RECH6 - 6th International Meeting on Retouching of Cultural Heritage
Valencia, Spain | 4th-6th November, 2021
Doi: https://doi.org/10.4995/RECH6.2021.13539

THE VOLUMETRIC AND CHROMATIC REINTEGRATION OF HYDRAULIC MOSAICS: COMPARISON BETWEEN FOUR DIFFERENT TECHNIQUES

Juan Bermejo-Soler (1)
Iñigo González-González (1)
Fernando Baceta Gobantes (1)
Mª Dolores Rodríguez-Laso (1)

(1) Universidad del Pais Vasco (UPV/EHU); Departamento de Pintura, Facultad de Bellas Artes, Universidad del País Vasco UPV/EHU Box 644, 48080, Bilbao, España. E-mail: juan.bermejo@ehu.eus; inigo.gonzalezg@ehu.eus; fernando.bazeta@ehu.eus; mariadolores.rodriguez@ehu.eus

ABSTRACT

The mosaic made of hydraulic tiles, is an architectural coating with a significant decorative importance, characteristic of both modernist and Art Deco architectures.

This technique appeared in France in the decade of the 1860s, spreading all over Europe with great rapidity, and with a remarkable impact until the beginning of World War II.

The decoration with hydraulic mosaic is based on the use of tiles made of compressed cement, adorned with intense colours and a glossy appearance.

After been used for more than a century, many of these decorations are in need of an immediate intervention. As they are serialized and mass-produced elements, their volumetric and chromatic reintegration becomes easier. Non-interventional procedures are not usually acceptable, as they often have pavement function.

In this work, four different restoration techniques have been compared. Starting from inorganic binders, we have proposed 1) white cement / silicate mineral paint; 2) acrylic resin / paint and 3) epoxy resin / paint. Last, reintegration tests were made on marble stucco using a combination of plaster, pigments and animal glue.

The results of these four systems were compared with the ones obtained from the traditional hydraulic mosaic, paying special attention to gloss, hardness, and porosity. As the goal is to choose the most appropriate technique applied to Cultural Heritage, its behaviour was tested through two accelerated aging tests. On one hand, a group of test samples have been exposed to the penetration of salts by capillarity, very common in pavements. On the other hand, the samples were placed in a climatic chamber with the aim of accelerating its aging, exposing them to humidity, heat and UV radiation.

These tests have made possible to know the potential of each of these materials and their suitability for volumetric and chromatic reintegration.

Keywords
Hydraulic mosaic; Hydraulic tile; Mortar; Conservation and restoration; Architecture.

1. INTRODUCTION

Hydraulic mosaic refers to a decorative technique based on compressed mortars, used for covering floors in the second half of the 19th century and the first half of the 20th [1]. Its main characteristic is a top face with a very fine texture, showing a glossy finish [2].

This decorative technique associated with architecture was chosen, and sometimes even designed, by the architects, since they usually have an important aesthetic impact. For all these reasons, its conservation and restoration requires a careful examination.

1.1 Beginnings and evolution of the hydraulic mosaic

In an aesthetic sense, the hydraulic mosaic is heir to the Roman geometric mosaic [3] but, in its technical aspect, the first predecessor of the system that concerns us are the tiles made 'al banchetto'. It is a traditional technique that appeared in Italy in the 18th century, in which a portion of natural cement was compressed into a wooden mould with the help of a mallet, to subsequently apply a coloured paste with a spatula and then burnish it. This technique produced irregular and relatively fragile pieces, not being used regularly in noble spaces [1, 2]

The hydraulic tile as such, emerged in France around 1860-1870 [4], spreading rapidly to Spain and Belgium. This decorative technique jumped from Europe to the old colonies, rooting strongly in Latin America and North Africa [5].

This type of floor expanded greatly until the early 30s, due to its low manufacturing cost, the simplicity of the production process, the possibility of making almost unlimited motifs and its ease of laying. After the Spanish Civil War, and World War II, its use was limited to an industrial level, but with a loss in aesthetics, seeking much simpler functional designs [5].

At the end of the 1950s, this system was gradually replaced by granite mosaic and terrazzo. In the 1960s, the production of hydraulic mosaic in Europe had practically disappeared, being only preserved in North Africa and Latin America [5]. At the beginning of the 21st century, traditional hydraulic pavement began to be valued by interior decorators.

1.2 Manufacturing process

As has been said before, this decorative technique is based on the manufacture of tiles through the compaction, in a press, of a series of sand and Portland cement mortars

The hydraulic mosaic is composed of three layers: the "pastina" (also called colour or finish) that forms the decoration, an intermediate layer called "seca" ("brasague" or fine), and the main structure of the tile formed by the "baña" (also named "gros", mix or backing) (figure 1). The mentioned "pastina", is the most superficial layer that forms the drawings and provides a glossy finish [1, 6].

First, the artist prepares the design in shape and colour of the pieces. Afterwards, the industrial artist chooses

Figure 1 – Surface and stratigraphy of a hydraulic mosaic

the most suitable quantity of pigments and prepares a trepa, an instrument that allows the different colours to be separated within the mould.

For the preparation of the colour or pastina, the pigment and cement are mixed dry in the desired quantity. Although the mixing can be done manually, it is recommended to mix it in a ball mill. González-Novelles [3] indicates proportions of between 5-12.5% of pigment in the cement. Gray cement is usually added, but for light colours it is necessary to use white cement.

Once the cement is coloured, fine sand is added to it in a proportion of 2,5 parts of coloured cement and 1 part of sand. The proportion of water must allow the mixture to be fluid enough to fill all the spaces of the trepa, but not exceed the absorption capacity of the seca. Excessive moisture in this layer causes problems both in manufacturing (blurred lines and difficulties in demoulding) and in aging (less hardness and greater ease of exfoliation) [1].

The seca is a mixture of fine sand and cement in a proportion of 20-30% sand in 70-80% cement. If a thicker sand is used, it can be applied at 50:50. The baña is also prepared dry, with 1 part of Portland and 4 or 5 parts of sand [1].

Once all the components have been prepared, the base of the mould is placed on the press.

Then, the frame is placed and a release agent is also added. Inside, the trepa is fixed and each space is filled with the corresponding colour pastina. Next, the trepa is removed and the seca is sprinkled on top [2]. This aims to absorb the water from the pastinas, preventing the lines from becoming blurred and sticking to the sides of the mould, although an excess of it can generate exfoliation problems already mentioned [1]. Subsequently, the baña is added and it is levelled, to put the cover on the mould and insert it into the press.

Once compacted, the piece is carefully removed and stored while the components harden (figure 2).

Many manufacturers air harden the pieces, although for a high-quality mosaic, it should be aired for a couple of hours, then left submerged in water for three or four days. The pieces are then removed from the water and moistened, often for another three or four days. Finally, they harden for the necessary time, around 20 to 30 days [1].

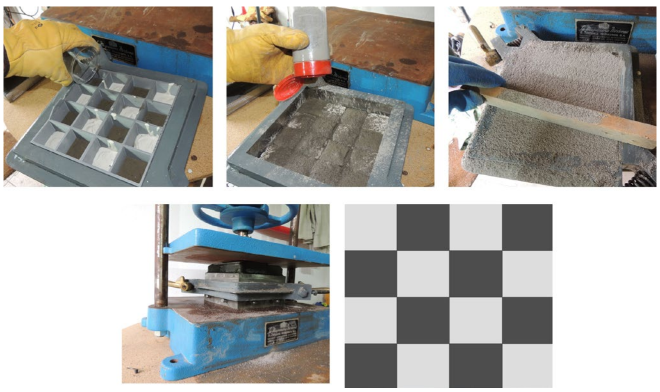

Figure 2 – Hydraulic mosaic manufacturing process

The simplicity of its production and its versatility led to the appearance of a large number of manufacturers, which generated variations both in its production method and in the final quality of the product. This especially affected the selection of pigments, which were not always suitable, as well as the process of pressing and curing of the pieces [1].
In the field of conservation and restoration, these materials have been intervened following methodologies designed for the recovery of ceramic tiles, which is not always the most appropriate.

2. MATERIALS AND METHODS

This research analyzes the use of four different techniques for the reintegration of hydraulic mosaics, these techniques have been chosen so that the volumetric and chromatic reintegration contain the same binder in order to improve the compatibility of both processes.
The following materials have been tested: white cement mortar and sol-silicate paint mixed with inorganic pigments, stucco and polychrome based epoxy resin with inorganic pigments, resin and acrylic paint, and inlaid marble stucco. For the tests, hydraulic mosaic fragments from the Mosaic Factory brand have been chromatically reintegrated.
For reintegration with white cement mortar and sol-silicate paint, firstly, it was reintegrated volumetrically with a Valderrivas CEM II/A-L 42.5 R. white cement mortar and Arija GRS05 sand, in a 1:3 ratio. For the chromatic reintegration, white sol-silicate paint from the Losung commercial brand was used, mixed with inorganic pigments.
For the epoxy-based reintegration, in the first place, it has been volumetrically reintegrated with a saturation mixture of matte plaster and Epofer EX401 resin, with its E432 catalyst in a 100:32 ratio, both from the Feroca commercial brand. Once hardened, the chromatic reintegration has been carried out with inorganic pigments agglutinated with this same resin.
For the acrylic-based reintegration, the volumetric part has been executed with Jesmonite AC100 resin with a powder-to-liquid ratio of 2.5:1. The chromatic reintegration was executed with acrylic paint from the Amsterdam range of the Royal Talens brand.
In the intervention with marble stucco, the volumetric and chromatic reintegration is done at the same time, since the pigment is applied "en masse". First, the mixture of plaster (Iberyola E33) and Zurich bone glue (CTS) with the predominant colour of the tile is prepared. The polishing process begins, in which this phase is alternated with the application of an increasingly finer grout. 120, 200, 400 and 600 granulometry sandpapers are gradually replaced. At this point, the areas to be coloured are reduced and filled with the appropriate mass. Then the polishing process continues with granulometries of 800, 1000 and 1200. Once completely dry, the samples have been protected with a coat of 8% beeswax in turpentine essence.

2.1 Gloss and colour measurement

To quantitatively control the colour and its possible changes, a 3NH brand NR10QC colorimeter was used, with the observer at 10º and Illuminant D65. The colour measurements have been carried out under the UNE-EN 15886 standard [7]. As indicated, the measurements are expressed through three values (L*, a* and b*) marking coordinates in the CIELAB space. To evaluate the colour changes, the following formula has been applied:

$$\Delta E_{ab}=[(L^*_a-L^*_b)^2+(a^*_a-a^*_b)^2+(b^*_a-b^*_b)^2]^{1/2}$$

Concerning to Cultural Heritage interventions, a perceptible change is considered by the human eye when ΔE>3 [8].
To control the gloss level, a 3NH model YG60S gloss meter was used, with a measurement angle of 60º.

2.2 Accelerated aging

For this investigation, a controlled environment chamber has been used that pretends to approach the conditions described in the UNE-EN ISO 11341:2005 standard [9]. As a base, a 40x25x20 cm glass terrarium has been employ, which has been protected on its sides with insulating foam and, on its lower and upper part, with a ceramic tile. The heat sources applied are: an 8W Heat Mat heater and two 100W Ceramic Heaters, all from the commercial company Exoterra. For the incorporation of humidity, the Reptile Fogger from the Inkbird company, an ultrasound-based humidifier, was used. The chosen radiation is of a 25 W Reptile UBV 200 bulb, also from the Exoterra commercial house, which has been chosen due to its high level in UV between 390 and 440 nm. To control the different values, the digital thermostat/hygrostat controller of the Reptiland commercial house was utilized, which activated or deactivated the different elements according to the values inside the chamber. This construction has provided an UV-visible type light, a temperature of 50ºC with a fluctuation of ±5ºC and a relative humidity of 80% with a fluctuation of ±10%.

Four 10x10 cm hydraulic mosaic samples have been prepared, which were reintegrated chromatically and volumetrically with the different techniques to be tested, to expose them to 300 hour cycles inside this device.

2.3. Salts absorption by capillarity.

Another set of 10x10 cm samples has been prepared to which a 5cm cement mortar base has been added. These, have been subjected to a salt absorption test by capillarity based on the works of Zornoza [10], and Rodríguez-Navarro and Doehne [10]. To do so, the lower part of each sample has been introduced into a container with a capacity of 500 mL, and a 25% p/p solution of NaCl poured in distilled water. The container was sealed using a molten paraffin, forming a layer of approximately 2 cm.

Figure 3 – Comparison of the behaviour of the reintegration in acrylic and silicate base

Once sealed, the water has no choice but to pass through the porous system of the sample, dragging its high salt content with it. The evolution was observed in a period of 15 days.

3. RESULTS AND DISCUSSION

The reintegration with white cement and silicate paint, turned out to be the most compatible technique, as it is based on a silicate matrix, just like hydraulic mosaic. However, aesthetically the finish is completely matt.
The reintegration with epoxy resin presents high hardness but shows an excessively glossy result and it is difficult to adjust the colours, especially the light ones, since the resin provides a base colour.
The reintegration with resin and acrylic paint is simple to execute. The resin provides a suitable colour and texture for the chromatic reintegration and the paint has a satin finish.

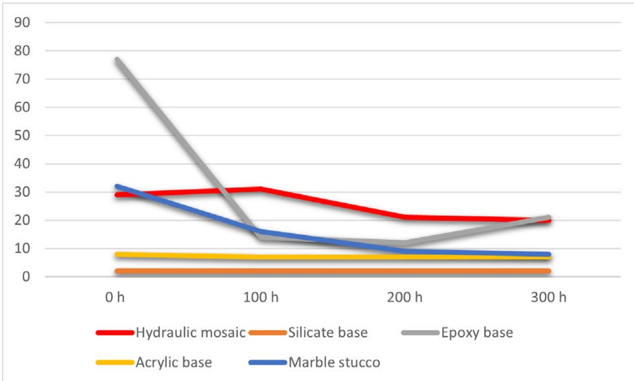

Figure 4 – Changes in brightness during accelerated aging. Gloss Units (GU) versus time (h).

Inlaid marble stucco is the slowest execution technique but provides the hydraulic mosaic a characteristic shine and allows an adequate colour palette.
After the test of salt absorption by capillarity, we found two differentiated behaviours, the most porous materials (marble stucco and cement mortar) allow transpiration similar to the original part, appearing saline efflorescences on the entire surface of the sample. On the other hand, the most impermeable materials (Epoxy and acrylic) concentrate all the efflorescence in the original areas, leaving these intact (figure 3).
Through accelerated aging, the future behaviour of different materials can be estimated. The gloss measurements (figure 4) indicate that the marble stucco presents the most similar behaviour to the hydraulic mosaic, both in gloss level and in aging. The epoxy resin has a very irregular finish, with measurements varying greatly from one point to another. The acrylic base is the most stable material in terms of gloss but shows much lower values than the hydraulic mosaic.
Contrary to the brightness, considering the colour, the behaviour of the different techniques has been very similar between them. The reintegration with cement mortar and silicate paint has suffered a slight alteration (ΔE>3). The other techniques have had an adequate behaviour, highlighting the acrylic base as the most stable one. Next, the measurements corresponding to the red colour in the different techniques are shown (table 1).

Table 1 – Colour alterations after the accelerated aging process (red colour)

		Silicate base	Epoxy base	Acrylic base	Marble stucco
0 h	L*	42,66	36,62	30,1	39,86
	a*	27,66	22,2	12,25	25,5
	b*	16,66	13,59	5,43	18,51
100 h	L*	41,9	38,46	29,82	38,83
	a*	27,32	23,72	11,7	25,91
	b*	17,19	15,3	4,59	19,01
200 h	L*	43,45	37,66	29,41	40,25
	a*	26,92	24,04	11,78	26,46
	b*	16,33	15,96	4,38	19,93
300 h	L*	44,71	38,15	29,83	40,8
	a*	25,61	23,31	11,57	26,61
	b*	15,27	15,18	4,18	19,81
ΔE 0-300 h		3.21	2.47	1.44	1.95

4. CONCLUSIONS

Once analyzed the results of the tests, inlaid marble stucco is the one that provides the most satisfactory result, especially due to its level of gloss, very similar to that of hydraulic mosaic. It also has the advantage of mass producing and resisting future polishing. The disadvantage of this technique is its slow execution, which can hinder large surfaces restoration projects.
If a volumetric and chromatic reintegration cannot be applied with marble stucco, a second option would be reintegration with resin and acrylic paint. The obtained results are of a lower quality, but it is a more affordable alternative.

REFERENCES

[1] Casabo, J. (1958) Fabricación de mosaicos y baldosas de cemento. Nigar S.R.L.

[2] Hernández, F. (2009). Las antiguas fábricas de mosaico hidráulico en Navarra. Cuadernos de Etnología y Etnografía de Navarra (CEEN), 84, 55-95.

[3] González-Novelles, N. (2010) El Mosaic hidràulic i la Casa Orsola Solà i Cia. (trabajo de fin de máster) Universidad Politécnica de Cataluña. Barcelona. España.
[4] Pitarch, A.J. y Dalmases, N. (1982) Arte e industria en España, 1774-1907. Blume.

[5] Bravo-Nieto, A. (2015). La baldosa hidráulica en España. Algunos aspectos de su expansión industrial y evolución estética (1867-1960). Revêtements céramiques (8).

[6] Aguirre, M. (1994) El mosaico hidráulico en Cataluña, un aspecto artístico de la industria (Tesis de final de licenciatura), Universidad de salamanca, Salamanca, España.

[7] Asociación Española de Normalización y Certificación. (2011). Conservación del patrimonio cultural. Métodos de ensayo. Medición del color de superficies. (UNE-EN 15886:2011).

[8] Sociedad Estadounidense para Pruebas y Materiales. (2006). Standard Test Methods for Lightfastness of Colorants Used in Artists' Materials (ASTM D 4303:2006).

[9] Asociación Española de Normalización y Certificación. (2005). Pinturas y barnices. Envejecimiento artificial y exposición a radiación artificial. Exposición a la radiación filtrada de una lámpara de arco de xenón. (UNE-EN ISO 11341:2004).

[10] Zornoza, A. (2016). Assessment with non-destructive techniques (NDT) of stone consolidation efficacy from architectural and archaeological Cultural Heritage: Influence of relative humidity to slow down damage and increase durability (Tesis doctoral). UPV/EHU, San Sebastian, España.

[11] Rodriguez-Navarro, C., & Doehne, E. (1999). Salt weathering: influence of evaporation rate, supersaturation and crystallization pattern. Earth Surface Processes and Landforms, 24(3), 191-209.