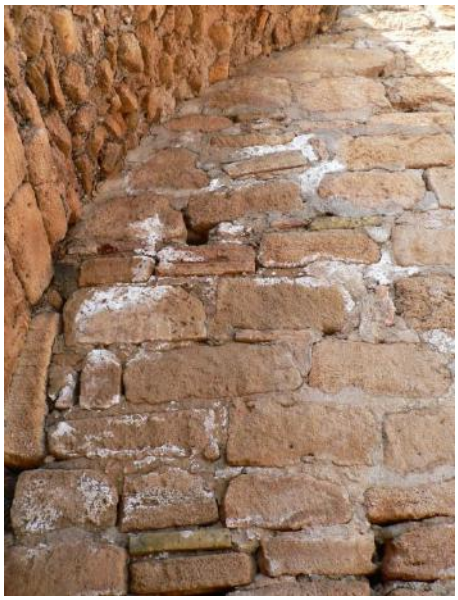

*Fig. 4: Damage Salt develops as encrustation covering the stone in interface with cement mortar*

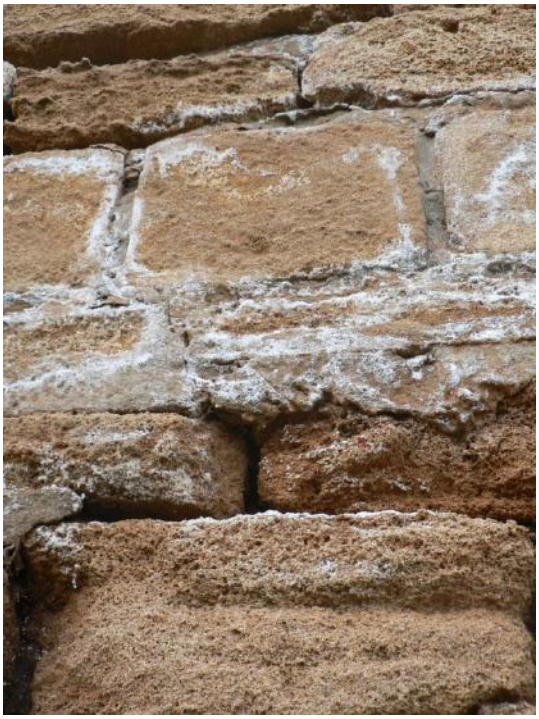

*Fig. 5: Details of the saline efflorecences and encrusting on the calcarenite of Salé, at the interface stone-mortar*

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*Fig. 6: Granular decomposition of a block of calcarenite, consequence of the use of a hard cement mortar. The rock has grown into a single alveolus.*

*Fig. 7: formation, on the stone surface, of deep interconnected cavities*

*Fig.8: In contact with cement mortar, the rock has deep grooves that hollow out the material highlighting the hardest levels*

## V. DETERMINATION OF SALINE PHASES

Sampling was carried out on the saline coverings developed at the stone-mortar interface and observed using the Moroccan Foundation for Advanced Science, Innovation and Research (MAScIR) environmental field emission electron microscope (FEG). Observations show that the surface of the rock is lined with deposits of potassium sulphate. “Fig. 9” and cracks propagating between the aggregates" Fig. 10 ".

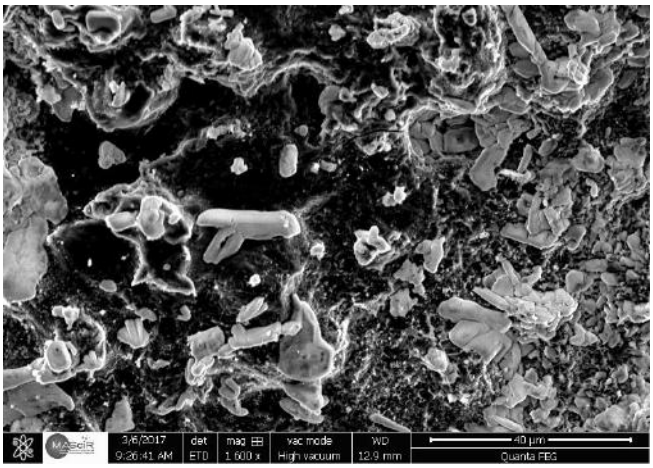


*Fig.9: observation with the MEB (X 1600) of potassium sulphate deposits recovering the surface of the calcareous rock*

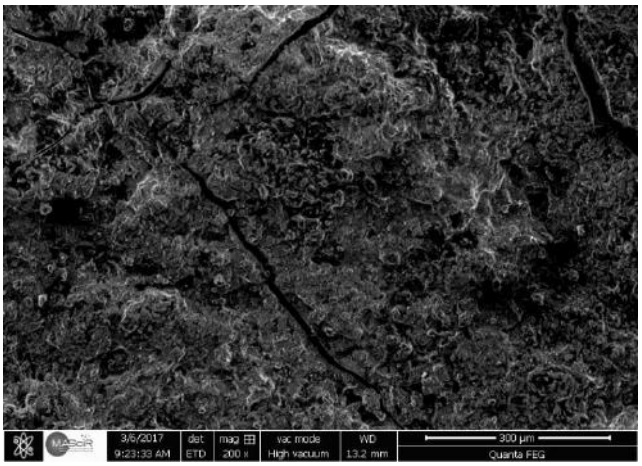


*Fig.10: development of microcracks propagating on the surface of the rock*

Analysis of the salt deposits formed shows the presence of potassium sulphate $K_2SO_4$. This salt is commonly used as a fertilizer, potassium being an element that promotes the accumulation of reserves in both raciness and fruit.

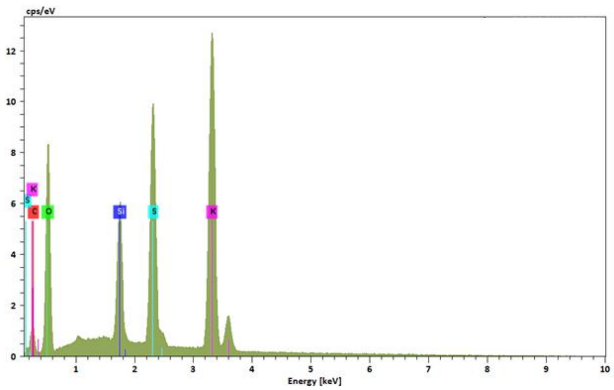


*Fig.11: elementary spectrum of analysis obtained with the MEB of crystallizations saltworks showing of the potassium and sulphur peaks*

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In Chellah, masonries are not isolated at their base. The capillary increase of water since the ground convey these salts which forward owing to the porosity of the rock. The cement mortar used to joint the blocks of calcarenite constitutes an obstacle for the mobility of the fluids which concentrate and deposit, during evaporation, the elements dissolved in the porosity of the rock. These salts generate disorders which are studied since the the 19th century (Turner, 1833). The constraints exerted by salts in the course of growth on the walls of the porous network of the rocks (Scherer 2004, Putnis and Mauthe, 2001) can in the long term create and/or to widen cracks in the rocks.

## VI. CONCLUSION

The restorations undertaken in the Sixties used the cement mortar to consolidate the structutres of the buildings going back to the Roman occupation. Cement's higher quality supposed then, dependening on its hardness and to the promptitude of the catch, had contributed to its very broad use in the field of the restoration. This hardness is unfortunately not the pledge of durability desired for masonries. Indeed, the strong sealing of the ciment mortar forbid the water contained in the stone to migrate in the mortar and to evaporate. Salts are trapped on the level of the porous calcareous rock contributing thus to the acceleration of its degradation. Various facies of degradation developed on the site: efflorescences saltworks, sandy disintegration and gullying of the blocks of rock under the effect of the pressures of crystallization which lead to the progressive unsetting of the components of the calcarenite.

The analyzed superficial saline efflorescences indicated potassium sulphates used like fertilizer and which forward in the rock owing to capillary lift.

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