"LA FENICE" THEATRE - FOYER AND APOLLINEE ROOMS - CONSOLIDATION OF FIRE-DAMAGED STUCCO AND MARMORINO DECORATIONS BY MEANS OF COMBINED APPLICATIONS OF ION-EXCHANGE RESINS AND BARIUM HYDROXIDE

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1. PREMISE

The fire-damaged decorative elements in the Foyer and the Apollinee rooms mainly consist of plaster and marmorino remains made up of calcium carbonate, and stucco elements made of plaster.
The strong presence of sulphate and chloride salts, not only on the surface but also deep inside the plaster and the walls, is the main cause of chemical deterioration even though such deterioration is closely linked to the presence of water, either from condensation or from capillary action or infiltration, which makes the plaster surface soft to the touch and locally covered with saline efflorescence.
Today, the stucco work is slowly dissolving to form sulphates which penetrate into the walls and the marmorino elements below, causing further deterioration.
The loss of the surface finishes is particularly serious for the restoration project directed by Aldo Rossi, since the loss of the painted film or the coloured layer inevitably means that a new finish has to be applied. This means that the restored original parts would no longer be clearly visible amongst the large quantity of newly executed decoration.
For this reason, it was necessary to devise a surface consolidation procedure that would safeguard the remains of the surface finishing, ensuring a degree of permeability to water vapour, and excluding conventional approaches which employ acrylic and silicone resins since these methods often lead to the risk of blistering and peeling over periods of time.

2. METHODOLOGY AND PROCEDURE

The procedure involves the formation of stable crystalline aggregates both in the case of stucco plasterwork and in the case of marmorino elements with lime components. This avoids a phase of preconsolidation using synthetic materials whose effectiveness over time is doubtful.
The proposed system for the tests enables action to be taken on any new formation of salts that might take place during the course of the procedure using this methodology, without altering or setting up surface barriers with reduced porosity:
a)first step with absorbent paper compress and de-mineralised water to remove the more soluble excess salts;
b)repeated applications (three times) of de-sulphating ion-exchange resins on the surfaces in order to eliminate the sulphate ion by transforming it into calcium carbonate. This chemical transformation usually (note: this application takes place on the first millimeters of surface and encourages better subsequent penetration of the barium hydroxide, avoiding the formation of barium sulphate, an insoluble salt which also has a whitening effect on the surface);
c)repeated applications of wads and compresses made of cellulose pulp soaked in a 5% solution of barium hydroxide (and/or saturated) in order to transform the sulphate ions present within the material into barium sulphate (an insoluble salt). Excess barium hydroxide is converted into barium carbonate by the CO2 , over a period of time similar to that required for the carbonation of lime.

3. CHECKING METHODOLOGY

To confirm that the proposed method is effective and not harmful, tests were carried out on- site under the supervision of the project managers and the government Superintendent, as well as a series of laboratory checks which were carried out before and after the application of the substances referred to in phases b) and c) above.
EDS and SEM investigation were conducted on 22 cross sections specimens; in addition, at the end of the second treatment (c) on-site, six tests of low pressure water absorption (pipette method) were carried out to measure any variation in the treated object's permeability compared with the untreated one.

4. CONCLUSIONS

The methodology proved to be valid through the analytical results carried out during checking.
However, it should be noted that the presence of soluble salts, such as sodium chloride (present in large quantities in some areas), can slow down or halt the effectiveness of the treatment both with resins and with barium hydroxide.
Therefore, to improve desalination, it is advisable to carry out a number of treatments using compresses with de-mineralised water and cellulose pulp where possible (marmorino elements) or using ion-exchange resins where it is not wise to use more water (objects in gypsum).
As things stand, the methodology seems to have achieved significant results in the field of surface consolidation. The treated surfaces are compact to the touch and do not form powder.
However, SEM-EDS analysis have demonstrated the need for a further reduction in chloride salts so as to achieve sufficient crystallisation of secondary calcium carbonate on the surfaces.
The use of barium hydroxide has saturated the colour giving it a wet-looking effect which is not a problem on the marmorino objects, but which has caused the yellowing at the edges mainly consisting of calcium sulphate. This drawback could be resolved by using desulphating resins, bearing in mind that the treatment is effective to a depth of about 100 mm, with the risk of future peeling or blistering.
Alternatively, the surfaces could be given a patina since they have already lost their finish and at present are gypsum-white in colour.
Even in the special case of the Fenice theatre restoration, it is felt that, with all due caution, this methodology can be tried out in the many restoration projects where it is necessary to eliminate soluble salts, but where it is not possible to use compresses with de-ionised water for desalinisation.
As of the date of this conference, it has been possible to evaluate the effectiveness of the procedure and its durability after nine months, with good vapour permeability and mostly absence of peeling or blistering of surfaces.

Figure 1 - Interior of ball room of Sale Apollinee before fire

Figure 2 - Same room after devastating fire

Figure 3 - Detail of marmorino walls at ground floor of Sale Apollinee with deep degradation for saline efflorescences

Figures 4-5 - Application of ion-exchange resin after preliminary desalinisation with de-mineralised water (4) and of paper compress with barium hydroxide (5)

STUCCO DECORATIONS GYPSUM MORTARS (samples 1-1A-1B)

Figures 6a-b - SEM micrographs and energy dispersion spectrum before treatments (BSE, magnification X82)

Figures 7a-b - SEM micrographs and energy dispersion spectrum after treatment with ion-exchange resin (BSE, magnification X82)

Figures 8a-b - SEM micrographs and energy dispersion spectrum after treatment with barium hydroxide (BSE, magnification X59)

BEFORE TREATMENTS

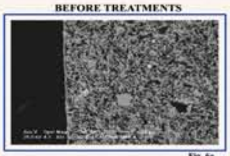

Fig. 6a

Fig. 6b

AFTER TREATMENT WITH ION-EXCHANGE RESIN

Fig. 7a

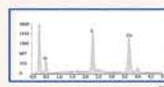

Fig. 7b

AFTER TREATMENT WITH BARIUM HYDROXIDE

Fig. 8a

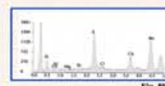

Fig. 8b

MARMORINO DECORATIONS MORTARS WITH LIME BINDER AND CALCAREOUS AGGREGATE (samples 2-2B-2C)

Figures 9a-b - SEM micrographs before treatments: overall (9a, SE, magnification X125) and detail (9b, MIX, magnification X928)

Figures 10a-b - SEM micrographs after treatment with ion-exchange resin: overall (10a, SE, magnification X125) and detail (10b, SE, magnification X1000)

Figures 11a-b - SEM micrographs after treatment with barium hydroxide: overall (11a, BSE, magnification X54) and detail (11b, BSE, magnification X1717)

BEFORE TREATMENTS

Fig. 9a

Fig. 9b

AFTER TREATMENT WITH ION-EXCHANGE RESIN

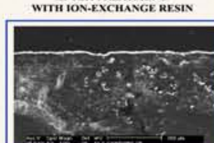

Fig. 10a

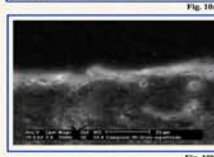

Fig. 10b

AFTER TREATMENT WITH BARIUM HYDROXIDE

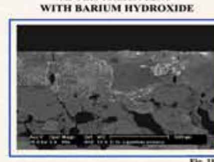

Fig. 11a

Fig. 11b

MARMORINO DECORATIONS MORTARS WITH LIME BINDER (PROBABLY MAGNESIAC IN PART) AND CRUSHED MARBLE AGGREGATE (samples 6-6F-6G)

Figures 12a-b - SEM micrographs and energy dispersion spectrum before treatments (BSE, magnification X84)

Figures 13a-b - SEM micrographs and energy dispersion spectrum after treatment with ion-exchange resin (BSE, magnification X29)

Figures 14a-b - SEM micrographs and energy dispersion spectrum after treatment with barium hydroxide (BSE, magnification X68)

BEFORE TREATMENTS

Fig. 12a

Fig. 12b

AFTER TREATMENT WITH ION-EXCHANGE RESIN

fig. 13a

Fig. 13b

AFTER TREATMENT WITH BARIUM HYDROXIDE

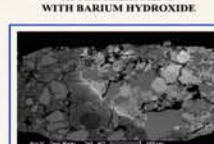

Fig. 14a

Fig. 14b

Figure 15 - Test on-site after consolidation, remain of silicon and saline efflorescences due to pipette method

Figure 16a-b - Same test on-site after 9 month

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