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Terranova Render: A "Polychrome Resource for Modern Aesthetics". A Study for Analysis and Characterization

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Abstract: The industry, which developed into an endless source of new formulations and technologies, supported the typological innovation that took place in the architectural field in the first half of the 20th century. The world of plaster was revolutionised by the introduction of ready-mixed mortars that only required the addition of water. The plaster was no longer created on site, and the workers only dealt with the application. In Italy, the so-called "special plasters" based on cement and/or lime with the addition of various substances, the formulations of which were kept secret by the manufacturing companies, appeared in the period after the World War I. Despite being widely spread, their composition is still little known today. Samples of Terranova plaster, characterized by high durability, were investigated in this study to understand their main characteristics. The analysed samples appear to be based on dolomitic lime with characteristic iridescent aggregates and high porosity, probably due to air-entraining agents and pigments based on oxides of different nature. The aim of this paper is to compare three samples of Terranova plaster from the Emilia-Romagna region with the literature.

Key words: Terranova plaster, modern heritage, material characterization.

1. Introduction

Literature on modern heritage materials, although now conspicuous, is lacking in many aspects, mainly due to the huge number of materials introduced during the 20th century. The so-called "special plasters" [1] based on cement and/or lime (with the addition of various substances) appeared in Italy during the first post-war period, the manufacturers of which kept the formulations secret. The innovations introduced during the 20th century led to not always adequate outcomes, being many modern materials characterized by a high degree of experimentation which easily led to their deterioration. On the contrary, Terranova plaster was characterized by high durability [2, 3].

In this study, a series of diagnostic investigations were conducted in order to understand if some samples of Terranova plaster match the properties declared by the manufacturer and if there are recurring characteristics among different samples. The ultimate objective is to understand whether there is a sort of "standard recipe" that allows reproducibility nowadays.

2. Terranova: A Ready-Mix Rendering Mortar

Engineer Carl August Kapferer founded the business Terranova Industrie C.A. Kapferer & Co. in Freihung, Germany, in 1893. The founder, in collaboration with Wilhelm Schleuning, started the production of Terranova render, a ready-mix colored render [4].

The first patent was presented to the imperial patent office in Berlin on November 19, 1895, and was registered on March 12, 1896, at no. 14702 (class 37). The popularity of Terranova plaster grew over the years, and new factories were opened in Munich, Frankfurt, Berlin, Nuremberg, and Vienna [4, 5]. After widespread

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diffusion throughout Europe, Terranova plaster arrived in Italy thanks to two industrialists: Aristide Sironi and Federico Griesser.

Sironi registered the “process for improving plaster mortars” in 1928 with industrial patent no. 247015 of the Kingdom of Italy.

In 1932, Sironi, Griesser, and Kapferer founded the Società Anonima Italiana Intonaci Terranova and started the production in Italy. Meanwhile, a new logo was registered at the central state archive, which underlined the presence of the product on the market since 1893[1]. With the opening of the factory in via Benaco in Milan and the presence of representatives in the major Italian cities, Terranova plaster found applications throughout the Italian peninsula. Since the first year of its establishment, the company participated in Milan’s *Fiera campionaria*, where national products were promoted, and their modern and rational qualities were exalted. Thanks to widespread advertising campaigns in sector magazines, durability, resistance to atmospheric agents, the vast range of colors, and the autarkic restrictions imposed by the fascist regime, Terranova became the reference plaster for the designers of the time. Used not only for exteriors but also for interiors with “a thousand and more very soft colors, it gives the architect and the builder the resource of polychrome and modern aesthetics”, according to a 1930s advertisement that appeared in many magazines, including Domus [5]. The use of Terranova also reached the world of art, and decorative inlay panels of Intonaco Terranova were exhibited in 1933 at the *Mostra dell’abitazione*.

Another key year for S.A. Intonaci Terranova was 1936, when they opened the factory in Stephenson Street in Milan and the factory in Civitavecchia, which was then closed in 1956. In 1945, the Sironi family took over the shares of Griesser and Kapferer, and the property became entirely Italian: the Italiana Intonaci Terranova S.p.A.

The Sironi family’s path at the helm of the Italian Terranova company ended in 1987, when the Austrian Terranova company took over all the shares. In 1993, the French company Weber & Boutin, a European leader in the production of colored and premixed plasters, purchased the company, which is now owned by Saint-Gobain Weber Co. [5].

2.1 Composition

Being subject to patent, the composition of Terranova plaster remains secret; however, among many uncertainties about its composition, it can be stated that since its origin the Terranova plaster produced in Italy has been a ready-mix powder mortar, i.e., a ready-to-use dry mortar, which only requires the addition of water for application. Some variations of this secret formulation, investigated by several studies in recent years, seem to emerge over time.

Before arriving in Italy in the late 20s, in Germany, Kapferer started to produce for the first time a ready-mix factory-colored dry mortar in 1911. It only needed water on the building site, probably to have more precise control over quantities but also to meet market demand for ease of installation.

Furthermore, in 1911, a new patent was issued for a “method of improving the permeability to air of dry plastering-mortar”, adding a “mixture of oil, acetone, and starch additives” [6].

In the first German formulations, according to studies conducted on patents [6], “clay (kaolin), feldspar (orthoclase), lime, and pure quartz sand were burned to produce cement clinker”.

In 1926, another improvement was made to give it a sparkling appearance by adding iridescent aggregates.

Research by the University of Potsdam [4] shows that white Portland cement was available on the German market only in 1926, long after the birth of the company and the start of marketing Terranova plaster throughout Europe. Since the manufacturer Terranova

[1] The trademark n. 46679 of the S.A. “Terranova” plasters was registered on October 18, 1932, in Milan to identify petrifying plaster for building use and registered on December 6, 1933, at the Archivio Centrale di Stato.

stated in 1990 that the product had not undergone changes since 1893 [5], it seems that, at least in the first formula, the binder did not consist of any quantity of white cement.

According to a manufacturer's technical data sheet, reported in Ref. [5], which claims to still produce Terranova according to the original formulation, it is reported that the plaster "is made up of a mixture of lime with the addition of a small quantity of cement, selected silica and quartz sands, and solid inorganic pigments to the light, which allow its production in a vast range of colours". However, it is not possible to define the nature of these binders and the aggregate-binder relationship.

An innovative aspect of the patent registered in 1928 in the Kingdom of Italy is the ability to start the silicatization process of the lime during hardening by adding powders of active silicic acid and sodium or silicon fluoride.

2.2 Color Chart and Application

In 1934, Griffini defined Terranova plaster in his dictionary as "plaster prepared with special substances and colored with natural pigments. (...) It presents an extensive variety of different colors and shades" [1].

In 1893, since the first stage of production, Terranova render was "offered in the colors yellow, light red, dark red, silver gray, yellowish, greenish gray and reddish, initially using different colored brick material" [4].

The handbooks of the 1930s report that the plaster was colored with natural pigments; however, as regards the color, there seems to be a first phase where, in addition to the binders used, which had a great influence on the coloring, there were additions of bricks, slate, chalk, ironstone, slag, molten brick, finely ground glass, and porcelain [4]; a second phase, however, was characterized by the use of "light-fast inorganic pigments that allow the production of a vast range of colors" [7]. The information contained in a patent specification also shows that the result, in terms of color, of a plaster mortar did not only depend on the choice of pigment but also on the method of addition [4].

The information provided by Griffini can be found on the back of an advertising flyer from 1932, which states that the product is sold in 50 kg paper and jute paper bags and in 90 colors, which are delivered to the construction site in ready-to-use bags and only have to be mixed with water. It is also reported that the application requires a few simple phases: spreading the mixture with a trowel, troweling, smoothing at the beginning of setting, and finally brushing.

The bladed Terranova "lamato", with its 5 mm thickness, was supplied in three grain sizes: fine grain with a yield of 7 m^2 per quintal, medium grain with a yield of 5 m^2 per quintal, and large grain with a yield of 4 m^2 per quintal.

The application by the company selling the product, in order to guarantee correct application, was continued until the 1980s.

3. Materials and Methods

3.1 Specimens

This paper illustrates and discusses the chemical-physical analyses carried out on specimens of Terranova render collected from three rationalist buildings in Emilia Romagna region:

- ex Mercato Ortofrutticolo (M.O.F.) in Ferrara (1937-1938);
- ex Gioventù Italiana del Littorio (G.I.L.) in Forlì (1933-1935);
- ex Asilo Santarelli in Forlì (1936).

Archival documentation supported the authenticity of the first two renders, but there was no firm evidence for the third. All these samples were compared with the previous study on the "Terranova" render of the Engineering Faculty in Bologna (1931-1935), which showed that almost a century after its application and despite direct exposure to rain, this render is in a perfect state of conservation [2].

Another interesting basis for the comparison is a specialist report relating to the restoration project of "ex

Asilo Santarelli" carried out by Istituto Giordano[2]. The MOF-1 sample (Fig. 1) shows a light green upper layer with an irregular surface and a thickness of approximately 2 mm and a light grey substrate with a thickness of approximately 14 mm. The sample taken from ex-GIL (Fig. 2) exhibits sparkling aggregates, and while the thickness of the colored layer increases considerably, reaching 7 mm, while the substrate settles at around 15 mm. Asilo Santarelli (Fig. 3) has a thickness of 3 mm in the colored layer and 15 mm in the substrate.

Fig. 1 Sample MOF_I taken from ex Mercato Ortofrutticolo (M.O.F.) building in Ferrara.

Fig. 2 Sample GIL_I taken from ex G.I.L. (Gioventù Italiana del Littorio) building in Forlì.

Fig. 3 Sample ASL_I taken from ex Asilo Santarelli building in Forlì.

3.2 Testing Methods

3.2.1 Porosity and Transport Properties

The ability of substances to be conveyed within a material is a function of pore quantity, size, and distribution. Knowledge of the void network, together with other properties, allows carrying out assessments both on the degradation mechanisms and on the requirements necessary for conservative treatments to be effective, compatible, and durable.

Hydrostatic weighting was used to determine real density and apparent density, total porosity, and open porosity, as illustrated in EN 1936 [8]. A water pycnometer was used on powdered samples to determine the real (or absolute) density.

Water absorption by capillarity was determined as described in EN 15801 [9]. After drying the samples to a constant mass, the samples were placed in a vessel with a bedding layer of gauze soaked in deionized water. The surface chosen for the determination of water absorption by capillarity was not polished in order to keep the typical roughness of the surface. The samples were weighed at appropriate time intervals.

The water vapor diffusion resistance coefficient of the render (μ) was determined by the wet cup method using a saturated aqueous solution of KNO_3, according to EN 12572 [10]. The test was carried out on the

[2] Attachment R4: Bando no. 2150 of 28.9.2018 of the Municipality of Forlì, "Analisi petrografica, analisi diffrattometriche, analisi al microscopio elettronico su campioni di intonaco esterno e determinazione della presenza di amianto su materiale massivo".

samples made up of two layers, without separating them.

M.I.P. (Mercury Intrusion Porosimeter) Thermo Scientific Pascal 240 and 140 allowed obtaining information on the quantity, size, and distribution of pores through the intrusion of mercury at increasing and isotropic pressure.

3.2.2 Composition and Formulation of the Render

In order to observe a flat cross section of the samples in an Olympus SZX10 S.O.M. (stereo-optical microscope), they were incorporated into resin, sawed, and lapped. This allowed determining some morphological characteristics, colors, and the state of conservation.

The samples were also studied in cross-section and on the external surface with a SEM (scanning electron microscope) Philips XL-20 equipped with EDS (energy dispersive spectrometer) microanalysis.

The Dietrich-Fruhling Calcimeter was used to determine the content of $CaCO_3$ (calcium carbonate), according to UNI 11139 [11] and UNI 111402 [12]. Different fragments were analyzed and they were identified by progressive numbers. Each sample was divided into its two layers, the colored one and the substrate, and crushed with the aid of mortar and pestle. To carry out the test, 1 g of powdered sample was used for each layer. Grinding facilitates the reaction between $CaCO_3$ and HCl, increasing the surface area of the sample in contact with the acid.

4. Results and Discussions

Open porosity, as shown in Table 1, is higher in the colored layer than support for samples MOF-1 and ASL_I-2. Comparing the data obtained with those carried out on the single-colored layer in Ref. [2], characterized by an open porosity of 22.9% defined through hydrostatic weighing, it can be noted that the only GIL-1 sample with a porosity of 25.33% is in line with this result, while the other samples exhibit higher porosities [7]. It is interesting to observe how the colored layer of the analyzed samples does not have a lower porosity than the support, unlike what is expected for historical plasters.

The water vapor diffusion resistance coefficient (μ) of the MOF-1 sample is less than half with respect to GIL-1. Terranova plaster of the Faculty of Engineering in Bologna was studied only in the colored layer, so a comparison should be avoided since this test on MOF-1 and GIL-1 was conducted on the plaster made up of both layers.

Technical characteristics provided by the manufacturer and reported in Ref. [5], indicate $\mu < 16$ for bladed Terranova "lamato" and $\mu < 4$ for sprayed Terranova "spruzzato", but there is no reference for these values, and therefore it is not possible to deduce from the text whether these are experimental values obtained in research or whether they were taken from handbooks. In both cases, the manufacturer's values refer to laboratory tests on hardened mortars, but it is underlined how the coefficients could be modified depending on the installation methods. Based on these data, only MOF-1 with a value of 7.7 is in line with the results obtained. The UNI 10351 [13] provides reference values for vapor permeability from 5×10^{12} kg/(m·s·Pa) to 18×10^{12} kg/(m·s·Pa) for lime or lime and cement-based mortars with a density of 1,400 kg/m^3 and cement mortars with a density of 2,000 kg/m^3.

Table 1 Open porosity measured with hydrostatic weighting (%P.A.$_{hw}$), open porosity measured with MIP (%P.A.$_{MIP}$), mean pore size (ϕ), bulk density (ρ_b), real density (ρ_r), capillary water absorption coefficient (C.A.), and water vapor diffusion resistance coefficient (μ) of Terranova samples. C: colored layer, S: substrate.

Sample	MOF-1		GIL-1		ASL_I-2	
Layer	C	S	C	S	C	S
%P.A.$_{hw}$	34.04	27.72	25.33	31.73	31.71	26.98
%P.A$_{MIP}$	32.86	30.89	28.28	24.66	31.30	33.66
ϕ	0.13	0.33	0.20	0.32	0.30	0.43
ρ_b	1.70	1.76	1.87	1.72	1.68	1.76
ρ_r	2.56	2.52	2.44	2.48	2.45	2.61
C.A.	0.068	0.078	0.056	-	0.128	-
μ	7.7	-	16.1	-	-	-

The capillarity water C.A., reported in Table 1, was analyzed in both directions only for MOF-1 sample, since the extremely irregular surface of the other samples would not have provided reliable results. The values are similar to the 0.068 kg/($m^2 \cdot s^{1/2}$) value found for the Faculty of Engineering in Bologna, while ASL_I-2 shows substantially different results compared to those present in the literature. However, it is noteworthy, as emerged from historical research, that the Terranova plaster itself existed in various formulations. The reduced value could be due to the presence of water-repellent organic additives or the presence of air voids that limit capillary absorption in the short term since they are filled only after the smallest pores and capillaries are saturated [2].

In Table 1, the values of bulk density (ρ_b) are also shown, which are in line with those provided by the Italian standard 10351 [13], in which lime-based mortars are characterized by a density of 1.8 g/cm^3. The test results are also similar to those provided by the manufacturer and reported in Ref. [5], equal to 1.7 g/cm^3. In Ref. [2], the density of the finishing layer is equal to 1.82 g/cm^3; the value is very close to that obtained for the sample GIL-1, but also the other tests on MOF-1 and on ASL_I-2 provided values in the same range.

In Table 1, the values obtained from the performed pycnometry are summarized. The coloured layer is found to have a higher actual density than that of the support only for the MOF-1 sample; the other samples analysed have higher values in the substrate than in the coloured layer.

M.I.P. test results are summarised and illustrated in Table 1 and Fig. 4. The %P.A. of the sample in Ref. [2] is slightly lower than those of the samples analyzed in this study; the most similar is GIL-1 with a value of 28.8%, while MOF-1, with the value of 32.86%, is the one that differs most. The average diameters of the pores of the analyzed samples are all smaller than the sample studied in Ref. [2]. The samples ASL_I-1 and MOF_1 have a cumulative pore size distribution curve more similar to that of hydraulic lime mortar, while the sample GIL-1 has a curve similar to the one of cement-based mortar [2]. However, cement-based mortars usually have porous diameter in the range of 0.002-0.1 µm, while, the sample GIL-1 has a peak between 0.2 and 1 µ m, in line with NHL mortars.

The observation with the optical microscope showed that all the samples are characterized by a rough external surface and perfect adhesion between the two layers. The irregularity of the surface appears to be a function of both the granulometric assortment and the methods of application. The thickness of the colored layer of GIL-1, equal to 6.5 ± 2 mm, is the highest among the samples, and higher than that suggested by the manufacturer. The literature values are in line with those observed in the ASL and MOF samples. The presence of iridescent aggregates, probably mica as in Ref. [2], was found in samples MOF-1, MOF-3, and GIL-1. In MOF-1 and MOF-3 iridescent aggregates are very widespread, while in GIL-1, they take up larger sizes compared to the MOF but in smaller quantities. The colored layer of GIL-1 has an aggregate size of up to 5 mm. The aggregates of the colored layer of the other samples have smaller size; samples MOF-1 and MOF-3 have a maximum size of approximately 0.5 mm, while the aggregate size of samples ASL_I-1, ASL_I-2, and ASL_II-1 is about 1 mm.

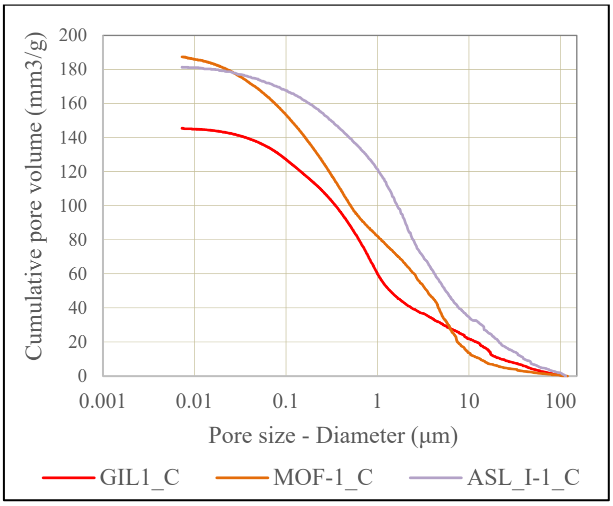

Fig. 4 Results of the M.I.P. test on the colored layer.

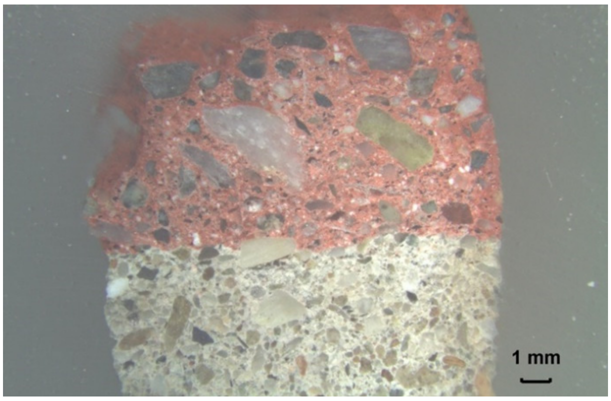

Fig. 5 SOM image of the Terranova render of ex G.I.L. building in Forlì.

EDS spectra show the presence of O, Si, Al, Mg, Ca, and C, although the aluminum peaks in all spectral spectra are due to the Al sputtering over the samples. Samples from Asilo Santarelli show similar spectra for coloured layers and support. The similarity between the two layers had already been observed with SOM (Fig. 5). This test allows for some hypotheses that need to be confirmed with further investigation about the pigments used for coloring the factory-tinted render. The following elements have been detected: titanium in the ASL_III sample, as well as in Ref. [2]. Titanium dioxide (TiO_2) is a white pigment used in coloring processes since World War I. Iron is in both layers of ASL_III and GIL-1 and in reduced quantities in the colored layer of MOF-1. Iron-containing coloring oxides are very widespread thanks to the possibility of obtaining color gradients from yellow to brown. Chromium was found in the colored layer of the samples MOF-1 and MOF-3. Chromium oxide, Cr_2O_3, is an opaque green-olive pigment.

5. Conclusions

In all three cases, the Terranova render is made up of two layers: the exposed colored one and a grey support. The wide range of colors proposed by the manufacturing company is represented, albeit in a small way, by the tones found in this study. The investigations conducted allow stating that the characteristic roughness of the surface is due not only to the methodologies of application but above all to the large size of aggregate (quartz and silicates). The granulometric distribution and color of the aggregates are not the same in the colored layer and in the support. The colored layer has aggregates with a reduced average diameter compared to those observed in the support, which is formed by aggregates that are better assorted. In the colored layer, there is a very widespread iridescent aggregate, probably mica, as shown in previous studies, which gives the render a bright appearance. The amount and size of this type of aggregate vary from sample to sample. The colored layer thickness is higher in all the analyzed samples in comparison with those declared by the manufacturer.

High open porosity (about 30%) is reflected in some patents of the manufacturing company that declare the use of air-entraining admixtures. The presence of pores, whose shape is variable, seems to guarantee excellent durability by increasing frost resistance, one of the main causes of degradation in modern architecture due to the lively and exposed corners [2]. The high porosity is in line with that of mortars based on natural hydraulic lime, while the average diameter of the pores of the analyzed samples is slightly lower.

The adhesion between the colored layer and the support is excellent, and a good compatibility between the two layers seems present both in terms of porosity and density. Despite the high porosity, the capillary absorption coefficient is low, in line with the values found in the literature for mortar based on natural hydraulic lime. The reduced value may be due to the presence of water-repellent organic additives or to air vacuums that limit capillary absorption in the short term. In conclusion, there does not appear to be a common formulation for the compared samples.

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