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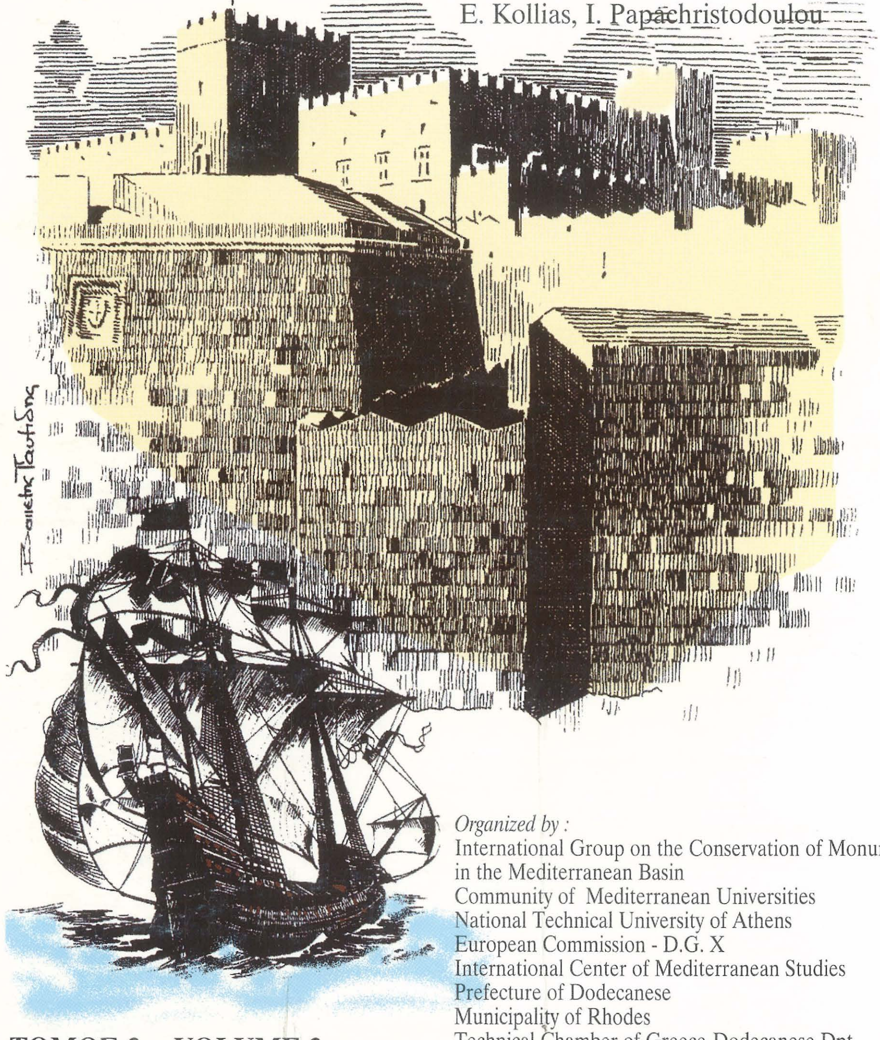

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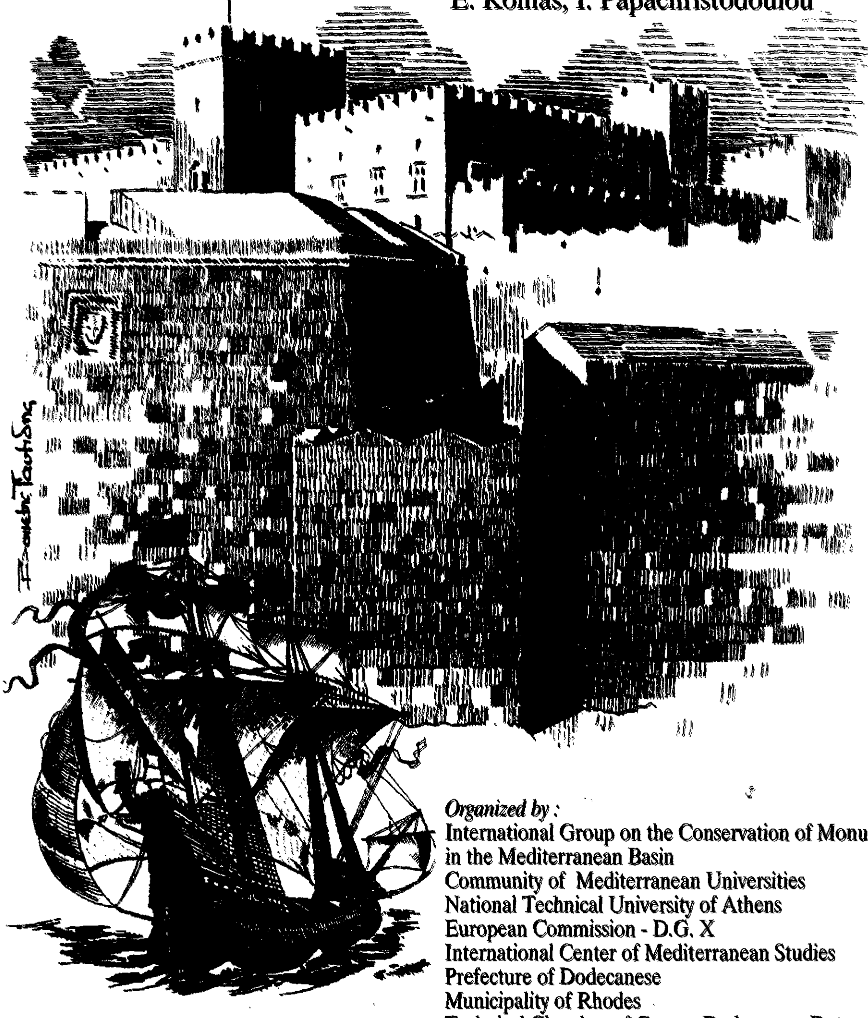

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STUDY OF THE TREATMENTS FOR THE ELIMINATION OF SOLUBLE SALTS AND DAMPNESS IN THE REPAIR OF COATING STONE BUILDINGS.

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ABSTRACT

We have elaborated two series of mortars using non-hydraulic lime, hydraulic lime, white cement and a mixture of non-hydraulic lime and white cement as binder.

A series of mortars has been treated with soluble salt inhibitors with germicide effect and an additive that eliminate the dampness.

It is compared the hydric and mechanical behavior among the samples without treatment and those which have been treated with additive products.

Electronics microscopy and X ray diffraction, among other analytical technique, have been used.

Key words

Mortar, soluble-salt inhibitors, density, porosity, mechanical testing, X ray diffraction, electronics microscopy.

INTRODUCTION

In the Mediterranean basin there exist a considerable number of coastal cities, the role of which has been of great importance in the cultural and commercial interchanges, and in which History has left interesting architectural works. These works were mainly made out of stonework or brick, which occasionally were left exposed but in the majority of the cases were faced with mortar or stuccoworks, either on the grounds of protection or because a good carving of the external faces of the ashlars or rough stones was rather complex. The alteration processes of natural stoneworks have been studied by many authors (1) reaching the conclusion that, in warm or mild weathers and in places near de sea, the most frequent causes of deterioration are due to dampness, especially when coinciding with the presence of salts coming from the soil or from the marine "spray" (2) generating as a result the sandization and alveolization of the stones and mortars, either covering ones or stonework rounding up ones. The action mechanisms of these salts

have also been studied being particularly harmful in highly porous chipboard materials such as sandstones, stones or mortars (3).
This is why the search for solutions to the mentioned problems raises a special interest, both to avoid dampness and to eliminate or to inhibit the action of the soluble salts.
In this study we propose to analyze the results achieved with porous additives which, added to the stuccos or mortars, give as a result the perspiration of the stonework and the elimination of dampness. They are therefore called cleaning-up mortars or drains, not being included in the study those mortars previously prepared by the manufacturer. Furthermore we should study soluble-salt inhibiting products that also have a bactericidal effect, the application of which is required to succeed in getting the above mentioned mortar to give the required results, without blocking the porous and avoiding pressures by crystallization that would detach them.

EXPERIMENTAL

We have elaborated a series of samples with four different types of mortars, frequently used in restoration, varying the type of the binder and using in all cases the same type of aggregate: a crushing sand with a 99% of $CaCO_3$ -calcite- and a high content in fine (17% that increased the needs of water but improves the workability).Non-hydraulic lime (**NHL**), hydraulic lime (**HL**), white cement (**WC**) and a mixing 1:1 of non-hydraulic lime and white cement (**NHL-WC**) have been used as binder.
NHL is the principal binder of most traditional mortars. Actually it is used too, sometimes with different additives for improve its properties (4). A classical application is like **NHL-WC**.
HL, due its ocher color, is perfect for its employment in mortars and plastered of works that they have acquired coloration to what is long of the time or in those which were dyed the mortars.
The **WC** (V/B in the RC 88 Spanish instruction) is a mixed cement with a content in clinker among 20 and 64% and the additions rest with a low compression strength. **WC** has a low retraction and, in our experience, it is very adapted for works of restoration.
The proportions of binder/aggregate/water in the different mortars have been:

NHL........................1:3:0.8
HL...........................1:3:0.75
WC..........................1:4:0.7
NHL-WC.................0.5:0.5:3:0.7

We are prepared the same types adding and porous additive (has been used the DRYMUR additive of the Italian Company Edilteco) in the proportion recommended by the manufacturer of 1 gr of product by each 50 gr of binder.

The action of this additive is different to that of the moistureproof products (5) since they should provoke in the mortar a high porosity and permeability the water steam.
The water proportions have been modified slightly in function of the workability of the mortar departing of a relationship water/binder = 0.5 and increasing it when was not possible to knead it adequately.
Of each one of the eigth different types of mortar have been elaborated the following samples:
3 of 4x4x16 cm^3 to accomplish to the flexural and compression tests (UNE 80-101).
3 of 4x4x16 cm^3 to calculate the capillary coefficient (RILEM COM.25-PEM: II 6).
3 of 4x4x16 cm^3 to calculate the porosity accessible to the water(RILEM COM.25-PEM: I).
3 of 4x4x16 cm^3 for X ray diffraction (**XRD**) and electronics microscopy (**SEM**).
6 of 4x4x4 cm^3 for immersion in three types of soluble salts with application or not of an inhibitor product.
For the accomplishment of the samples has been taken into account the methodological proposal of the ICCROM (6). The total number of samples with and without additive is of 144.

RESULTS AND DISCUSSION

Hydric and mechanical testing of mortars

The samples have been measured and weighted after the first 28 days of their production, being the density obtained (Kg/dm^3) with the following results as an average value:

Mortar	Without additive	With additive	(Increase)%
NHL	1.69	1.58	-6%
HL	1.76	1.33	-24%
NHL-WC	1.86	1.62	-13%
WC	2.00	1.63	-18%

Density expressed in Kg/dm^3

As was to be expected, the additive presence increases the porous field and reduces the density. If **NHL** was to be used there would be less reduction because of its fineness, which has an effect on the filling of the empty spaces.
Subsequently the mechanical strength has been tested being the following the obtained average results:

Mortar	Without additive	With additive	(Increase)%
NHL	10.63	8.85	-16.75%
HL	4.45	1.70	-61.80%
NHL-WC	13.45	10.43	-22.45%
WC	44.23	44.23	-27.20%

Flexural strength in Kg/cm^2

The loss of flexural strength is related to the previous results, it being less in the **NHL** and more in the **HL**, although it has been very high anyway because they proved to be some too friable samples that disintegrated, probably because of the poor quality of the employed lime.

Mortar	Without additive	With additive	(Increase)%
NHL	22	15	-31.8%
NHL-WC	44	26	-41.0%
WC	275	170	-38.2%

Compression strength in Kg/cm^2

For compression strength is a similar process but somehow more significant, more logical because of the higher degree of influence of the increasing porosity in this kind of mechanical action. It should be taken into account that German DIN normative establish for these mortars a maximum strength limitation, since it implies a higher effectiveness of the additive.
As regards the tests on capillary suction, which are very important when it comes to material alteration (7), the results are reversed, that is, the treatment samples have less suction capacity, in spite of their higher porosity, probably because a capillary web is not formed, as will be seen later. It must be taken into consideration that the test is carried out with side-face impermeabilization, which blocks the evaporation. However this type of additives must allow the steam transfer, in order to have the wall dry-up effect. These were the results:

Mortar	Without additive	With additive	(Increase)%
NHL	0.290	0.213	-27.00%
HL	0.400	0.285	-28.75%
NHL-WC	0.248	0.160	-35.50%
WC	0.097	0.073	-24.75%

Capillary coefficient in $Kg/m^2.s^{0.5}$

If we look at these numbers it can be deduced that the suction is affected in a similar way in all the mortars, even in the **WC** one, where values without additives are by nature very low. It is interesting to notice the suction evolution in the tests by means of the diagram (**fig. 1**) were a different evolution can be seen in the **NHL**, since it is less in the treated samples during the first hours, but later on it becomes leveled, a fact that does not take place in all the other mortars.

The water absorption by immersion has also been tested with these results:

Mortar	Without additive	With additive	(Increase)%
NHL	19.86%	16.78%	-15.5%
HL	16.26%	14.77%	-9.2%
NHL-WC	10.20%	11.56%	+13.3%
WC	13.60%	11.61%	-14.6%

Absorption of water by immersion

Even though it is again reduced by means of the additive , the differences are much lesser, since here it is only the accessible porosity that counts. In the case of the mixed mortars it even increased, although it can be due to the great results shift (from 8.5 to 14.51%) which could be caused by the limited size of the samples and their preparation.

SEM and XRD analysis

Using SEM we can clearly observe the differences in the porous field generated in the treated and untreated samples to any of the mortars studied (except **HL** mortar) at the same magnifying power (**photos 1a-1f**) Whereas the non additivated samples show a compact surface (**photos 1a** and **1e**) or having some macropores (**photo 1c**), in the additivated ones a field is always formed having great many micropores inferior in diameter to 50 microns. These pores are not connected to each other, so they do not form a capillary web, and for this reason water finds difficulty in circulating inside the samples. However the water vapor transfer actually takes place because it is a larger size molecule (8). In the **photo 2** is shown a pore corresponding to a WC mortar sample with an halo due to additive product..

The samples analyzed by XRD show a mineralogy composed solely by calcite (corresponding to the aggregate) and portlandite (the hydrated phases of the cement, with exception of the portlandite, they are non-crystallines). Nevertheless of the interpretation of the XRD espectra can be extracted some interesting conclusion: in the **fig 2** have been drawn superposed the XRD spectra corresponding to the **NHL** mortar samples with and without additive (the calcite intensity are similar) indicates that the carbonation process is slower.

Soluble salts effects

In order to analyze the action of the soluble salts on the mortars, their mobility inside the samples according to their solubility must be taken into account (9). The most soluble salts such as the NaCl create alveolizations on the surface of the materials when crystallizing very close to it (10).

In this study three different solubility degree salts were used: sodium chloride -NaCl-, sodium sulfate -Na_2SO4- and magnesium sulfate -MgSO4-, dissolving 35 gr of each in one liter of water and pouring each solution into a try containing three samples of each and every one of the eight types of mortar. One of the samples had been previously treated by immersion with a saline efflorescences inhibiting product, formulated as a siloxane.

The samples were submerged for 72 hours in the solutions and later they were drained in a drying chamber at 60ºC.The formation of efflorescences has been virtually zero with the MgSO4, low with the NaCl and very high in the case of Na_2SO4 the solubility of which was medium, especially in the **NHL** (**photos 3 and 4**). The treated samples (with a product called Tecosel produced by the Italian firm Edilteco) show no sign of crystallization.

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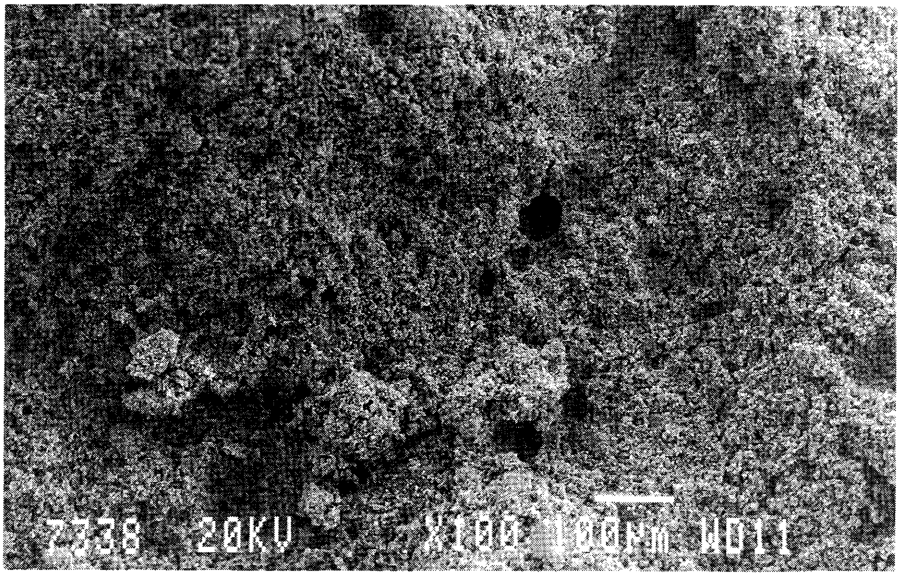

photo 1a) Non-hydraulic lime without additive

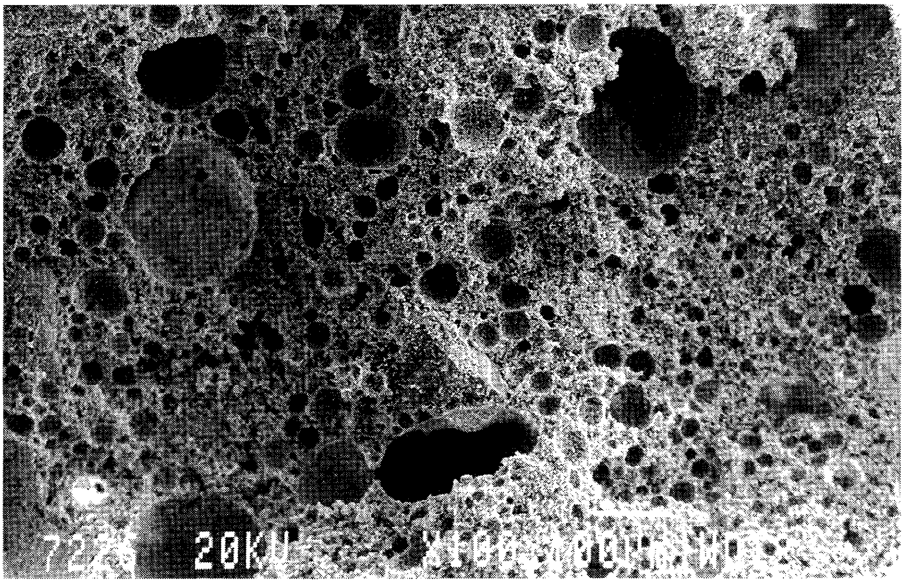

photo 1b) Non-hydraulic lime with additive

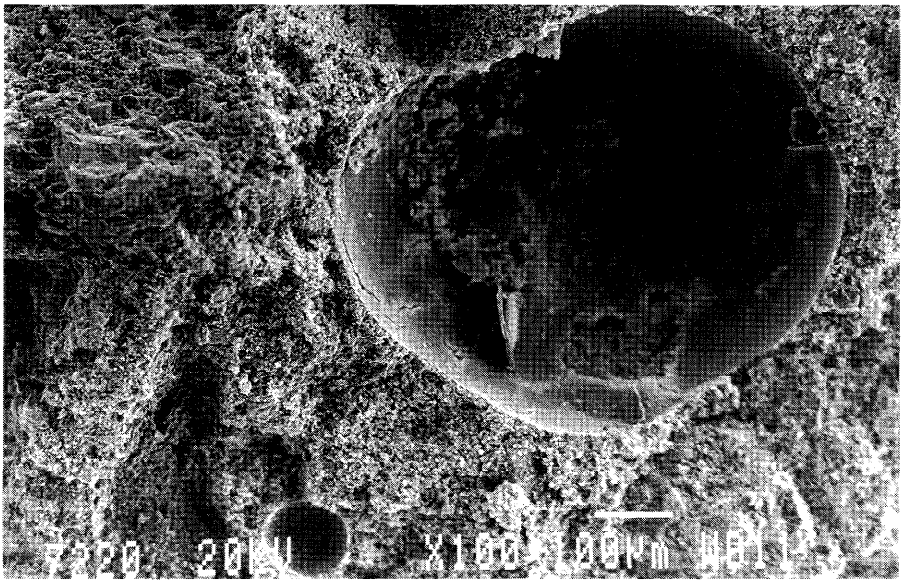

photo 1c) Non-hydraulic lime and cement without additive

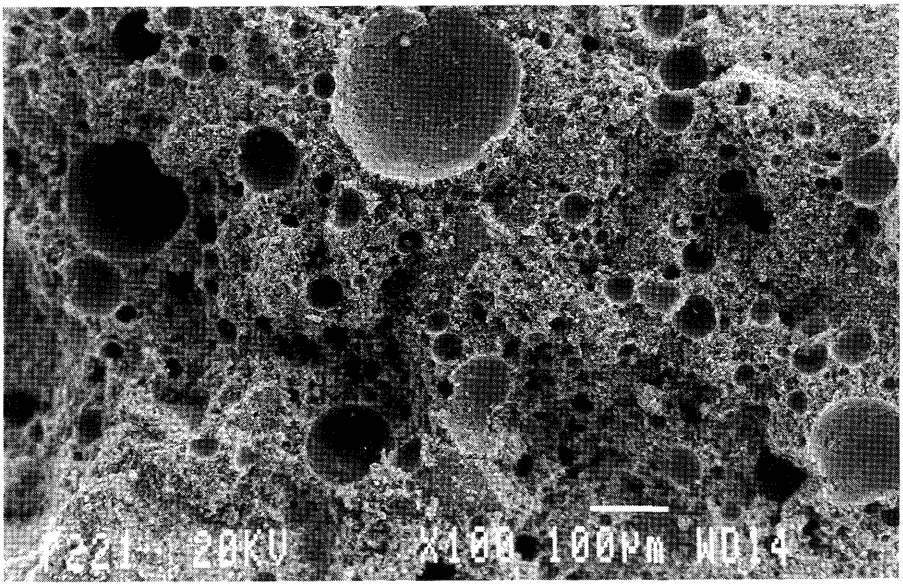

photo 1d) Non-hydraulic lime and cement with additive

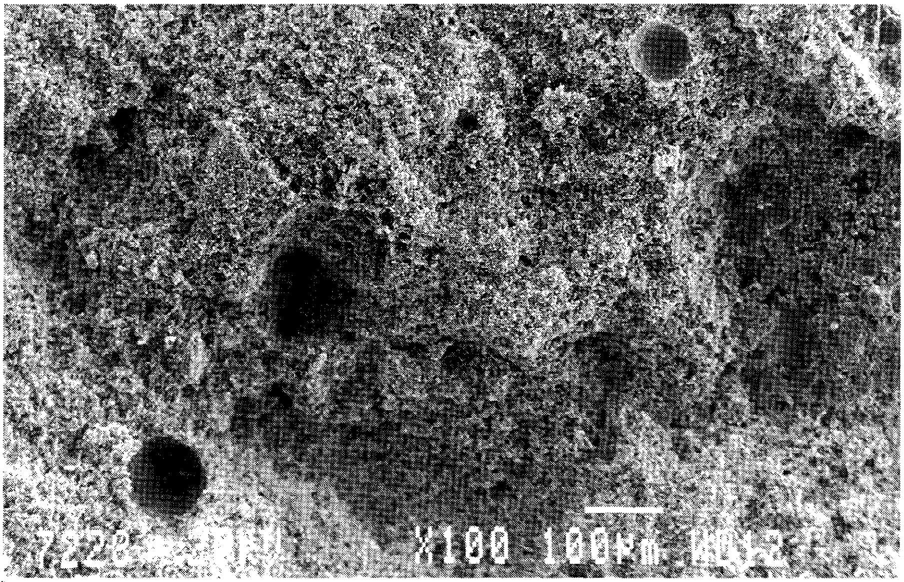

photo 1e) White Portland Cement without additive

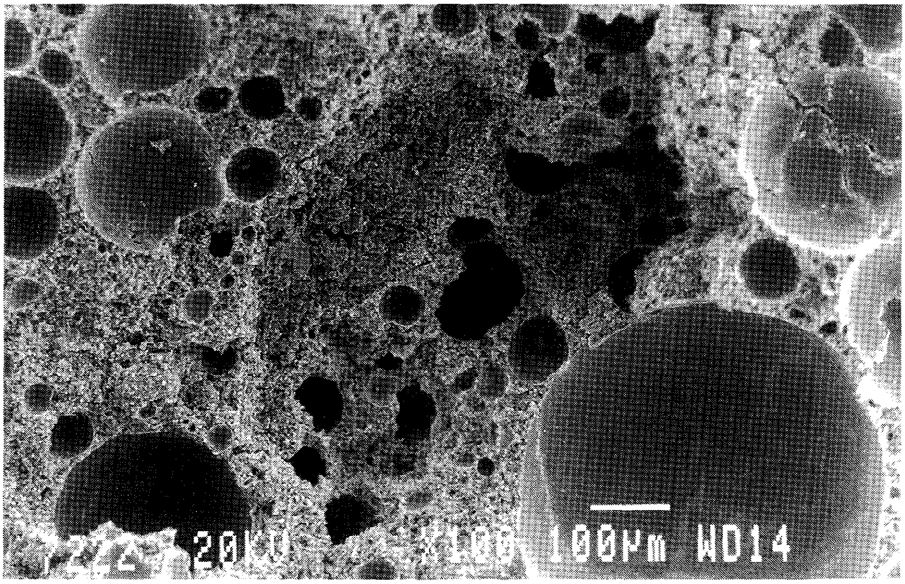

photo 1f) White Portland Cement with additive

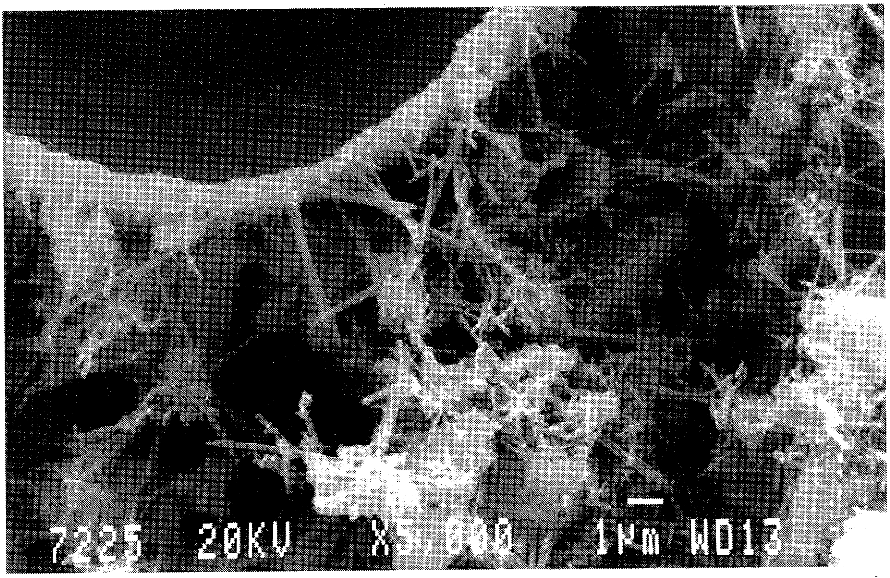

photo 2: pore corresponding to a WC mortar sample treated with additive.

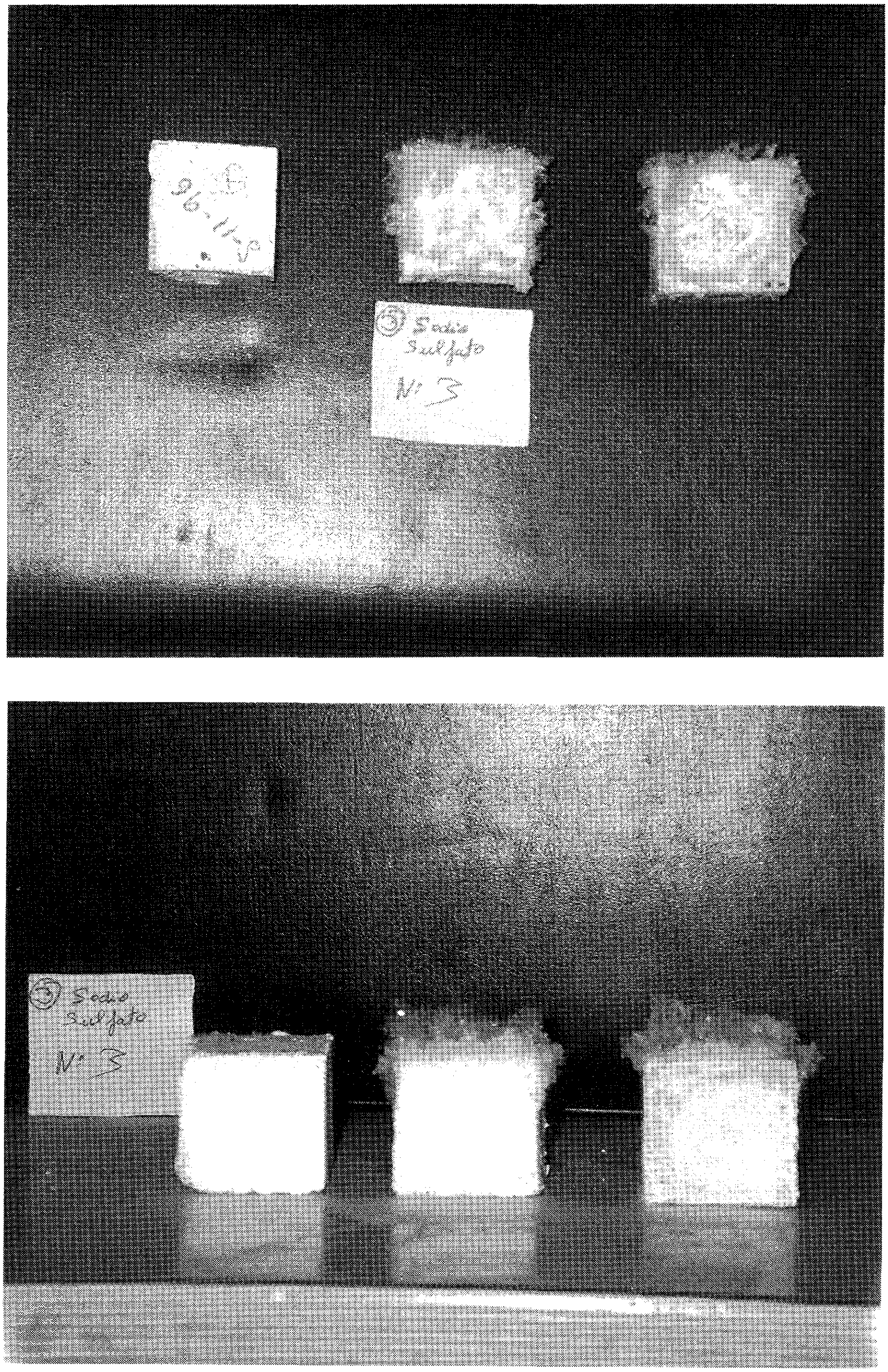

photo 3: effect of the sodium sulphate. In the right side, sample with inhibitory treatment.

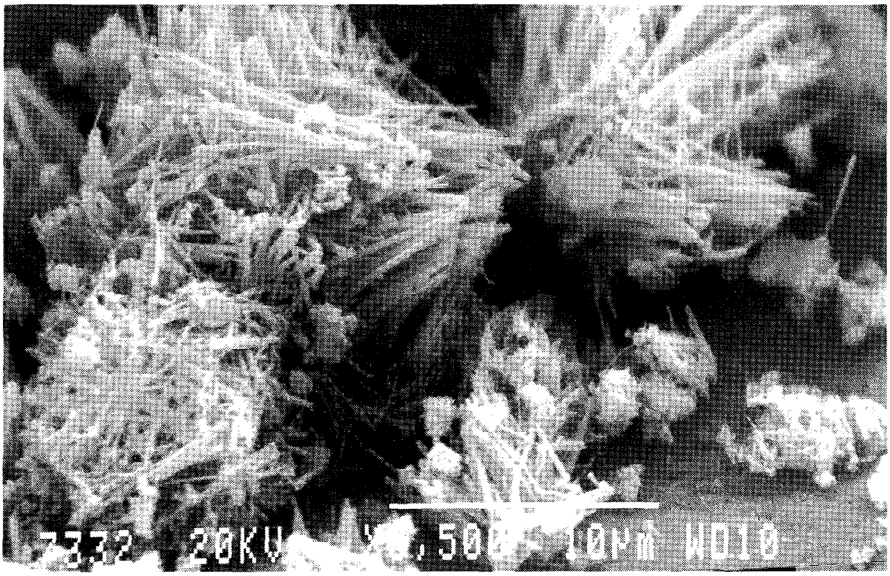

photo 4: Na_2SO4 efflorescences in a WC mortar sample with Tecosel product

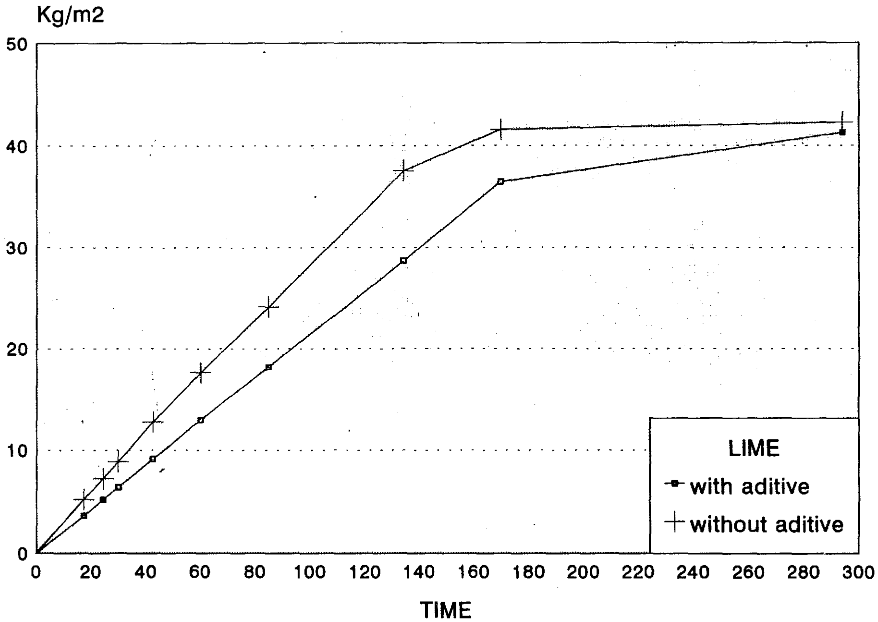

Figure 1a

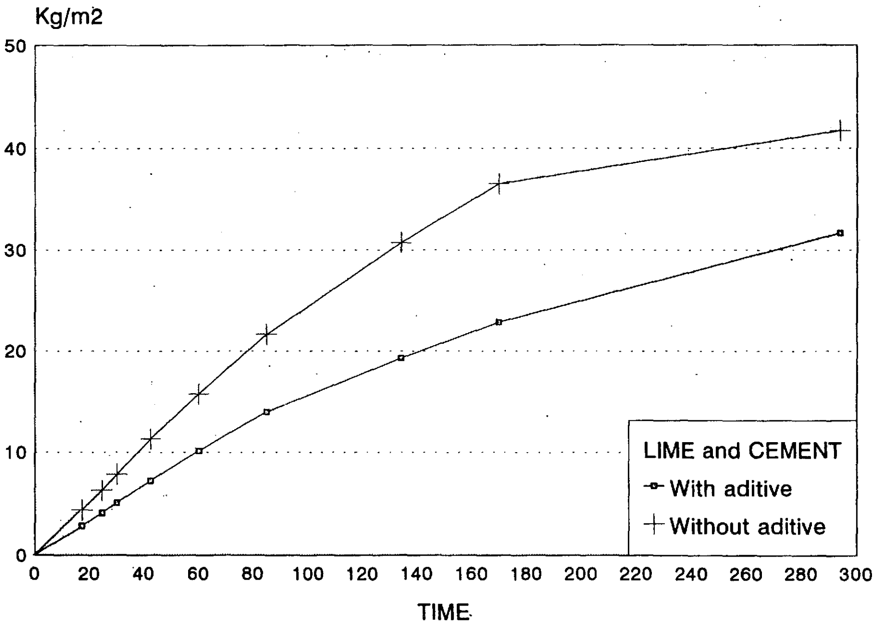

Figure 1b

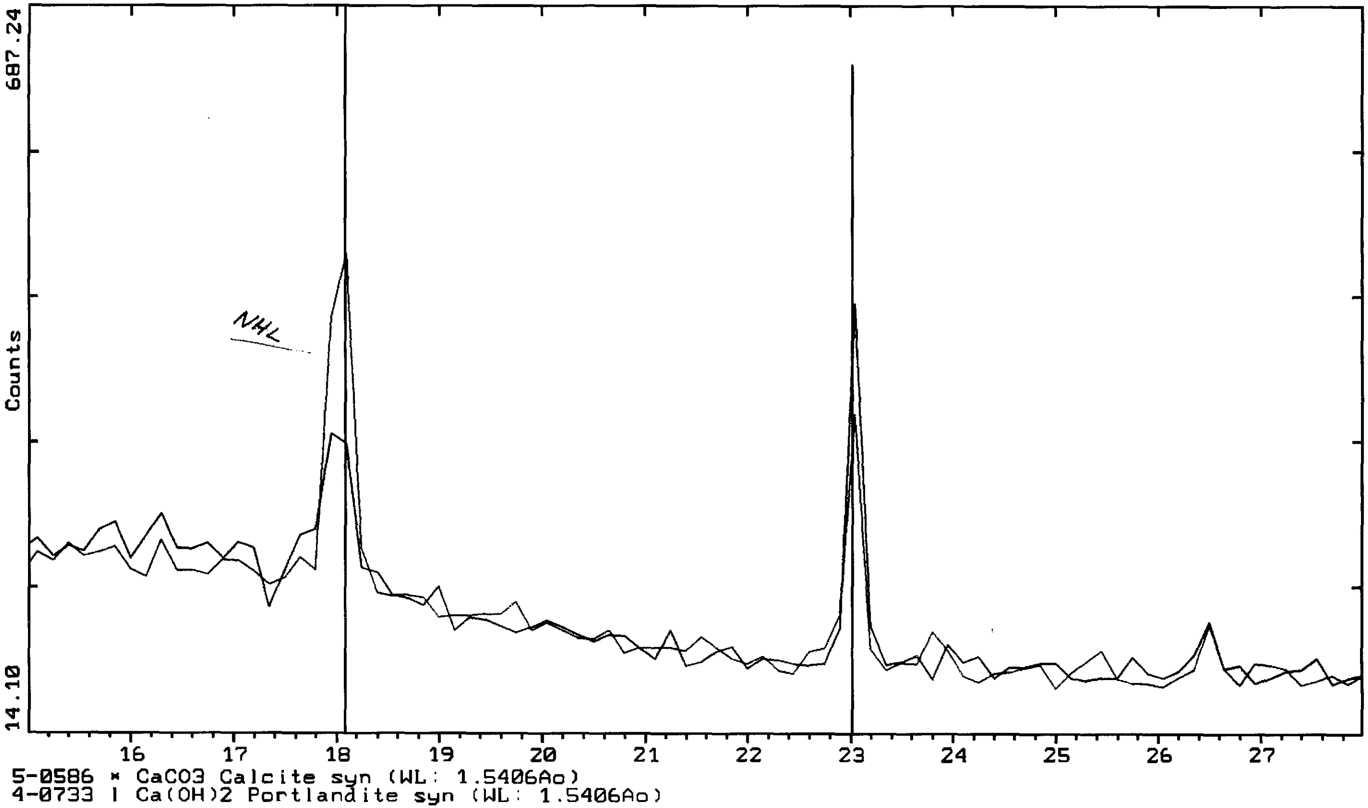

Fig. 2: XRD spectra corresponding to the NHL mortar samples with additive (blue color) and without additive (red color).