Decorative renders simulating stone of middle 20th century in the region of Lisbon

Maria do Rosário Veiga[1], António Santos Silva[2], Cláudia Martinho[3], Paulina Faria[4]

(1) Buildings Department, National Laboratory for Civil Engineering, rveiga@lnec.pt

(2) Materials Department, National Laboratory for Civil Engineering, ssilva@lnec.pt

(3) Dep. Civil Engineering, FCT, NOVA University of Lisbon, cm.martinho@campus.fct.unl.pt

(4) CERIS and Dep. Civil Engineering, FCT, NOVA University of Lisbon, paulina.faria@fct.unl.pt

Abstract

Housing and public urban buildings of the middle 20th century period, in Portugal, are characterized by a sober, rather severe, architectural and constructive design, known as “Estado Novo” period. In the region of Lisbon, the façades of many of those buildings are covered with a very durable unpainted decorative type of render, called “marmorite”. Considering that cementitious binders were already often used in that period, both in structural elements and in coatings, and due to the darkening effect of fungus, soiling and pollution, there was a generalized belief that *marmorite* renders were cement-based mortars. As a consequence, repair interventions used materials and techniques chosen for cementitious renders. However, the characterization of the *marmorite* render of the National Laboratory for Civil Engineering main building, in Lisbon, revealed that the render was composed by air lime, limestone and marble. Later, an experimental characterization campaign of samples of *marmorite* renders of 20 other buildings in the region of Lisbon revealed that they were generally composed by air lime, sometimes coloured with an inorganic pigment, and mainly limestone and marble aggregates of different colours selected to obtain an aesthetic effect.

Introduction

Housing and public urban buildings of the middle 20th century period, in Portugal, are characterized by a sober, rather severe, architectural and constructive design. It is the so-called Estado Novo Portuguese style, that integrates the late modernism period. In the region of Lisbon, many of those buildings were covered with very durable unpainted decorative renders, simulating stone, known as “marmorite” renders, expression that could be translated as something like “marbled” renders or “marmoreal” renders (Figures 1-3).

A special application technique was used to obtain the stone effect, consisting on: application of a common regularization render layer; application of a finishing render layer with a mineral binder and aggregates selected to obtain an aesthetic effect, usually of limestone or marble nature; short drying period for partial hardening; washing of the superficial skin of the binder in order to let the aggregates visible; very careful curing to avoid cracking of the render, which was rich in binder to provide a good key for the aggregates.

These *marmorite* renders were used both in public buildings of some importance, such as Lisbon University (1961) and National Laboratory for Civil Engineering – LNEC (1952) (Figure 1), and in housing urban buildings of the same period for medium and medium-high classes (Figures 2 and 3). They have also been used to retrofit older housing urban buildings, some for rent.

Being a very durable kind of render, after more than 5 decades, they show few anomalies, such as some cracks, stains and fungi and punctual erosion and lacunae (Figure 3).

Figure 1 – Façade of LNEC main building covered with *marmorite* render: a) General view; b) Detail of *marmorite*

In Institutional buildings, neutral colours were used (combinations of grey and cream colours) (Figure 1), while in housing buildings several colours, such as red-pink, green and yellow, were adopted by adding inorganic pigments to the binder and choosing marble and limestone aggregates of matching colorations (Figures 2-3).

This finishing technique for these façades is thought to be based in techniques of the same type used in Central Europe in the period between wars [1, 2]. However, the mortars were artisanal, produced in situ, opposite to most of the Central European ready-mixed mortars reported in literature.

Considering the period – middle 20th century – in which cementitious binders were already often used, both in structural elements and in coatings, and due to the darkening effect of fungi, soiling and pollution, there was a generalized belief in the technical milieu that these decorative renders were cement-based mortars. This belief was enhanced by the existence of an official specification document referring the use of a cement mix [3].

Figure 2 – Façades covered with colourful *marmorite* renders of Av. De Roma, Lisbon

As a consequence, repair interventions on those building façades used materials and techniques chosen for cementitious renders.

In 2006 a restoration of the main building of the National Laboratory for Civil Engineering, in Lisbon, was planned. It is a building of the late modernism period in Portugal, constructed between 1950 and 1952, designed by a team coordinated by the architect Porfírio Pardal Monteiro, one of the most reputed building designers of that period [4, 5]. The façade is rendered with a cream/light grey coloured *marmorite* (Figure 1), which presented dark stains and some cracks. To guarantee a suitable restoration, the original render has been analysed, from the points of view of material, performance and technique. It was then verified that the *marmorite* render had been applied with a thickness variable between 5 and 8 mm, on a first coat of hydraulic render and was composed at 95 % by calcium carbonate [6] meaning that the binder was air lime, opposite to expectations.

Was this building an exception? It was possible to identify and interview some retired old masons that applied *marmorite* in the past and the majority also referred that cement was the binder used. But they also explained that the formulation of the *marmorite* mortar was generally kept secret by the expert professionals [7].

A large experimental campaign was later accomplished to clarify the composition of *marmorite* renders of that period, in the Lisbon region. Samples of 20 buildings from 3 different districts (Lisbon, Santarém and Setúbal) were collected and characterized from the chemical, mineralogical, microstructural, physical and mechanical points of view [8].

Revealing the materials and compositions used and highlighting the employed technique, this study aims at gathering information in order to allow the planning of suitable, compatible interventions and in this way contributing for the preservation of this characteristic decorative render.

Figure 3 – Pink-red traditional *marmorite* render in Lisbon: a) General view during cleaning; b) Detail of red/pink *marmorite*

Materials

Samples of *marmorite* renders were collected in the districts of Lisbon, Santarém and Setúbal (within the region marked by the red circle in the map of Portugal mainland - Figure 4), in LNEC´s main building, located in a heavy car and plane traffic, and in housing buildings mainly of the decades 1950-1960, with different colours. It should be noticed that the collection of samples was generally only allowed by the owners in the case of renders with anomalies and in limited quantity and dimensions. Such low quantities permitted chemical, mineralogical and microstructural tests, but in many cases were not enough for physical and mechanical testing (Figure 5).

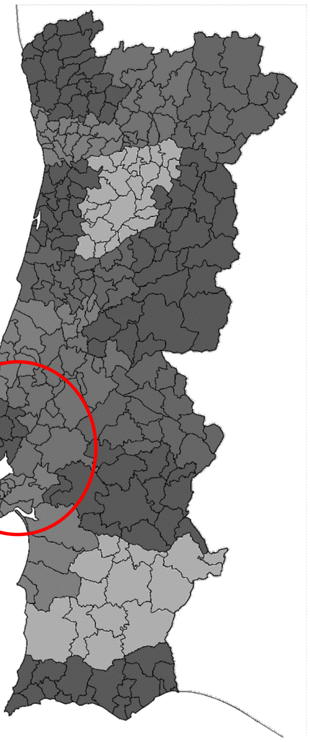

Figure 4. Map of Portugal mainland signalizing the region were the samples were collected

Figure 5. Samples of differently coloured *marmorites* collected

Methods

The tests used for the characterization of the samples were [6, 7]:

a) Mineralogical, chemical, petrographical and microstructural tests:
   - X-ray diffraction analysis (XRD) in a *Philips PW3710 X-ray diffractometer*, with 35 kV and 45 mA, using Fe-filtered Co Kα radiation of wavelength λ = 1.7903 Å.;
   - Thermogravimetric and differential thermal analysis TGA/DTA) performed in a *Setaram TGA92 analyser*, under argon atmosphere

(3 L/h) and using platinum-rhodium crucible of 50 µl capacity, with heating rate of 10 °C/min, from room temperature to 1000 °C.;

- Soluble silica, sulphates and alkalis content evaluation was made by gravimetric and atomic absorption spectrometry analysis;
- Granulometric analysis of the sand (separated from the binder by a controlled acid digestion according to a LNEC internal protocol for mortar samples with limestone aggregates) and stereozoom observation of the obtained granulometric fractions;
- Observation of vacuum impregnated polished and thin sections by optical microscopy (OM), using *Olympus PMG3 and BX50* microscopes;
- Scanning electron microscope (SEM) coupled with an energy dispersive X-ray microanalysis system (EDS). The SEM used was a JEOL JSM-6400, and the EDS is an INCA X'Sight detector from Oxford Instruments. Samples were gold sputtered, and the acceleration voltage used was 15 kV using the backscattered electron image mode (BSE).

b) Physical tests:

- Open porosity by the method of hydrostatic weighing based on EN 1936 [9];
- Mercury intrusion porosimetry (only one case);
- Water absorption by capillarity by a method based on EN 15801 [10] and adapted for irregular samples [11] (Figure 6 a);
- Compressive strength using a method based on EN 1015-11 [12] and adapted for irregular samples [11] (Figure 6 b), using a Hoytom S.L., model HM-S equipment, with load cells of 200 kN and 2 kN.

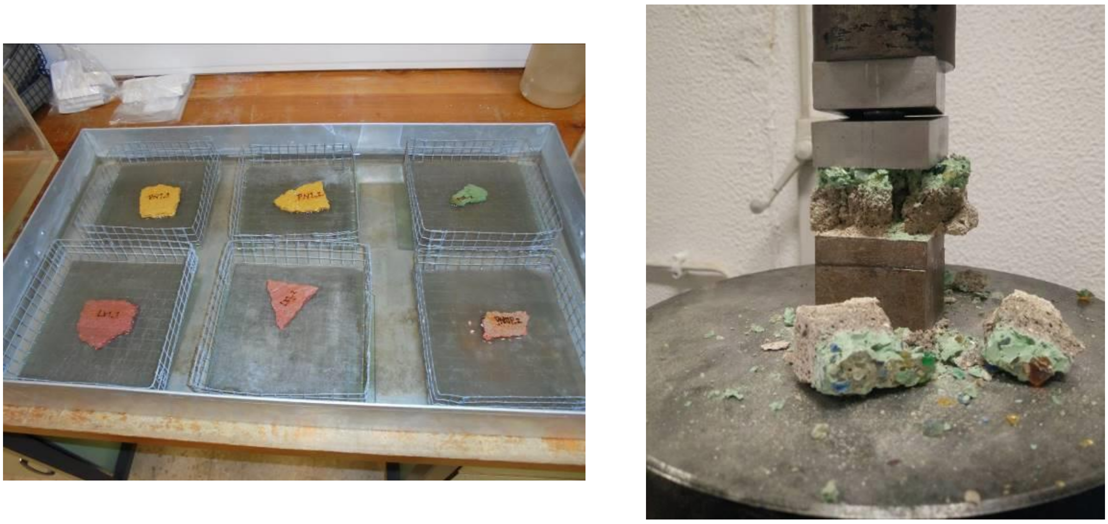

Figure 6. Physical and mechanical testing: a) Water absorption by capillarity; b) Compressive strength

Results and Discussion

LNEC main building

The results of the characterization of the *marmorite* of LNEC's façade are presented in tables 1 and 2 and in Figure 7.

Table 1 – Chemical, mineralogical and granulometric results of LNEC's *marmorite* samples [6, 4]

Sample	XRD	TGA/DTA	IR and grain size distribution	Chemical analysis (wt. %)	b/a (wt.)
LNEC's main building	Mainly calcite, some quartz and traces of hematite	95 % calcium carbonate	IR: 2.5%; Soluble fraction: 2.5%; Grain size distribution mainly 1.25 to 2.5 mm	Sodium: 0.02; Potassium: 0.03; Sulphates: 0.36; Soluble silica: 0.50	1:1

IR – Insoluble residue in acid; b/a – binder/aggregate ratio

Table 2 – Physical results of LNEC's marmorite samples [4, 8]

Sample	Bulk density (kg/m^3)	Porosity (%)	MIP	Coefficient of capilarity ($kg/(m^2.min^{1/2})$)
Façade of LNEC's main building – tests in 2006	2330	12 (MIP technique)	Bimodal structure with the following peaks: 0.02 and 0.5 µm	0.48
Façade of LNEC's main building – tests in 2017	2056	20 (hydrostatic weighing technique)	-	0,56

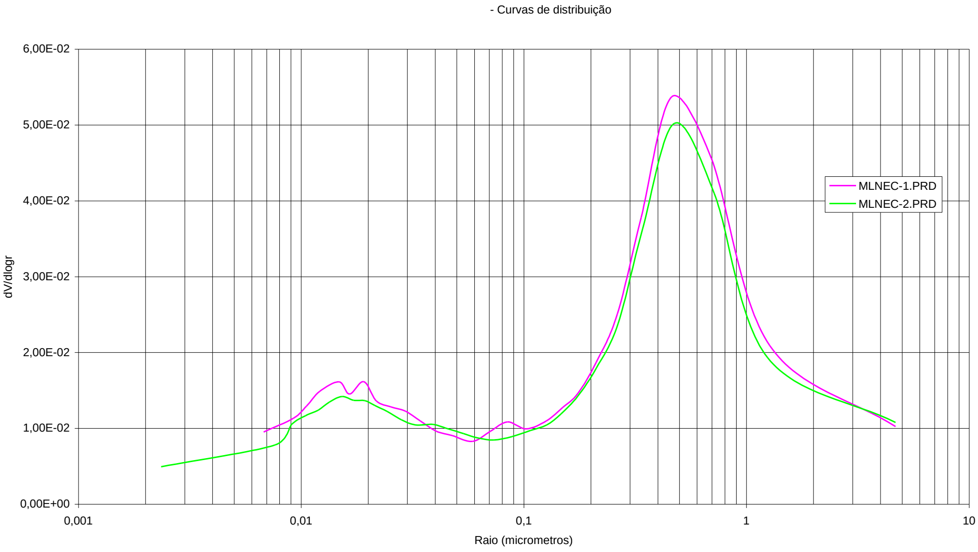

Figure 7. Pore size distribution of the *marmorite* of LNEC's façade [4]

The results of the characterization tests, presented in table 1, allowed to establish the composition of the LNEC´s marmorite render as mainly constituted by about 95 % calcite and small proportions of quartz and hematite, as well as some contamination with sulphates, probably from the environmental pollution. The very low alkalis and soluble silica contents indicated that there are no hydraulic compounds. The aggregates, of limestone and marble, are constituted by subangular grains from under 0.075 - 2.5 mm with predominance of the fraction 1.25 – 2.5 mm.

The main physical characteristics, presented in table 2, indicate relatively low porosity with a bimodal structure with critical pore size of 0.5 µm and capillary coefficient considered low when compared with other air lime mortars [11, 13, 14].

Housing buildings

The analysis of 20 samples of *marmorite* renders extracted from building façades of 3 districts in the Lisbon region showed thicknesses varying between 2 and 8 mm, applied on a thicker coat of render. The results of the samples, distributed by colour, in order to highlight the pigments used, are summarized in table 3 and allow to conclude that the samples are mostly composed by air lime as a binder and mainly calcitic aggregate, in some cases with also dolomitic and siliceous grains and sometimes including glass residues.

The composition data also confirm that the colours of the binder were obtained with oxides: hematite for red, goethite for yellow and chromium oxide for green, which were the colours commonly used. The aggregate was chosen in order to match these colours.

The proportions binder:aggregate, in weight, are very variable, from about 1:1 (PN8, PN6, PN11) to about 1:6 (PS4, RM4). However, for those with low content of binder, it is possible that, for such thin samples, surface washing and erosion may have influenced some reduction of the binder content.

A synthesis of the composition, together with the results of physical and mechanical characterization, are presented in table 4, for the samples now organized by district and not by colour, in order to investigate local influences. As referred before, only part of the samples could be tested for bulk density, porosity and water absorption by capillarity and only 3 could be subjected to the determination of compressive strength (Figure 6), due to size limitations.

Table 3 – Compositional results of *marmorite* samples

District / Local	Sample	Colour	Calcite	Calcitic Agg.	G	Glass	H, Go, Cr	D, F	Q	Cem	b/a (wt)
Lisbon / Campo de Ourique 1951	LX1	Pink / Red	94.30	63.88	-	-	1.00 H	4.70 Q	4.70	-	1:3.0
Lisbon / Moscavide 1950-1956	M1		93.25	71.36	-	-	-	1.00 F	5.75	-	1:4.8
Setúbal /Setúbal 1948	S4		94.73	40.91	-	-	-	1.00 D	4.27	-	1:1.1
Setúbal / Pinhal Novo <1951	PN11P		80.09	30.03	1.86	5.00	1.00 H	-	12.05	-	1:1.2
Setúbal / Pinhal Novo <1951	PN5P		77.84	37.72	-	5.00	1.50 H	-	15.66	-	1:2.0
Setúbal / Pinhal Novo	PN12		63.02	59.87	-	-	2.00 H	-	5.00	25.7	1:2.5
Lisbon / Mem Martins <1953	MM3		89.05	68.15	-	-	-	-	5.00	-	1:4.7
Santarém / Rio Maior 1971	RM6		33.93	10.18	-	32.79	0.50 H	-	32.79	-	1:4.3
Santarém / Rio Maior	RM7R		28.50	5.70	-	21.15	-	1.00 F	49.35	-	1:4.6
Setúbal / Pinhal Novo 1948	PN1R		95.05	64.39				1.00	3.95		1:3.0
Setúbal / Pinhal Novo <1951	PN5R		93.16	71.29	2.96				3.88	-	1:3.9
Lisbon / Sintra (1956?)	PS4	Dark grey	90.93	77.15	2.25	-	-	1.00	2.00	-	1:6.4
Setúbal / Pinhal Novo <1951	PN11R		83.75	48.85	-	5.00	-	-	11.25	-	1:2.5
Setúbal / Pinhal Novo 1948	PN1P	Yellow	94.23	63.83	1.77	-	1.00 Go	1.00	2.00	-	1:2.7
Setúbal / Pinhal Novo	PN2V		40.93	12.28	-	-	-	-	59.07	-	1:3.4
Santarém / Rio Maior	RM7P	Green	30.57	9.17	-	62.93	1.50 Cr	-	5.00	-	1:4.9
Santarém / Rio Maior	RM4		27.59	8.28	-	66.41	1.50 Cr	-	5.00	-	1:5.5
Setúbal / Pinhal Novo	PN8		78.95	23.69	2.10	14.05	1.00 Cr	1.00	5.00	-	1:1.0
Setúbal / Pinhal Novo	PN6		78.30	23.49	-	14.70	1.00 Cr	1.00	5.00	-	1:1.1
Setúbal / Pinhal Novo	PN2P		27.64	8.29	1.48	23.29	1.00 Cr	-	23.29	-	1:4.9

G – Gypsum; H – Hematite; Go – Goethite; Cr – Cromium; D – Dolomite; F – Feldspar; Q – Quartz; P – Portlandite; Cem – Cement; Si – Silica; b/a – binder / aggregate ratio

Table 4 – Composition and physical and mechanical results of *marmorite* samples

District / local / const date	Sample	Composition	b/a (wt)	Bulk density (kg/m^3)	Porosity (%)	Coefficient of capilarity (kg/(m^2.min$^{1/2}$))	Compressive strength (MPa)
Lisbon / C.Ourique / 1951	LX1	Air lime : Calcitic and silic agg	1 : 3	2159	18	0.33	-
Lisbon / Moscavide 1950-1956	M1	Air lime : Calcitic and silic agg	1 : 4.8	-	-	-	-
Lisbon / Mem Martins < 1953	MM3	Air lime : Calcitic, dolomitic and silic agg	1 : 4.7	2088	18	0.18	1.33
Lisbon / Sintra Aprox. 1956	PS4	Air lime : Calcitic, dolomitic and silic agg	1 : 6.4	2245	10	0.25	-
Santarém / Rio Maior 1967	RM4	Air lime : Calcitic, silic and glass agg	1 : 5.5	-	-	-	-
Santarém / Rio Maior 1967	RM6	Air lime : Calcitic, silic and glass agg	1 : 4.3	-	-	-	-
Santarém / Rio Maior 1971	RM7P	Air lime : Calcitic, silic and glass agg	1 : 4.9	2006	16	0.73	4.43
	RM7R	Air lime : Calcitic, silic and glass agg	1 : 4.6	-	-	-	-
Setúbal / Pinhal Novo / 1948	PN1P	Air lime : Calcitic, dolomitic and silic agg	1 : 2.7	2249	14	0.51	-
	PN1R	Air lime : Calcitic, dolomitic and silic agg	1 : 3	-	-	-	-
Setúbal / Pinhal Novo	PN2P	Air lime : Calcitic, silic, glass and ceramic agg	1 : 4.9	-	-	-	-
	PN2V	Air lime : Calcitic and silic agg	1 : 3.4	-	-	-	-
Setúbal / Pinhal Novo < 1951	PN5P	Air lime : Calcitic, silic and glass agg	1 : 2	-	-	-	-
	PN5R	Air lime : Calcitic, silic and glass agg	1 : 3.9	-	-	-	-
Setúbal / Pinhal Novo	PN11P	Air lime : Calcitic, silic	1 : 1.2	2118	13	0.17	-

< 1951		and glass agg					
	PN11R	Air lime : Calcitic, silic and glass agg	1 : 2.5	2254	13	0.47	-
Setúbal / Pinhal Novo	PN6	Air lime : Calcitic, dolomitic, silic and glass agg	1 : 1.1	-	-	-	-
Setúbal / Pinhal Novo	PN8	Air lime : Calcitic, dolomitic, silic and glass agg	1 : 1	1983	21	0.88	-
Setúbal / Pinhal Novo	PN12	Cement : Calcitic, and silic agg	1 : 2.5	2205	21	0.04	31.03
Setúbal /Setúbal / 1948	S4	Air lime : Calcitic, dolomitic and silic agg	1 : 1.1	-	-	-	-

All the cases present air lime as a binder, with the exception of PN12 (in Setúbal / Pinhal Novo), which is a cementitious render. As it is the only case, it is possible that it is a substitution render applied in an intervention.

The aggregates vary depending on local geology and on vogue/fashion. The aggregates of the Lisbon cases are mainly calcitic, namely of limestone and marble origin, sometimes also dolomitic, with small proportions of quartz. The case studies of Santarém, which are the most recent of the analysed group, all have calcitic and siliceous aggregates and include glass residues as a part of the aggregates. In Setúbal the case studies are the oldest and have a more heterogeneous mix of aggregates, including glass and ceramic pieces in one case, besides calcitic, dolomitic and small proportions of quartzitic aggregates.

The physical characteristics, synthetized in table 4, evidence that porosity is also very variable, between 10 % (PS4) and 18 % (LX1 e MM3), nevertheless lower than the usual values for air lime mortars [15] which are generally in the order of 20-30 %. Capillary coefficients obtained are of the same order of magnitude as those obtained for LNEC's *marmorite*: between 0.18 to 0.73 kg/(m^2.min^{½}). Porosity, capillary absorption and also bulk density point out to vary compact mortars, which is consistent with the artisanal technique used of squeezing against the substrate, followed by washing to remove superficial binder and by careful curing conditions. The few results of compressive strength obtained (only three samples included pieces with the dimensions needed for this test) show moderate results for air lime *marmorite* mortars (1.33 and 4.43) and a very high value for the cement *marmorite* render (31 MPa for PN12).

With the short sampling that was possible to test, it is not possible to find a pattern of correlation between binder:aggregate ratio and porosity, capillary coefficient or compressive strength. Nevertheless, this lack of correspondence is common in air lime renders, as there are many other factors with overlapping influence, such as the technique of application (namely the squeezing against the substrate and the application and curing conditions), the water absorption of the aggregates and of the substrate, and the packing of the aggregates.

Conclusions

In the decades of 1940-1960, in the region of Lisbon, a decorative type of render with a finishing thin layer simulating stone, with visible aggregates, known as *marmorite* render, was commonly used.

Although most of those buildings already had a structure of concrete, or at least partially of concrete (for example concrete slabs between floors supported by structural masonry walls), it was verified that *marmorite* render was an air lime render with mainly carbonate aggregates of marble and limestone. That was not in accordance with what was gathered in interviews to old masons differncet that could be explained both by the secrecy that involved the *marmorite* mortars formulation and by the fact that those old masons consider cement as the “new” building material that presented a revolution on their old way of building, therefore, they prefer to remember and to talk about building with cement.

In Institutional buildings, the renders presented neutral colours, obtained by the selection of the raw materials (white calcitic air lime and chosen aggregates) while in housing buildings different colours were used, obtained by the addition of inorganic pigments and selection of matching marble aggregates. The pigments found were hematite, goethite and chromium oxide, according to the typical façade colours: red/pink, yellow and green. Those coloured façades originated picturesque quarters, typical of the modernist zones of Lisbon. In some areas, usually out of the centre of towns, more open colouring was chosen, through the use of glass and ceramic residues, clearly showing the joyful individual taste of their owners.

Marmorite renders that still protect and decorate many façades in the region of Lisbon are now aged of more than fifty years. Most of them never had any maintenance operations in this period and they still present efficient conditions, with suitable cohesion and adhesion, due to well-chosen materials and a careful and efficient application technique. Therefore, apart from effective technical characteristics, one can say they have a low embodied energy because the environmental impact is divided by a long period without maintenance and repair materials. In the last decade many of them started decaying, partly due to traffic pollution that attack carbonate materials and to the corrosion of reinforcing steel bars of some of the concrete substrates. Due to lack of knowledge about their composition and their particular application technique, the interventions were directed to the painting of the façades, hiding the *marmorite* render sometimes in an irreversible way and completely changing the brightness, the typical colour tonalities and the whole image of those quarters.

Therefore, revealing the materials and compositions used, this study intends to generate data to allow the planning of suitable, compatible interventions and the preservation of these durable and specific render.

Acknowledgements

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