# EFFECTIVENESS OF CONSERVATION TREATMENTS OF A VOLCANIC TUFF VERY SIMILAR TO ADOBE

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SUMMARY

Blocks of volcanic tuff (Cangahua) were used to build the platforms of Cochasquì, Ecuador. Although not man made, this material presents remarcable similarities with adobe, from the conservation point of view, as the analyses of physical properties show. On the basis of the experience of conserving both adobe and stone, treatments with Silester (ethyl silicate), Transkote (aluminum stearate) and a combination of both were tested. The results of the treatments were evaluated by comparing selected physical properties measured on both treated and untreated samples. Accelerated ageing tests by wetting-drying cycles, representative of the major cause of alteration, were also performed.

The treatments tested proved to be very effective in guaranteeing the consolidation and preservation of this material.

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## NTRODUCTION

The site of Cochasquī, Equador, is in the process of being transformed into an archaeological park. It consists of a great number of "tolas", pyramids or platforms built with blocks cut from a volcanic tuff and put together without mortar. At present the tolas are covered with a tall layer of grass and can hardly be distinguished from natural hills. A small portion was excavated in the seventies, from which the samples used in this paper were taken. The general idea for the park (Oberem, Crespo, Lara,1975) is of having at least a section of one tola excavated and preserved to be seen as a representative sample of all the others. To acheive that goal several surface protecting treatments were tested on the cangahua. Part of the laboratory results have already been communicated (Rossi-Manaresi, Pellizzer, 1979).

## CHARACTERISTICS OF THE MATERIAL AND CAUSES OF ALTERATION.

Sampling. The samples used to determine the characteristics of the material and for the treatments were 4 cm cubes dry-cut from a single block. This allows one to make a comparison between the various measurements.

Petrographic characteristics. Analysis in thin section shows a chaotic aggregate of crystalline and lithic fragments (about 50 % of the rock ) immersed in a matrix consisting of consolidated vitreous powder.

The crystalline fragments (0.01 to 3 mm in size) are mainly plagioclase, green hornblende and small quantities of piroxenes. The whole rock is intensely coloured due to the presence of diffuse ferruginous substances, formed as a result of oxidation phenomena (concretions of haematite are visible).

The structural and textural characteristics of the material correspond to those of pyroclastic rocks; on the basis of its mineralogical composition, the rock must be classified as a phenoandesitic tuff.

Physical characteristics. The following physical characteristics were determined:(Working Group ICOMOS/RILEM PEM, 1978)

Bulk density: mass per unit of apparent volume; the volume was determined by hydrostatic weighing of the sample saturated with water under vacuum (pressure 0.1 mm Hg).

Porosity: the total open porosity was determined by the Kobe method based on the evaluation of the volume of air that fills the interconnected pores of the rock. It is expressed as percent of the apparent volume of the sample. The porosity was also determined by saturation with water under vacuum; a mean value of 47.7 vol. % was obtained in agreement with the value obtained with the Kobe method (48.8).

This agreement confirm that for very porous materials, like the one considered here, the water saturation method can give reliable data, but this is not the case when not very porous materials are concerned.(Poggi Brigenti, Ciancabilla, 1973).

Compressive strenght: determined perpendicularly to the stratification; expressed in $Kg/cm^2$.

Water absorption: determined by measuring the mass of water absorbed by the sample (previously dried at 60°C till constant mass) in 48 hours of immersion at atmospheric pressure. Expressed as per cent of the dry sample mass.

Saturation coefficient: the ratio between the volume of water absorbed by the sample in 48 hours immersion and its total volume of open pores. Expressed in per cent.

Capillarity (water absorption coefficient): determined by measuring at time intervals the mass of water absorbed by the sample immersed to a depth of 2 mm and plotting the mass of water absorbed (in $Kg/m^2$) as a function of the square root of time (in seconds). The absorption coefficient ($Kg/m^2\ s^{0.5}$) corresponds to the slope of the straight line passing through the origin.

The mean values of the results obtained are reported in the first column of table 1.

Causes of alteration. The poor quality of the material is clear from the physical characteristics reported in table 1: the cangahua exibit very poor cohesion, high porosity and absorbs very quickly large quantities of water (about 10 $Kg/m^2$ in 3-4 minutes). The fact that after two or three simple immersion in water, the untreated sample completely disaggregated points to the heavy rains typical of the Cochasquī climate as the major cause of alteration.

TABLE 1. - Physical characteristics of untreated and treated Cangahua.

| | | Untreated | | Silester | Silester + Transkote |
|---|---|---|---|---|---|
| Bulk density | (Kg/m$^3$) increase % | 1464 | 1506 (2.9) | 1590 | 1593 (8.8) |
| Compressive strenght | (Kg/cm$^2$) increase % | 15.0 | 28.3 (87.8) | 50.1 (232.8) | 60.3 (300.8) |
| Porosity | (vol. %) (+) decrease % | 18.8 | 41.3 (15.3) | 42.4 | 38. (21.2 |
| Water absorption | (mass %) decrease % | | 6.9 (75.1) | 1.0 (60.4) | 8.4 (30. |
| Saturation coefficient | decrease % | | 0.25 (69.9) | 0.41 (50.6) | 0.76 (8.4) |
| Water absorption coeff. | (Kg/m$^2$s$^{1/2}$) decrease % | 0.7 | 0.01 (98.3) | 0.05 (92.9) | 0.19 (73. |

(+) The porosity values reported here are those obtained with the Kobe method. The porosity was also determined by the method of water saturation under vacuum, but the values obtained for the treated samples were evidently distorted due to the water repellency provided by the treatments. The phenomenum has already been observed (Rossi-Manaresi, Alessandrini, Fuzzi, Peruzzi, 1979) and further confirms that when it is necessary to compare the effect of different treatments the determination of the total open porosity by the water saturation method cannot provide reliable results.



The second more important factor of decay is vegetation, which plays, though, an ambivalent role. In the present state of conservation of the tolas the grass roots alter the superficial layer; but also the grass itself constitute a protection from erosion due to rain that would take place at much higher rate on the bare unpreserved monument. A sort of balance has been reached that would be altered for the worse by simple removal of the grass layer. For that part that will eventually be excavated and preserved, on the other hand, special care should be devoted to avoid both grass and lichens.

The action of wind is probably involved too, favouring the drying of the stone (thus accelerating the wetting-drying cycles) and acting as a mechanical removal agent as well.

## TREATMENTS.

Three groups of samples (three cubes each) were respectively treated as indicated below. Keeping in mind the probable difficulty of carrying out the treatment on completely dried material "in situ", the samples, after drying to constant weight, were left at room temperature for a week. When treated, they thus contained about 1.9 % of water. The treatments were the following:

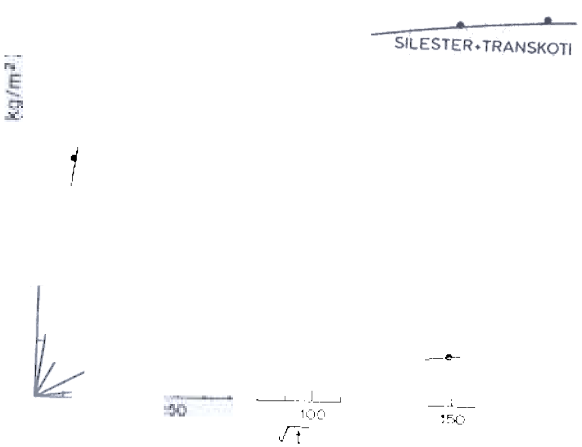
1) Silester ZNS (ethyl silicate). The commercial product (P. Carini, Milano) was diluted 1:2 with ethanol; 0.5 ml of HCl 1 N per litre of final solution were added. The samples were treated by immersion , (first partial, then total). The treatment was repeated three times at intervals of 24 hours for a total of 15 hours immersion.

2) Transkote (aluminum stearate), by Sandtex, Trieste. The solution supplied by the firm was used as it was. Treatment was by immersion as indicated above, and repeated a second time after a week. Total immersion time was about 10 hours.

3) Silester + Transkote. The samples were first treated with Silester, with the same procedure indicated in 1). After being left at room temperature for a month, the samples were then treated with Transkote in the way indicated in 2).

## ASSESMENT OF TI EFFECTIVENESS OF THE TREATMENTS.

Physical characteristics. All the physical characteristics previously determined in the untreated samples were also measured in the treated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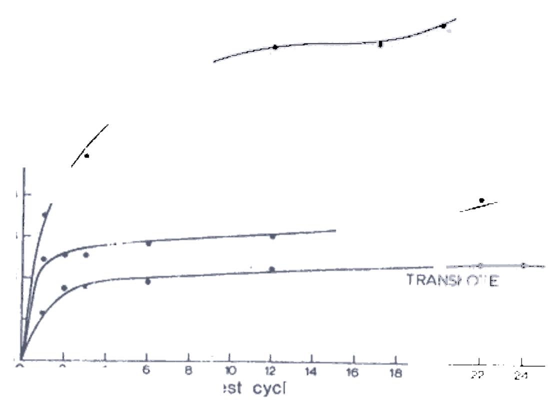
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## METHOD OF APPLICATION.

It must be pointed out that the very good results obtained in the laboratory tests are probably due in part to the total impregnation of the samples obtained by immersion. Had the permeation only be partial, the results would certainly have been worse. On the other hand a treatment 'in situ' can obviously only be superficial. Previous experiences tell us that the conservation problem is shifted from the surface to the plane deviding the treated from the untreated part.The thickness of the consolidated section depends upon many factors: mainly the porosity of the surface (or better the absorption capacity with respect to the permeating agent); the amount of liquid used, which obviously dictates the final cost per square unit of the treatment; and the modalities of application (for example by spraying or with a brush).

To achieve an effective protection the separation surface should not be smooth, but as irregular as possible, to obtain a natural keying effect. A gradient of impregnation (and consequently of physical properties) should also be favoured to avoid sharp distinctions between crust and inner wall. But the most important point is to avoid any weak part on the surfacethrough which water can penetrate inside the wall, beneath the treated layer. In this case the effect of the water would be devastating despite any thickness of impregnation.

Twelve years of experience on application of Silester to mud-brick surfaces in the field suggest the spraying technique (Torraca, Chiari, Gullini, 1972) as the most practical and effective. There is practically no limit to the amount of liquid that can be driven into the wall ; therefore the decision concerning the quantity of product to be used should be taken on the basis of the consolidation desired (also in view of the 'quality' of the wall to be treated) and the cost affortable for that goal. A sufficient amount of time should lapse between applications (15 days to a month) to allow the wall to resume its porosity.

For the Transkote, its normal modality of application on stone surfaces is by brush. Given the extremely friable condition of the cangahua, 'in situ' tests of application both ways should be done.

Finally, when the samples were treated in the laboratory they contained a fairly moderate amount of water; the good results obtained indicate that the material does not necessarily need to be completely dried for the treatment to succeed. However it must be remembered that the treatment should be carried out on materials which are as dry as possible.



## CONCLUSIONS.

From all the results obtained, one can conclude that the two products, applied individually, are both very effective in guaranteeing the conservation of this material.

Silester is relatively more effective in imparting compactness and mechanical resistance; Transkote instead is more effective in supplying water-repellency and resistance to the process mainly responsible for the decay.

The successive application of both treatments may possibly produce an overlapping of the single effects of the two individual treatments, but the two applications must be separated by very long periods of time and only used after careful checking.

Finally, whereas ethyl silicate is no longer extractible from the rock structure, although modifying it very little, the aluminum stearate can be extracted with organic solvents, thus guaranteeing the reversibility of the treatment.

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