Rendering Products for the Protection of Historical Buildings

Enduits pour la protection des bâtiments historiques

Putzmörtel für den Schutz von historischen Gebäuden

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SUMMARY

The protection of artistic and historic buildings must be among the first commitments of a nation, even if restoration problems are often complicated by the compatibility with the existing substrates. This paper studied the performances of different types of rendering mortars in order to furnish the operators with a proposal of methodologies for an 'appropriate' choice between various products.

RÉSUMÉ

La protection des bâtiments historiques et artistiques doit être une des premières responsabilités d'une nation, bien que les problèmes des réparations soient souvent compliqués par la compatibilité avec les matériaux déjà appliqués. Ce rapport étudie les performances de différents types d'enduit afin d'offrir aux utilisateurs une méthodologie pour un choix approprié parmi divers produits.

ZUSAMMENFASSUNG

Der Schutz historisch und kulturell wertvoller Gebäude muss eines der wichtigsten Ziele jeder Nation sein, wenn auch Unterhaltsarbeiten oft mit Verträglichkeitsproblemen behaftet sind, die zwischen den neuen und bereits verwendeten Baustoffen auftreten. Dieser Bericht studiert die Eigenschaften und Einsatzmöglichkeiten verschiedener Produkte, damit Anwendern die Wahl erleichtert wird.

1. INTRODUCTION

In Italy there is the highest concentration of hystorical and artistical monuments in the world. The problems of maintenance or repair of this heritage are very large. In the past years there was some cases in which the repairs caused serious damages to the existing structures. For these reasons a true scentific approach to the ancient structures repair problems has been considered necessary. The aim of this paper is principally to show example of this scientific approach in a particular and very important field: the rendering mortars for hystorical buildings. This is in order to give to the field operators a proposal of methodologies for an appropriate choice between the commercial products.

2. EXPERIMENTAL PART

The following systems have been evaluated:

- EMACO RESTO (MAC SpA - Italy) + sand
- Plastocem (Italcementi - Italy) + sand
- Hydraulic lime (Lafarge - France) + sand
- Hydrated lime (Ceprovip - Italy) + pozzolana

2.1 Mixes preparation

Mortars with typical workability conditions have been made; the measure of the workability has been performed according to UNI 7044. Water/binder ratios have been varied in the systems in order to have approximately 90% of flow (Tab.1).

2.2 Tests

The above mentioned systems were cured in standards conditions (20°C and 95% R.H.), execpt for the hydrated lime+sand system (room conditions). Thechnological, physical and chemical properties have been evaluated according to the relevant standard methods.

2.2.1 Compressive strength

The compressive strength was measured according to UNI 7102 standard (D.M. 03.06.1968) after 7,28 and 90 days of curing.

2.2.2 Sulfate resistance

According to Anstett test, the expansion of the hydrated binders in presence of 50% of weight of gypsum has been detected.

2.2.3 Capillarity water absorption : according to Normal 11/85.

2.2.4 Water absorption by total immersion : according to Normal 7/81.

2.2.5 Water vapour permeability : according to Normal 21/85.

2.2.6 Porosity and mercury porosimetric distribution: according to Normal 4/80

2.2.7 White paint quantity requested to cover the mortar colour

The same white paint, silicates based in water solution, has been applied on the samples until the same whitness degree, measured by a reflectance colorimeter.

2.2.8 Water vapour permeability on the painted mortars

According to Normal 21/85 the same samples of previous test were used; the surface of evaporation was the painted surface.

2.2.9 Resistance to the salts crystallization

Samples have been kept at cycles of 24 hours in Na_2SO_4 solution and 24 Hours in a windy oven at 60°C until the formation of visible cracks on the samples. After which the samples were washed in order to eliminate the residual sodium sulfate, and further the capillary and total water absortion tests were carried out.

2.2.10 Soluble salts content

The soluble salts content was measured after acqueous extraction, according to Normal 13/83, by ionic chromatography.

2.2.11 Efflorescences formation tendency

This test has been performed on samples of 4x4x16 cm size, partially dipped in deionised water, with the lateral faces covered by a paraffin layer. The efflorescences have been determined qualitatively and quantitatively after 28 days.

2.2.12 Shrinkage

The appearance of cracks on the mortars, applied on brick walls of 1.30 m x 2 m size, previously water saturated, has been observed in the first days, in order to make evidence on plastic shrinkage, and after approximately 2 years, to verify the hydraulic shrinkage. Also the surface appearance after an external exposition was observed.

3. DISCUSSION

3.1 Mixing water

EMACO RESTO, Plastocem and the Lafarge+pozzolana systems requested approximately the same mixing water quantity, as indicated in Table 1. In this table, we have to consider that hydrated lime was about 40% of solids.

3.2 Mechanical strength

The four systems were very different as far as it concerns this property, as showed in Table 1. In all systems the compressive strengths were not very high, in order to have a better mechanical compatibility with the hystorical structures. Emaco Resto showed the highest compressive strength, so indicating the possibility to have an efficient restoration.

	bleeding	*water added*	*flow UNI*	*compressive strength (MPa)*		
	%	%	%	7 days	28 days	90 days
EMACO RESTO+sand	absent	15	90	2.7	10.5	13.0
Plastocem+sand	absent	15	100	1.7	4.6	7.8
Lafarge+sand	absent	17.2	100	1.6	2.7	3.9
Ceprovip+pozzolana	0.1	8	95	1.5	2.9	3.5

Table 1 Mechanical performances of renderings

3.3 Anstett test

EMACO RESTO had the lowest expansion (0.75%). Hydrated lime and pozzolana gave an expansion of 3.8%; Plastocem expanded of 31% after 28 days, with the appearance of large cracks on the surface of the sample.
Lafarge lime showed an initial low expansion and, after 7 days, suddendly arrived until the total destruction of the sample (Tab.2).

	EXPANSION (%)			
renderings	1 day	3 days	7 days	28 days
EMACO RESTO+sand	0.50	0.75	0.75	0.75
Plastocem+sand	1.31	9.06	14.56	31.25
Lafarge+sand	0.71	1.00	1.42	destr.
Ceprovip+pozzolana	0.40	3.10	3.50	3.80

Table 2 Anstett test expansion

3.4 Water absorption by capillarity and total immersion

Ceprovip and pozzolana systems had the highest values of absorption in terms of capillarity coefficient and plateau values; the other products had a similar behaviour between them.
It has to be noted from the analyses of the absosption curves that EMACO RESTO and Plastocem show a behaviour similar to porous materials treated with hydrorepelling products.

3.5 Water permeability

Data obtained in this test are are consistant with those detected in the water absortion test: as higher the Imbibition Coefficient and the capillary absorption, as higher the vapour permeability values.

3.6 Water vapour permeability of painted mortars

The presence of a paint, that is necessary when you need to vary the colour of a rendering mortar, reduces the permeability, but maintains the initial relative difference.

3.7 Demand of white paint

All the systems obtained approximately the same whitness degree (close to whitness degree of pure paint) by applying the same quantity of colour and the same application conditions (Tab.3).

	EMACO RESTO + sand	Plastocem + sand	Lafarge + sand	Ceprovip + pozzolana	Plain
Y (%)	88.17	88.3	88.88	87.01	89.91
paint weight (g)	0.84	0.72	0.62	0.45	--

Table 3 Brightness test

3.8 Crystallization resistance

The systems were placed in Na_2SO_4 solutions at 70 g/l and 700 g/l, in order to expose to very hard conditions the materials. In the more diluted solution Ceprovip was resistant to 2 cycles and Plastocem to 8 cycles; in the more aggressive conditions (700 g/l) Lafarge+sand overpassed 3 cycles.
Finally, only EMACO RESTO was resistant to all the 10 cycles.

3.9 Interaction with water after weathering

The hydrated based and Lafarge systems were destroyed during the washing. The values obtained with EMACO RESTO and Plastocem are generally consistant with the values on the "fresh" samples, even if higher. This is reasonable as a similar artificial weathering induces surely some structural internal modifications, increasing the porosity.

3.10 Soluble salts release

The chemical analyses made on the aggregates indicate, as expected, lower concentrations of free ions in the sand and higher quantities of sodium and potassium in the pozzolana.
The anhydrous binders contain principally sodium and sulphates. These ions generally decrease in all the samples after the setting.
EMACO RESTO had, at the beginning, the highest concentration in those ions, confirmed by a tendency of this system to an efflorescences formation (mirabilite).
In cooperation with the formulator, the origin of this compound was defined.

So, the verification of the same mix, in wich the cause of the origin of the ions was eliminated, confirmed better results. In fact, there was not efflorescences formation (Tab.4).

	sulfate	*sodium*	*potassium*	*magnesium*	*calcium*
EMACO RESTO	0.50	0.14	< 0.05	< 0.05	2.26
Plastocem	1.40	0.10	0.30	< 0.05	1.70
Lafarge	0.40	0.12	< 0.05	< 0.05	8.10
Ceprovip	not availab.	not availab.	not availab.	not availab.	not availab.
Pozzolana	< 0.1	0.12	0.11	< 0.05	0.70
Sand	< 0.1	0.04	< 0.05	O.06	0.53
EMACO RESTO+sand	0.27	0.14	< 0.05	< 0.05	0.64
Plastocem+sand	0.05	0.10	0.44	< 0.05	0.40
Lafarge+sand	0.08	0.03	0.07	< 0.05	1.10
Ceprovip+pozzolana	0.07	0.10	0.12	< 0.05	0.62

Table 4 Soluble salts content (% by weight)

3.11 Porosimetric characteristics

The three hydraulic binder based systems have a similar total porosity, between 23 and 30%. Otherwise, the mortar made with Ceprovip+pozzolana has a total porosity higher than 50%.
Following these results the Ceprovip system, that has a higher porosity with finer pores, shows the highest water absorption.
Quite unexpectedly the mix with Lafarge, having a porosity lower than Plastocem and EMACO RESTO, has a higher water absorption and permeability.
Since the last three mixes were made with the same quality and quantity of sand, the differences observed in the porous structure and in the behaviour with water, seems to be due to the different chemical behaviour of the binder.

3.12 Plastic shrinkage

The plastic shrinkage of EMACO RESTO is of about 100 microns/m, that of Plastocem reaches 700 micron/m.
Otherwise the shrinkage of Lafarge system and moreover of Ceprovip system is much higher, showing also the presence of many cracks.
The samples are still under observation for the evaluation of the behaviour in open air conditions.

4. CONCLUSIONS

The analytical methodology choosed in this study gave the possibility of distinguishing between the examined rendering mortar systems and making evidence of the peculiarity of each one especially with regard to the possible use in architectural restoring works.
The hydrated lime based mortar system must be considered separately between studied systems. In fact it was taken into consideration as reference material, because already largely used since ancient times.
The comparison between the two "modern" binders having an hydraulic lime base shows that the two products are quite similar but not equivalent. They are different especially with regard to compressive strength, Anstett test and salt crystallization resistance.
The comparison between those two systems and the "cementitious" product specifically formulated indicates that this one provide generally better performances.
The grey colour of this product should often require the application of a paint of different colour. The higher content of sodium and sulfate and the consequent formation of efflorescences is a negative feature that it was possible to eliminate thanks to the results of this study.
However, we should wish that the employ of mortars for restoring purposes would always be tested first by the experimenter.
The cooperation on a scientific base between the "operator" and the "formulator" could allow an improvement of the product to the aim of meeting the specific need of monumental repairs.

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