

## **CAPPADOCIAN RUPESTRIAN CHURCHES AND CONSERVATIVE STRATEGIES: FROM THE LAB TO THE ARCHEOLOGICAL SITE**

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The uniqueness of Cappadocian landscape (Turkey) is related to the differential weathering and erosion of the Miocene-Pliocene ignimbrites [1] changed in characteristic “fairy chimneys”. They were carved by ancient populations and transformed in dwellings or rupestrian churches with very precious wall paintings. The fairy chimneys are affected by decay phenomena as freezing-thawing cracks, scaling, flaking, crumbling, discoloration [2] and lichenic colonization that threat the conservation of rupestrian churches. Objects of this paper are the rupestrian churches of Tokalı in Göreme Open Air Museum and of the Forty Martyrs in Şahinefendi village (Fig. 1). The study of the minero-petrographic features of the ignimbritic rocks and especially how well preserved they are, suggest that a consolidation intervention is needed to slowdown the weathering processes.

The goal of this paper is to test some consolidating products, compatible with the rocks composition, and to evaluate their effectiveness [3].

The following products have been used at several concentrations: NanoEstel (water dispersion of silica nanoparticles), Estel 1000 (ethyl silicate in white spirit), Estel 1100 (ethyl silicate and polydimethylsiloxane in white spirit), Syton W30 (water dispersion of silica particles) and Syton X30 (water dispersion of silica nanoparticles).

The analyses were carried out both in laboratory and *in situ*. In laboratory, the products have been applied on rock specimens to evaluate their performance by colorimetric test, SEM-EDX analysis to detect penetration depth, measurements of porosity by capillarity test [4] and mercury intrusion porosimetry (MIP).

Moreover, products and ignimbrites fragments were mixed to evaluate their re-aggregating capability and suitability for stucco. The consolidated specimens (Fig. 2) were subjected to peeling test, point load test and shear strength test.

After laboratory tests, some treatments have been selected and applied *in situ* nearby the Tokalı and Forty Martyrs churches. The products have been applied both as consolidant and stucco. Their behaviour have been assessed by means of colorimetric and peeling test. The application was carried out inside and outside the churches, choosing areas on the basis of their surface degradation, exposition to atmospheric agents and solar exposure.

The laboratory analysis on rock specimens confirm the suitability of the products to restoration interventions: after treatment, colorimetric variations are not perceptible by the human eye [5]. Capillarity test and MIP show that the consolidant products don't modify the original porosity of the rock. Products diluted in white spirit penetrate more than those dispersed in water, this difference is mainly due to the better wettability and the lower surface tension of the white spirit with respect to water.

Peeling tests and geotechnical tests carried out on consolidated specimens indicate that NanoEstel Syton W30 e Syton X30 have the best consolidating properties, whereas Estel 1000 and Estel 1100 show an acceptable efficiency just at high concentration.

On the basis of the laboratory experiments, NanoEstel, Syton W30 and Estel 1000 were chosen to be tested directly on the rupestrian churches' rocks (Fig. 3).

In the Cappadocia sites the treatments were carried out during summer in 2012 and 2013 in the same climatic conditions. Nevertheless the lab results point out the 20 and 30 wt% as best performer, the first applications in site showed the scarce penetration of these treatments that produced a superficial and visible coating; therefore 3 and 6 wt% concentrations were selected. Besides water and white spirit solvents were applied on the surface before the treatments, to increase the product penetration in the substrate. The colorimetric measurements and peeling test (Fig. 4) suggest the good performance of the products especially of NanoEstel and Syton W30 thanks to best and faster penetration than Estel 1000. Besides the solar exposure and high temperatures favored the absorption of treatments in the rock.

The work demonstrated the influence of several factors on the consolidation efficiency, first of all, the environmental conditions and the application modalities, suggesting a functional strategy for a conservative intervention.

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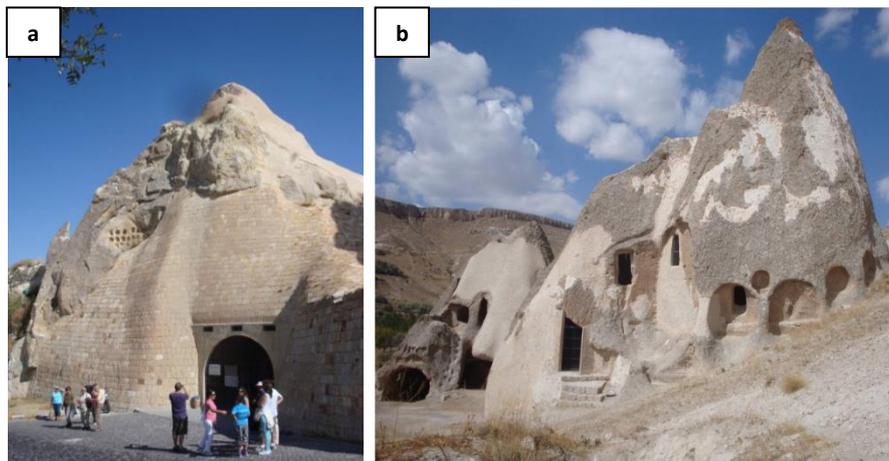


Fig.1. Tokali (a) and Forty Martyrs (b) churches.



Fig. 2. Consolidated specimens



Fig. 3. Treatments in the Tokali church.



Fig. 4. Peeling test on consolidated (a) and unconsolidated (b) areas on Forty Martyrs outside wall.

## References

- [1] Pasquarè, G., 1968. Geology of the Cenozoic volcanic area of Central Anatolia. *Atti della Accademia Nazionale dei Lincei*, 9: 55-204.
- [2] Topal, T., 2002. Quantification of weathering depths in slightly weathered tuffs. *Environ. Geol.*, 42: 632-641.
- [3] Normal 20/85 Interventi conservativi: progettazione esecuzione e valutazione preventiva.
- [4] UNI 10859, 2001. protocol "Cultural Heritage". Natural and artificial stones. Water Repellent-Application on Samples and Determination of their Properties in Laboratory.
- [5] La Russa, M.F., Ruffolo, S.A., Rovella, N., Belfiore, C.M., Palermo, A.M., Guzzi M.T., Crisci, G.M., 2012. Multifunctional TiO<sub>2</sub> coatings for Cultural Heritage. *Prog. Org. Coat.*, **74**: 186-191.