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PREFACE

It is my great pleasure to welcome you, the participants of the 6th Historic Mortars Conference (HMC 2022), live and online, at the Faculty of Civil and Geodetic Engineering of the University of Ljubljana. The HMC 2022 Conference is held this time as a hybrid conference, with seventy live and ten online participants. The participants come from all five continents, despite the restrictions due to the COVID-19 disease.

Today, we can already say that the HMC conferences have become an internationally recognized series of conferences designed to inform the scientific and professional public about the progress of materials and technologies in the field of preservation, conservation and strengthening of historic structures. The implementation of the conferences is supported by the members of the technical committees of RILEM in the fields of historic mortars and grouts and test methods for evaluating their properties. Therefore, HMC 2022 is a conference supported by RILEM. Ljubljana is the sixth European city in a row to host a HMC conference, after Lisbon, Prague, Glasgow, Fira on Santorini and Pamplona. I would therefore like to take this opportunity to thank my predecessors who have presided over these conferences. Rosario Veiga, Jan Valek, John Hughes, Ioanna Papayianni and Jose Ignacio Alvarez, without you there would be no HMC 2022.

The topics of HMC 2022 are not much different from those of previous conferences. This time, however, the focus is more on historic materials, where Portland cement is the binder, and on the structures in which these materials are used. This is related to the Slovenian architect Jožef Plečnik, who used cement and concrete in abundance. Ljubljana, but also Vienna, Prague and Belgrade, were most influenced by his architectural work. In 2021, selected works by Plečnik in Ljubljana were included in the UNESCO List of World Cultural and Natural Heritage, and the Government of the Republic of Slovenia declared 2022, when we celebrate the 150th anniversary of the architect's birth, as Plečnik Year.

It is therefore no coincidence that both invited speakers at HMC 2022 will focus on Plečnik's legacy. Prof. Johannes Weber will present the advantages of image-related microanalysis using samples from Plečnik's buildings, while Ana Porok, curator of the Plečnik House, will present Plečnik's Ljubljana to the conference audience.

The venue of the conference is the main building of the Faculty of Civil and Geodetic Engineering of the University of Ljubljana, which is protected as architectural heritage. I would like to thank many who made HMC 2022 possible: the faculty's management and support services, the sponsors for their invaluable support, my colleagues at the Chair of Testing in Materials and Structures, as well as Robert Klinc and Romana Hudin.

The conference does not only consist of lectures and discussions after lectures and during the breaks. An important part is the informal gatherings of the participants. In Ljubljana, we will meet in two important historic buildings, the Ljubljana Castle and Cukrarna, a former sugar refinery that now serves as an exhibition space for contemporary art. This was made possible by the Mayor of Ljubljana, Mr. Zoran Janković. Therefore, a heartfelt thank you to the City of Ljubljana and the Mayor.

My special thanks go to the members of the Scientific Committee of the conference for their dedication and responsiveness in the process of reviewing the papers, and for many constructive comments and suggestions for improvement. Thanks to your, the contributions in the conference proceedings are of very high quality.

Last but not least, I would like to thank all the speakers, chairpersons and conference participants. Together you make this HMC 2022 a success.

prof. dr. Violeta Bokan Bosiljkov

HMC 2022 Chair

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A STUDY ON HISTORIC MORTARS FOR RESTORATIVE APPLICATIONS IN PERSEPOLIS WORLD HERITAGE SITE: CURING IN SITE VS LABORATORY

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Abstract: Two types of air lime mortars with inclusion of sesame cooking oil were synthesized. The behaviour of mortars in the site conditions and the laboratory can be distinct. Hence, the mortars were cured in two laboratory and natural climatic conditions of and Persepolis World Heritage Site. The mortars were monitored for two years under both conditions and the results demonstrated distinctions in characteristics of mortars, emanating from curing conditions. The air lime mortars cured in the site conditions exhibited increment in durability and hydric properties. In the natural outdoor conditions, some effects of addition of organics to mortars, such as retarding their setting time were less highlighted compared to laboratory curing mortars.

1 Introduction

Compatibility is a key requirement for restorative materials. Lime mortars are generally known compatible materials for historical masonries restorative actions; however, inclusion of various additives have been carried out to improve the function of these materials toward water and water vapour. Hydric improvements of lime mortars were usually concluded when various fatty organics were included in the mixes in modern and studies [1-3]. A study demonstrates that the unsaturation level of additive fatty acids is a key parameter for hydrophobization of oiled lime mortars [4]. Nevertheless, most of the characterizations and studies have been occurred when the mortars were made and cured in laboratory conditions, whilst the complexities of climatic parameters in real climatic conditions could occur substantial alterations in the tests results.

This study has investigated restorative mortars for actions in Persepolis world heritage site (Iran) where a great need for provision of economic, compatible and sustainable restorative mortars was reflected. Conservation actions in the historical developing is highly dependent on economic part of plan of conservation [5] as economic values of restorative materials can increase the conservation domain potentials [6-8].

The organic additions has been demonstrated enhancements in a recent study under laboratory conditions, [4] with a similar mix-design used in this study. This research explores the lime mortars with local components in inclusion of sesame cooking oil in laboratory and the natural site conditions of the designated historical site (Persepolis), simultaneously.

2 Materials and Methods

As commercial lime putty production in the country of the in-situ application (Iran) is not valid, high calcium content lime putty (Calcium hydroxide) as the main component for the mortars mixes was produced in the laboratory. The putty was classified as CL 90S according to EN 459-1 [9] composed of micronized high calcium powder as a commercial product (90%<Ca(OH)2<93%) was slaked for 3 months with distilled water to produce 49 w.t.% water content lime putty. The non-reactive part of the mortars was composed by three different stone powders and a type of sand (particle size of 1-2 mm), from a local (Pulvar) river.
The characteristics of the additive sesame oil used in this research and the methods for mixture creation and casting is explained in detail in a previous study [10].

Table 1. Mix-design of the investigated samples.

Sample	Mix	Curing Condition	$Ca(OH)_2$ [wt. %]	Non-reactive part [wt. %]	Kneading water [wt. %]	Oil [wt. %]
SITE1	M1	In-situ	27	66	7	0
SITE2	M2	In-situ	25	66	7	2
LAB1	M1	Laboratory	27	66	7	0
LAB2	M2	Laboratory	25	66	7	2

The mortars were molded in disc-shaped plastic molds (diameter = 60 mm, thickness = 20 mm) over a glass support and were demolded after 24 hours. The laboratory series of the mortar samples (LAB) were kept at lab conditions (Temperature=22 ± 2 °C, RH=50±5 %) for the rest of their curing period. The outdoor curing series (SITE) of mortar samples were kept in the site (temperature of the mortar production week=8-23°C, RH=23±5 %). In order to enhance the comparability of the characterizations with the recent studies, the samples were characterized after 180 days of curing.

3 Characterizations

The mortar samples were characterized in terms of

- Calcium carbonate formations by a Dietrich Fruhling calcimeter
- Open porosity by mercury intrusion porosimeter (MIP)
- Water absorption (WA) in 24 hours by the formula: $WA24h = [(mssd - mdry)/mdry] \times 100$
- Vapour permeability according to EN 1015-19 [11]
- Superficial durability by destructive freeze-thaw life cycles

The detailed process and methods of the characterizations in explained a previous paper [10].

4 Results and Discussions

The results of the open porosity values, calcium carbonate formation, impermeability (water vapour resistance) coefficients, and water absorption values are reported in Table 2.

Table 2. Results of various characterizations of the mortar samples

Samples	Open porosity [%]	Calcium carbonate formation [%]	Impermeability coeficient	WA_{24h} [%]	Surface soundness after 15 destructive freaze-thaw cycles
SITE1	35.0	78	4.9	18.1 (± 0.3)	NO
SITE2	34.5	77	3.9	1.2 (± 0.4)	YES
LAB1	40.5	72	4.2	16.5 (± 0.3)	NO
LAB2	33.2	68	4.5	4.5 (± 0.5)	YES

As it can be found in the results, addition of sesame cooking oils in the air lime mortars led to substantial hydrophobic effects such as considerable reductions in water absorption values: over 70 % water gain reduction when the samples were cured in laboratory and about 90 % reduction when the mortars were cured in the site conditions. The oiled mortars demonstrated higher hydrophobicity when cured in the natural climatic conditions.

The open porosity values, did not demonstrated a considerable alteration for the oiled mortars, in various curing conditions. However, open porosity of the mortars cured in the laboratory, showed a 7 % reduction in inclusion of additive oils.

Oil additions in the air lime mortar samples adversely affected carbonation and permeability values for the mortars cured in laboratory. This had been reported in previous studies. Nevertheless, when the mortars were cured at the outdoor conditions no negative effect on carbonation process and permeability of the samples was observed. This can be due to existence of numerous climatic parameters in the outdoor condition of natural site, compared to the laboratory such as air flow and thermal variations. These parameters affected the condition for the site cured mortars: the carbon dioxide gains and microstructural alterations consequently demonstrates 78-80% of calcium carbonate after 180 days of curing.

The inclusion of fatty acid-based organics as additives in the mortars, could raise concerns regarding long term durability issues such as biological attacks. Apart from all laboratory scale verifications that are required in the future researches, a preliminary monitoring of the mortars was necessary. In this stage, the mortars were applied in the in-situ applications and monitored for two years. The appearance stability, durability, verification of hydrophobic values and contact angles after 24 months exposure to weathering we studied and the results after thorough analysis will be reported in the future publications. The oiled mortars manifested a sound physical appearance, however, the non-oiled samples demonstrated various detachments due to their water gain and extended volume of the frozen water in their porous hydrophilic structure.

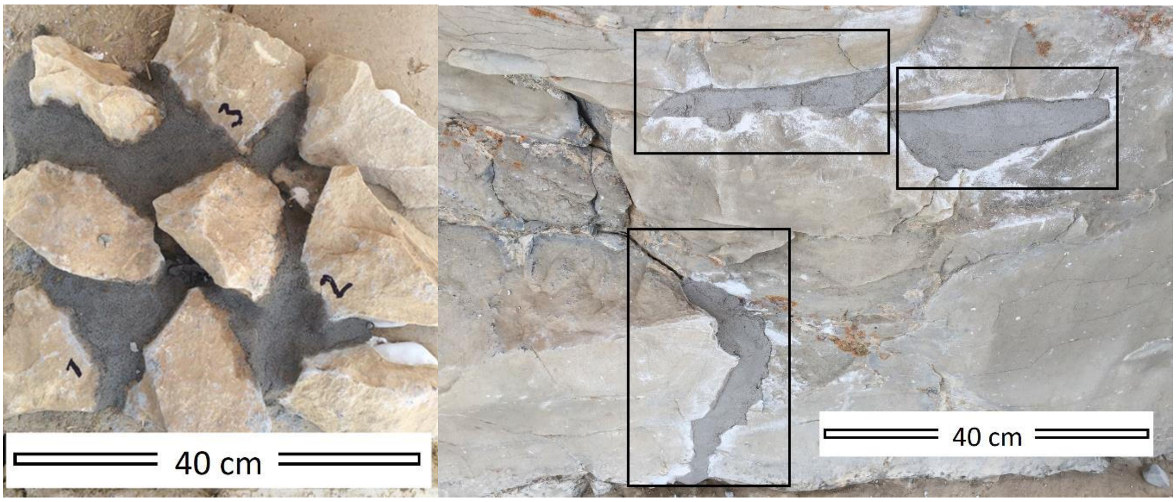

Figure 1. Left: Repointing the staged condition of stones in the site; Right: Repointing joints of a real structure in Persepolis site for durability monitoring

5 Conclusions

Climate change and considerable reduction of relative humidity in the recent years of the region of this application (10 % reduction of RH since 2010) urges the application of air lime mortars rather than hydraulic lime for conservation actions. Addition of sesame oil to air lime mortars have considerably enhanced their hydric properties. Furthermore, no biological attack or durability issue was reported in the two years of the in-situ monitoring of the applied mortars. An enhancement of hydric properties of air lime mortars in presence of sesame oil occurred in the in-situ conditions with more complicated climatic parameters compared to the laboratory. Effect of some climatic parameters such as air flow and daily thermal variations did not manifest adverse effects on the characteristics of the studied mortars.

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