VIII Congresso Nazionale di Archeometria
Scienze e Beni Culturali: stato dell'arte e prospettive
Bologna 5 - 7 Febbraio 2014

INNOVATIVE CONSOLIDATING AGENTS FOR STONE MATERIALS: CLIMATE IMPACT EVALUATION

I. Natali[1*], F. Becherini[2], A. Bernardi[2], C. Ciantelli[1], M. Favaro[3], O. Favoni[4], V. J. Forrat Pérez[5], I. Olteanu[6], M. D. Romero Sanchez[5], P. Tomasin[3], A. Bonazza[1]

[1]Istituto di Scienze dell'Atmosfera e del Clima, ISAC-CNR, Bologna
[2]Istituto di Scienze dell'Atmosfera e del Clima, ISAC-CNR, Padova
[3]Istituto per L'Energetica e le Interfasi, IENI-CNR, Padova
[4]Università Politecnica delle Marche
[5]Instituto Tecnológico de la Construcción, AIDICO, Spain
[6]DUCT SRL, Bucuresti, Romania

Climate and environmental parameters are directly or indirectly involved in almost all decay processes for outdoor cultural heritage. In this context, climate change is believed to play a driving role in diversifying future damage processes and efforts have focused on the prediction of the impact of climate change on damage effects on stone materials [1-4]. Therefore, consolidating and protective agents are often needed to reduce the effects of the environment on original substrates. Among inorganic consolidants, nanostructured materials have been largely studied and successfully used according to criteria of stability and high compatibility with the inorganic matrices [5-8] although data still lacks regarding their durability in outdoor conditions.

The European Project NANOMATCH is focused on the development of innovative and durable inorganic nanomaterials for the consolidation and protection of Cultural Heritage substrates. An alkaline earth alkoxide as precursor of calcium carbonate has been synthesized as stone consolidating agent, being capable to penetrate the porous substrate and to form a calcium carbonate coating on the pore walls. Efficacy, compatibility and durability are the three main goals to be achieved by the innovative consolidating agent developed within the project.

After the identification of the most suitable synthetic route to produce the metal-alkoxides, a final formulation for stone treatment has been set up for the application on carbonate stones. Representative carbonate building stones from different European countries and historical substrates characterized by ongoing damage processes have been selected to be treated and then exposed to outdoor conditions in four different European sites (Tab. 1) in order to test efficacy, compatibility towards substrates and durability against climate attack of the innovative consolidating agents.

Rain, relative humidity, temperature, wind and solar radiation have been prioritized among climate parameters for establishing methodologies aimed at assessing the long-term behaviour of treatments. Moreover, specific pre-treatments aimed at simulating deterioration on Carrara marble specimens as well as on Savonnières limestone ones have been carried out (Tab.1). The scheme of exposure is illustrated in Fig.1. Furthermore, microclimatic stations have been installed nearby the rack hosting stone samples.

The performance of the newly developed product is evaluated by comparing results obtained: (i) before exposition, (ii) after six month and (iii) after one year of exposure by means of Optical Microscopy, Scanning Electron Microscopy, Mercury Intrusion Porosimetry, Spectrophotometry (color measurements), Scotch Tape Test and Capillarity water absorption

tests aimed at investigate surface properties, penetration depth, interactions with substrate, cohesion, color change.
Preliminary results concerning consolidating effect are presented and discussed.

Tab. 1. Summarizing table of substrates' treatments before exposure

SITE	SUBSTRATES 10x10x5 cm^3	ARTIFICIAL DETERIORATION	TREATMENT
Florence, Italy Santa Croce Basilica	**Carrara Marble**	**Thermal shock (600°C for 1h)**	**NANOMATCH Product - CaLoSiL**
Cologne, Germany Cathedral	**Carrara Marble**	**Thermal shock**	
	Savonnières limestone	**contaminated with a 5% w/w Na_2SO_4 solution**	
Oviedo, Spain Cathedral	**Carrara Marble**	**Thermal shock**	
	Laspra dolostone	**-**	
Bucharest, Romania Stavropoleos Monastery	**Carrara Marble**	**Thermal shock**	
	Albeşti limestone	**-**	

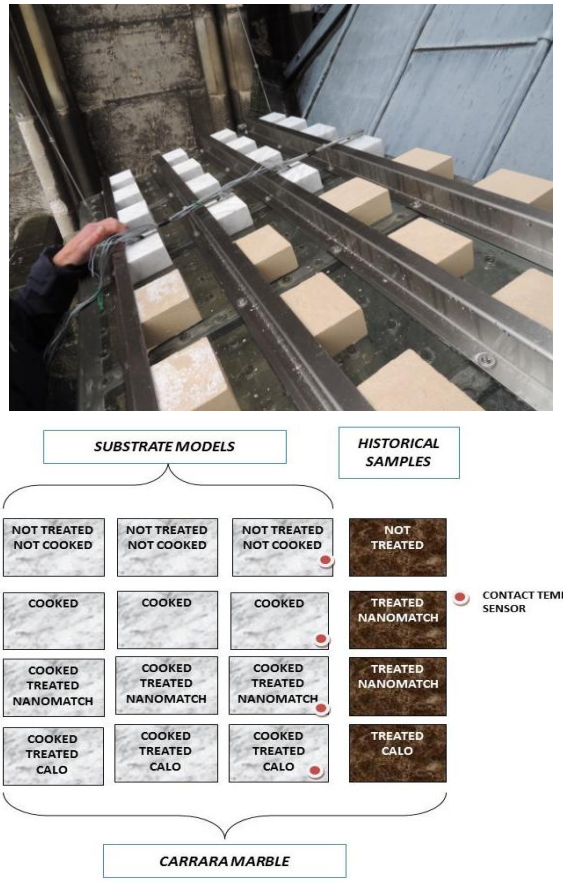

Figure 1. Field exposure tests at Cologne Cathedral, Germany (left); scheme of exposure for Carrara Marble in Florence (right).

Acknowledgments
This research has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement number: 283182.

References

[1] Sabbioni, C., Brimblecombe, P., Cassar, C. (Eds.), 2010. The Atlas of Climate Change Impact on European Cultural Heritage. Scientific Analysis and Management Strategies, Anthem Press. ISBN 9781843317982.
[2] Grossi, C.M., Brimblecombe, P., Harris, I., 2007. Predicting long-term freeze-thaw risks on Europe built heritage and archaeological sites in a changing climate. Sci. Total Environ., 377: 273-281.
[3] Grossi, C.M., Bonazza, A., Brimblecombe, P., Harris, I., Sabbioni, C., 2008. Predicting twenty-first century recession of architectural limestone in European cities. Environ. Geol., 56: 455-461.
[4] Bonazza, A., Messina, P., Sabbioni, C., Grossi, MC., Brimblecombe, P, 2009. Mapping the impact of climate change on surface recession of carbonate buildings in Europe. Sci. Total Environ., 407: 2039-2050.
[5] Ambrosi, M., Dei, L., Giorgi, R., Neto, C., Baglioni, P., 2001. Colloidal particles of $Ca(OH)_2$: properties and applications to restoration of frescoes. Langmuir, 17: 4251–4255.
[6] Rodriguez-Navarro, C., Ruiz-Agudo, E., Ortega-Huertas, M., Hansen, E., 2005. Nanostructure and irreversible colloidal behavior of $Ca(OH)_2$: implications in cultural heritage conservation. Langmuir 21: 10948–10957.
[7] Dei, L., Salvadori, B., 2006. Nanotechnology in cultural heritage conservation: nano-metric slaked lime saves architectonic and artistic surfaces from decay. J. Cult. Herit., 7: 110–115.
[8] Natali, I., Saladino, M.L., Andriulo, F., Chillura Martino, D., Caponetti, E., Carretti, E., Dei, L., 2013. Consolidation and protection by nanolime: Recent advances for the conservation of the graffiti, Carceri dello Steri Palermo and of the 18th century lunettes, SS.Giuda e Simone Cloister, Corniola (Empoli). J. Cult. Herit., http://dx.doi.org/10.1016/j.culher.2013.03.002.