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THE USE OF MORTAR TO IMITATE WHITE MARBLE AND OTHER STONES

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Abstract

The reproduction of natural stone using different kinds of mortars has always been an important character of the architecture of Lombardy (Italy). Many examples of artificial stone, made of a coating of lime mortar on stone or brick structures, are available from Roman times. At the turn of the 20th century, a new kind of material, based on Portland cement and crushed stone, made possible a quite perfect reproduction of different kinds of stone and the making of complicated decorative elements. The raw materials employed to reproduce white marble and other stones used in Lombard architecture were investigated starting from the 'Fontana di Camerlata' (Como, 1936–62).

***Keywords**: Mortar; Artificial stone; Cast stone; Marble; Granite; Calcarenite*

Introduction

The use of a material reproducing the aspect of the stone was already widespread in the Greek world. The high cost of working and transporting a natural material was an important factor that encouraged the combined use of brick and other materials and different kinds of mortar.

The reasons leading to use a surrogate instead of a natural stone are well testified by an excerpt of Vasari's *Life of artists*, which referred to the construction by the architect Giulio Romano (late 16th century) of the Palazzo Te in Mantua, a city set in the Northern Italian alluvial plain (*Pianura Padana*) far from any rocky outcrops: «Giulio Romano set his hand to the work [Palazzo Te](...). And since the place [Mantua, southern Lombardy] has no living rock, and no quarries from which to excavate material for hewn and carved stones, (...) he made use of brick and baked stone, which he afterwards worked over with stucco; and with this material he made columns, bases, capitals, cornices, doors, windows and other things, all with most beautiful proportions» [1].

Vasari pointed out a specific character of the stone reproduction, which lasted until the early XXth Century: a poor material as structural backing then covered by plaster or stucco, with suitable colour and texture to look like marble. In Greece, the marble to make early Doric temples was unavailable, so the local porous limestone was covered with a coat of stucco giving

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the proper smoothness to the surfaces [2]. In Rome, a stucco looking like marble was described by Vitruvius in the third chapter of his seventh book [3], and it was employed in Rome and all over the Roman Empire, to coat soft stone, brick and tuff columns, or to simulate marble slab veneers (i.e. the *domus* of Augustus on Palatine Hill); to cover and to decorate, with architectural elements and fine bas-reliefs, the brick walls (the Domitianic complex then adapted for Christian use as the church of St Maria Antiqua in the Roman Forum) or the concrete vaults (*Thermae Antoninianae* — Baths of Caracalla) [4]. This technique was still in use in the Early Middle Ages, mainly in the eastern Mediterranean regions and in Southern Europe under the Arab influence [5]. The stucco, as smooth and white as possible to look like marble, was brought back by Giovanni da Udine (early 16th century) and developed by Mannerist artists as Giulio Romano and Primaticcio [6]: the composition still comprised lime and marble powder and the laying included also the insertion of more or less projecting nails in the wall to produce mouldings or bas-reliefs 'becoming like marble' [1].

Later, the architecture of the Baroque and Neoclassical periods is famous for the white and coloured marble decorations of the churches, chapels and palaces, and so on in Rome, Naples or Palermo; at the same time, several recipes were developed to simulate marble, using lime or plaster of Paris together with marble powder to make the stucco coat. These products are well represented by statues, bas-reliefs, friezes, cornices or twisting volutes executed in Northern Italy and other European countries by craftsmen coming from Valle d'Intelvi (north of Como) [7, 8]. Gypsum plaster was mixed with glue and pigments to make a particular kind of material, called *scagliola*, allowing to finely reproduce also the most variegated marbles (18th and 19th centuries).

Since the end of the XVIIth Century, dozens of recipes were proposed to enhance the hydraulic feature of a lime mixed with clay and fired at high temperature. Different hydraulic cements were proposed by Parker, Vicat or Frost and then the true Portland cement (1824) together with some modifications and additions (reinforced concrete, 1854) gradually assumed the greatest importance all around the world. The use of Portland cement allowed the preparation of a new material showing good mechanical properties, proof against weathering and chance to imitate natural stones [9]. This cement was a cheap substitute for stone dressing, using different kind of moulds, and for tooling both on wet surfaces (brush) or on dry surfaces (chisel, bush hammer, …) [10]. It is possible to define two kinds of artificial stone: one (*cast-in place*) to be used as a mortar and another one (*cast-stone*) to be used to make architectural and decorative elements (*pre-cast*) and containing a coarse-grained core covered by a fine-grained finish coat.

Present-day reproduction of natural stone involves crushed stone and different binding materials (*Pierre reconstituée*) or polyurethane (*Faux stone*).

The cast stone

The cast-stone (*cemento decorativo* in Italian) was a distinctive character of the Italian architectural style, called 'Liberty', started in the last decade of the 19th century then flourished in the first decades of the XXth Century [11]. The use included pilasters, capitals, entablatures, window and door jambs, balcony balustrades, two-dimensional pieces for wall veneering and a great variety of ornamental artefacts, etc. Portland cement was mixed with different kinds of crushed rocks (Fig. 1), to obtain a coarse grain aggregate; the rocks were limestone, dolomite, marble together with mica, alabaster, mother-of-pearl, and pyrite crystals [12].

Single elements were 'pre-cast' (using also metal rods) then manufactured on the spot using the same tools as for the natural stones: this process improved the colour and the texture of the material. The patterns of the ornaments came from the architectural tradition (geometric shapes, volutes, mascarons, human figures) but also from new sources of inspiration: the botanical and zoological world (chestnut, wisteria, vine, lion, unicorn, etc.) or even achievements of the mechanical industry. In some cases, the ornaments carried items strictly related to the building itself: i.e. the Municipal Aquarium (Milano, architect G.S. Locati), built for the 1906 International Exhibition, shows round medallions on entablatures decorated with fishes, crocodiles, frogs, lobsters and windows decorated with prows of Roman triremes [13].

The favourable outcome of the cast-stone produced, in few years, a strong decline of natural stone, thereby causing the abandonment of a great number of hard stones quarried in the whole Lombardy. On the contrary, the use of cast-stone decorations was minimized when easy-to-work soft stones were available: i.e. the *lambourde* and the *pierre à plâtre* on the Art-Nouveau buildings of Paris.

Fig. 1. Different kinds of imitation of stone (conglomerate, red or brown limestone, pink or white granite, veined marble etc.) executed using mortars made of Portland cement mixed with sands or crushed stones (early XXth Century, Milano, Italy)

The aim of this study is to point out the features of artificial stone used to imitate some marble elements, starting from the conservation works carried out on the 'Fontana di Camerlata' in Como.

Materials and methods

Different analyses were carried out using Optical microscopy on thin sections, X-ray diffraction on powders and Infrared spectroscopy on powders.

Optical microscopy

Preliminary morphological observations were carried out on micro-fragments using a Leitz Wild M420 stereomicroscope. Thin cross sections (30μm thick) of the samples were observed in reflected light (Leitz Ortholux microscope with Ultropack illuminator) and in polarized light (Nikon Eclipse E400Pol microscope with Nikon Pol objectives).

X-ray diffraction

Small fragments were pulverized in agate mortar. Instrument PANalytical X'Pert PRO MPD; operating conditions: generator settings 40mA and 40kV; radiation Cu-Kα $\lambda = 1.5406$Å; scan range 3–35° 2θ; step size 0.017 2θ; scan step time 10.3376s; continuous scan type; software PANalytical X'Pert HighScore.

Fourier Transform Infrared Spectroscopy

The samples were analyzed as KBr (Sigma-Aldrich FTIR Grade) pellets by a FTIR spectrophotometer BioRad Excalibur Series FTS 3000, DTGS detector, in the transmission mode (400 to 4000cm^{-1}, 4cm^{-1} resolution, 16 scans). Regarding the extraction protocol, around 50mg of fine powders of the samples were put in a glass test tube, completely dipped into organic solvents (around 0.5mL) and sonicated for 15 minutes. The extractions were conducted using hexane (Sigma-Aldrich 95% anhydrous), toluene (Sigma-Aldrich 99.8% anhydrous) and ethyl acetate (Sigma-Aldrich 99% anhydrous), to extract nonpolar and polar components respectively [14, 15]. The test tubes were centrifuged for 3 minutes. The soluble fraction was placed on a NaCl plate and analysed in the transmission mode after gentle evaporation of the solvent. Solvent blanks were prepared to check for contaminations.

Results and discussion

Fontana (Camerlata — Como)

The Fontana di Camerlata is nine metres tall 'rationalist' fountain consisting of four horizontal circles alternately superimposed to four spheres; circles and spheres stand on the edge of a circle (pool) set on the ground and facing another circle, vertically set. The fountain was erected in 1962 in Camerlata, a southern district of Como (Lombardy, northern Italy), strictly following the original one exposed by Mario Radice and Cesare Cattaneo at the '6th Triennale', the International Exhibition of Architecture held in Milano (1936) (Fig. 2). Circles and spheres were made of a metallic lattice wrapped by an iron net, then encrusted with a white mortar. Only the circle on the ground is a solid body, still made of white mortar with rock splinters aggregate (Fig. 3) [16].

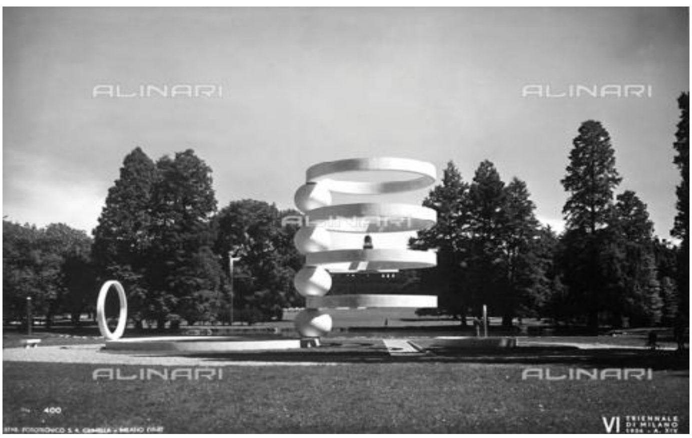

Fig. 2. The Fontana di Camerlata (Milan, 1936).
The original location at the 6th Triennale Exhibition (photo by Alinari)

Fig. 3. The Fontana di Camerlata (Camerlata, 2015).
A big circle made of white cement with rock splinters

Scientific analyses of the original plaster detected a double coat of mortar (total thickness 1.5–2.0cm) containing Portland cement as binder, with homogeneous texture and sub-rounded cavities, mixed with a very high proportion of marble clasts as aggregate. In the render coat, the aggregate shows a coarser grain-size (0.1–2.5mm) (Fig. 4) than in the finish coat (0.05–0.2mm). Marble splinters were clearly visible on the plaster surface, but further restoration works overlaid the surface with a whitewash. The marble was identified as a coarse grain grey marble from Musso (quarried in the northern part of lake Como), which in this case was specifically crushed to reach the required grain size. The finish coat contains traces of organic compounds, possibly modern resins used in conservation treatments (Fig. 5).

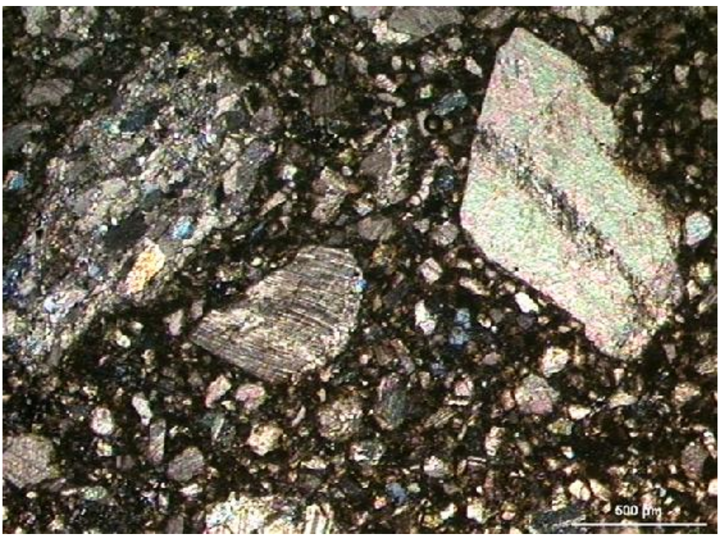

Fig. 4. The Fontana di Camerlata (render coat).
White cement and aggregate of Musso marble (thin section)

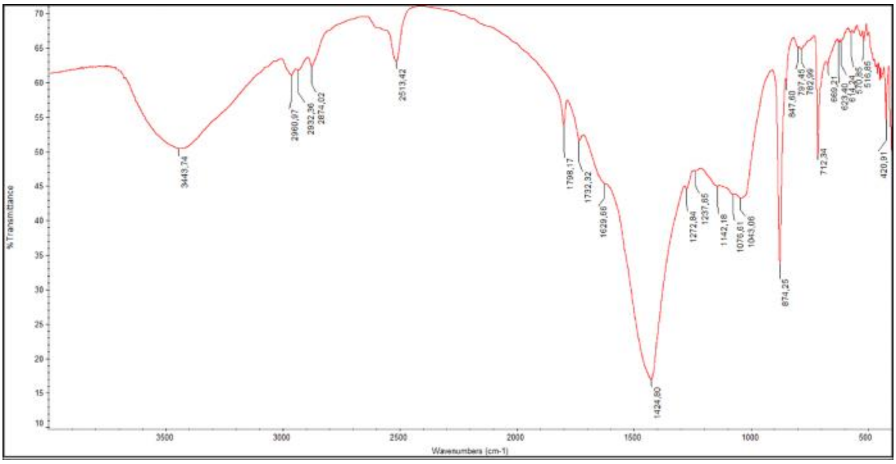

Fig. 5. The Fontana di Camerlata (finish coat). IR spectroscopy transmission spectrum.
The signals of calcite, silicates, quartz, gypsum and trace of organic compounds are shown

Different features of cast-stone

Countless buildings erected in Milan at the turn of the XXth Century offer an opportunity to detect the features of cast-stone. The reproduction of the natural stone was based upon the colour and the original texture (grain size, cavities) and involved natural stones used in the ancient architecture of Milan as igneous rocks (granite); clastic sedimentary rocks (conglomerates and calcareous sandstones) and metamorphic rocks (marble) [17].

Cast-stone was normally made of a core containing a coarse aggregate made of sand or gravel from alluvial deposits with rounded elements and a finish coat containing an aggregate made of two kinds of stone mechanically crushed: the stones were selected based on colours to match in the best way the aspect of the natural stone. The process of crushing produces clasts with angular contour useful to make a good aggregate.

White marble (Marmo bianco ordinario)

The typical dark colour of the Portland cement, obviously, prevented the reproduction of white marble, a stone material widely diffused in Italy to make statues or decorative elements and coming from the world-famous quarries near Carrara in Tuscany. Researchers worked to develop a process to produce true white cement, especially suitable to the preparation of decorative elements. A factory (*Officina per la produzione del Portland*) owned by C. and A. Pesenti at Alzano Lombardo (Bergamo) first produced, in 1893, a white cement (*cemento bianco*): the manufacturing process remained unknown, but the raw material was, probably, a local siliceous limestone ('Radiolariti' formation, upper Jurassic). The white cement was tested in the intricate decoration of some Neo-Gothic buildings of the Pesenti family (Oratorio, Villa Pesenti, Officina Pesenti in Alzano Lombardo): the angular aggregate was obtained by crushing a stone called *pietra di Zandobbio*, a Triassic dolomite quarried about 10km east of Alzano featuring a crystal size between 0.1 and 0.8mm, giving a particular brightness to the surface of the artefact (Fig. 6). White cement and calcite crystals or *marble powder*, coming from crushing of crystalline limestone, are already present in the former Palazzo della Borsa (now Poste Italiane, piazza Cordusio, Milano) built by the architect L. Broggi in 1901.

The *cemento bianco* was produced, since 1927, by Italcementi spa (Bergamo) and widely employed in the following years [18]. A recipe of white cement suitable to substitute the white marble was reported by Ghersi using pure limestone and pure clay (FeO content lower than 0.8%) together with ammonium chloride [19].

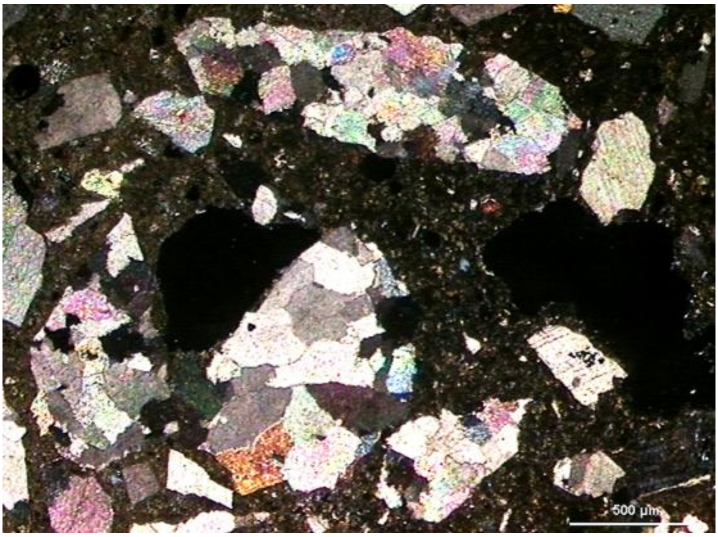

Fig. 6. Oratorio Pesenti (Alzano Lombardo, Bergamo).
The coat with aggregate of "pietra di Zandobbio" (thin section)

Granite (Granito di Baveno e Granito di Montorfano)

Baveno pink granite is one of the most important stones used in Milan; in particular, thousands of shafts for columns were produced and used for porticoes and loggias of public or private buildings, since the beginning of the XVIth Century till the XIXth Century and later on. The use of these granites was also spread in the whole Italian territory, from Torino to Roma. At the end of the XIXth Century *Baveno granite* was mainly employed to make columns for monumental doorways, brackets supporting balconies or thick slabs (about one metre high) for building basements. The cast-stone imitation mainly involved slabs for basement: the granite texture was reproduced using a pink limestone from Rosso Ammonitico formation (monti Lessini, Verona) and a black limestone coming from different Triassic formations (Lombard Prealps).

Montorfano white granite was another key stone material to make columns, brackets and building basements. The cast-stone imitation involved Apuanian marble and Triassic black limestone, as in the staircase and in fencing pilasters of Villa Gajo (built in 1907 at Parabiago near Milano by E.Zanoni – Fig. 7).

Calcarenite (Pietra di Viggiù)

This stone was a building stone of major concern used in Milan since Roman period for ashlars, column shafts, mouldings and sculpted ornaments and it was widespread in the 19th century for balconies balustrades on building façades. The cast-stone imitation involved the same *pietra di Viggiù* to obtain clasts of the aggregate, as shown in some floral decorations of the main staircase of Grande Albergo del Campo dei Fiori (Varese), built by the architect G. Sommaruga (1911). In other cases, different limestones were used to obtain the same purpose, for example the ornaments of the façade of an apartment house (via Boccaccio 27, Milano, built in 1910) were made using clasts from a fossiliferous limestone of the Colli Berici (Tertiary hills south of Vicenza) [20, 21].

Conglomerate (Ceppo dell'Adda)

This stone was widely used in Milan since the Roman times. The reproduction involved different elements as mouldings for balconies, windows and doors or ashlars for basements:

pebbles of different size, colour and nature (granite, porphyry, gneiss, limestone, dolomite) together with siliceous sands, both coming from pre-alpine river deposits, were variously mixed in the mortars based on Portland cement.

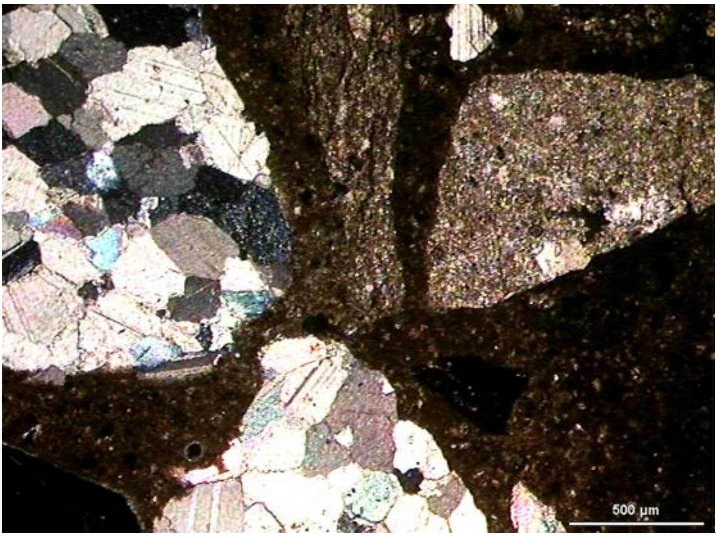

Fig. 7. Villa Gajo (Parabiago, Milano).
The aggregate fraction made of white marble and black limestone (thin section)

Rosso di Verona (Rosso Ammonitico)

Rosso di Verona is an ammonitic limestone coming from the famous quarries in the hills north of Verona (Sant'Ambrogio di Valpolicella): this stone was extensively employed since the Roman times, because of the intense red colour. The cast stone imitation involved the use of the same *Rosso di Verona* to obtain clasts of the aggregate as shown in cornices, window frames and pediments and ornaments of the opera house of Bergamo consecrated to the composer Gaetano Donizetti and built in 1903 by the architect P. Via.

Conclusion

The architectural use of different materials simulating a natural stone is a technique diffused since Roman times. The reproduction of stone was normally made by covering a structural material (stone, brick, etc.) with a coat of plaster; since the early XIXth Century, the reproduction involved all architectural elements using a mortar of Portland cement as binder and crushed fragments of sedimentary rocks as aggregate (cast-stone or *cemento decorativo*). Some stones used in ancient Lombard architecture, as *Granito di Baveno* or *Granito di Montorfano*, were reproduced using different kinds of crushed stone in order to simulate the texture and the colour of the original stone. Particularly, the cast-stone made to reproduce white marble contained an aggregate made of crushed marble; in the case of the Fontana di Camerlata the marble chosen was the *Marmo di Musso*, coming from the quarries opened in the upper part of lake Como since Roman times. In other cases, the aggregate was made from *pietra di Zandobbio* a crystalline dolomite coming from the Bergamasque Prealps. Furthermore, it is to be noted the use of an aggregate made by crushing the same stone to be reproduced as *pietra di Viggiù* (brown clastic limestone, quarried near the lake of Lugano) or *Rosso di Verona* (red ammonitic limestone, quarried in the north of Verona).

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