Colorimetry in the conservation of assets integrated into heritage properties: comparative analyzes of hydraulic tiles

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ABSTRACT

With the advent of color measurement technologies in the area of architecture, design and cultural heritage, the use of colorimetry has enabled advances in the conservation of heritage properties, in a non-invasive way. In this sense, the object of study of the research is the Paço dos Açorianos of Porto Alegre - Rio Grande do Sul - Brazil, with thematic delimitation in the hydraulic tiles located in the entrance hall of the ground floor of the building which, currently, present various pathologies. The objective is to use a colorimeter to measure the color of the Paço tiles and compare it with the color sample of the Fábrica de Mosaicos de Pelotas, a company supporting the research and the largest in the segment in the State of Rio Grande do Sul. The methodology used consisted of measuring the samples produced by Fábrica de Mosaicos as a standard and the Paço tiles as a sample and comparing it with, evaluating the differences (deltas) between the measurements to determine if they are within the tolerance established for the color standard, as described by the manufacturer. The results indicated which colors obtained the greatest similarity. The tolerance value used follows the difference formula of CIEDE2000. The work is part of doctoral research that examines the feasibility of using technologies to conserve assets integrated into the building, emphasizing the historical and cultural importance of hydraulic tiles. He proposes a collaboration between science and industry to conserve and enhance these elements, with a view to future restoration works on the pavement.

KEYWORDS colorimetric analysis, cultural heritage, hydraulic tile

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1. Introduction

Colorimetry, the study of color, is essential in the preservation of cultural heritage. With technological advances for instrumentation in color measurement, colorimeters analyze color with and without contact, using the spectrum generated by reflected light. This is essential in the conservation of assets integrated into listed properties, such as hydraulic tiles, as they do not cause damage to property.

Silva, Nogueira, and Amaral (2020) emphasize that, despite the neglect of color studies in contemporary architecture, the knowledge and treatment of pigments on historical architectural surfaces are essential for the restoration, conservation, and prevention of their degradation. In their research, the authors used a Digital Colorimeter to measure, identify, and map the colors present in the parietal layers of the Solar dos Rollemberg building, in Aracaju, SE, in Brazil. The use of this device enabled a precise characterization of the materials in the mural paintings, ensuring a scientific process of inventory, conservation, and restoration.

Hydraulic tiles, known as mosaics, are manufactured by hand, using methods passed down from generation to generation. Being part of heritage assets, they represent both material and intangible heritage and must be preserved. In addition to their aesthetic value, they contribute to the preservation of memory and local identity in built heritage.

In this sense, the object of study addressed in the research are the hydraulic tiles present on the ground floor of Paço dos Açorianos, an emblematic building located in Porto Alegre – RS, of great historical and cultural relevance. As the former headquarters of the City Hall and the Pinacoteca Aldo Locatelli, this space carries with it the administrative memory of the city and the architectural expression of its time.

The objective of the research is to use a colorimeter to analyze the color of the tiles present on the floor of Paço dos Açorianos, followed by comparing these results with the color sample made available by the renowned Fábrica de Mosaicos de Pelotas. This company, which offers research support, stands out as the largest representative of the sector in the State of Rio Grande do Sul, being recognized as a Brazilian industrial heritage due to its position as the oldest tile factory in continuous operation in Brazil.

The collaboration of Fábrica de Mosaicos de Pelotas not only enriches the research with its vast experience and knowledge in the field of hydraulic tiles, but also demonstrates a joint commitment to the preservation of the State's cultural heritage.

The methodology adopted involved measuring the samples produced by the Mosaics Factory as a standard, and the Paço tiles as a sample, using a colorimeter. The measurements were compared, evaluating the differences (deltas) to verify whether they are within the tolerance established by the manufacturer for the color standard. The tolerance value used follows the difference formula of CIEDE2000 (CIE, 2001), based on data provided by Sharma, Wu and Dalal (2005).

In the present research, a similar colorimeter was used to differentiate the acquired data, based on a color calculation methodology of the spectrophotometric method.

Based on these criteria, a comparison was made between the previously measured standard (factory sample) and the sample (Paço tiles), following the colorimeter manufacturer's instructions.

This data is represented in CIELAB space, where "L" is luminance and "a" and "b" are chromatic axes. The "a" axis represents the green/magenta spectrum, while the "b" axis indicates the blue/yellow spectrum. The location of the color in this space makes it possible to compare colors, with the difference measured as ΔE.

Through comparative analysis of the pattern and samples, it was defined that the colors of the Paço dos Açorianos tiles that were most similar to the Factory's display were: 05 Orange, 09 Chocolate, 10 Dark Grey, 14 Dark Blue, 18 Bronze, 21 Off-White and 22 Caramel.

Challenges during data collection, such as lightness, can affect color perception and cause errors. Geometric metamerism can also lead to color mismatches. Measuring and evaluating the colors of the Paço tiles is challenging due to yellowing, dirt and excessive shine from the waxes applied over the years. To achieve greater color accuracy, it would be necessary to sand the damaged surface, which is not feasible due to the heritage status. Therefore, colorimetric measurements, using a colorimeter, are themselves non-invasive.

The work is part of doctoral research whose main focus is to investigate the feasibility of means for conserving assets integrated into the building (MEDEIROS, 2023). The research carried out in partnership between a public university and the Ball Mosaic Factory generated important benefits for the conservation of a heritage relevant to Porto Alegre and the Rio Grande do Sul. This collaboration between science and industry resulted in an applied research, promoting a dynamic interaction between institutions. The cooperation allowed the Factory to sustainably and replicate the research results, pointing out new paths for future restoration and conservation projects.

This research was funded by the Coordination of Superior Level Staff Improvement (Capes) together with the Postgraduate Program in Design (PGDesign) at the Federal University of Rio Grande do Sul (UFRGS), in partnership with the Fábrica de Mosaicos de Pelotas and carried out with the support of the Cultural Memory Coordination of the Porto Alegre - RS Department of Culture and the Design and Material Selection Laboratory (LDSM) of UFRGS.

1. 2. *Color measuring instruments: colorimeter*

In order to improve understanding of the procedures used to measure color with equipment, it is essential to investigate the crucial role of the colorimeter in this context.

The International Commission on Illumination - CIE (Commission Internationale de l'Éclairage - international organization whose work is based on the use of light and color) conducted studies to determine the intensity of each color present in the visible spectrum, using three primary colors: green, blue and red. Through these studies, it was possible to map all colors and represent them graphically in three curves (XYZ). This advance allowed the development of color measurement devices, capable of capturing and calculating the corresponding tristimulus values (DELTA COLOR, 2023).

The colorimeter is a device composed of an internal light source and three sensors that filter blue, green and red colors. Using mathematical matrices, this system is capable of measuring the amount of light reflected by the sample and converting the data to the XYZ color space, thus seeking a representation similar to human visual perception (DELTA COLOR, 2023). It is important to note that this assumption is true only for tristimulus colorimeters.

The L*, a*, and b* coordinates in CIELAB are utilized to determine the position of any color within the uniform color space defined by this system. However, in most industrial contexts, it is employed to assess how much an object's color deviates from the standard, both in colorimetric terms and in visual match acceptability. For this purpose, similar to the Hunter Lab system, it is possible to quantify differences for each L*, a*, and b* coordinate, and also to calculate total color differences using the following formula (MACDOUGALL, 2002):

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]\ ½$$

ΔE enables the measurement of variations in hue and density. The average observer typically notices differences of 5 or 6 ΔE or more. Only a highly trained eye can detect differences of 3 to 4 ΔE. The human eye is significantly more sensitive to changes in gray levels and midtones, and in such cases, it can perceive differences as small as 0.5 ΔE (MACDOUGALL, 2002).

For color quality control applications widely adopted in industry, the use of a colorimeter may be appropriate and provide satisfactory results, for example, in hydraulic tile factories that require control over the color pattern used. This instrument is capable of measuring a color standard and comparing it with the samples produced, evaluating the differences (deltas) between measurements to determine whether they are within the tolerance established for the color standard.

2. Hydraulic tile

Hydraulic tile is a coating composed of cement, aggregates and pigments, used on floors and walls. NBR 9457 (ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS, 2013, p. 1) defines it as a double-layer parallelepiped cement slab, produced by pressing, with the surface exposed to traffic smooth or in low relief.

The primary raw material is Portland cement, as specified by the standard, which also stipulates the composition of the mortar, allowing the use of additives and pigments. Water plays a crucial role in hydrating the cement during the curing process, in order to avoid cracks and cracks in the tiles.

Despite being mechanized in series, hydraulic tiles are considered manufactured products, as each piece is individually made by the artisan, giving them uniqueness.

Historically, its popularity grew during the Modern period, influenced by Art Nouveau and Art Deco, with several specialized designers and prominent artists responsible for creating the patterns. The predominant colors are brown, green, pink, yellow, cream, gray, white and black, although others are also used (NAVARRO, 2006).

However, the advancement of demolitions of historic buildings threatens the preservation of the history of hydraulic tiles, whose centuries-old manufacturing process remains, although some raw materials have evolved or become extinct.

In recent years, architecture, engineering and design professionals have valued these coverings as an integral part of cultural heritage, recognizing their importance in both material and immaterial dimensions. It is essential to understand the definitions of heritage to determine which category the hydraulic tile is classified in.

2.1. *Integrated assets and cultural heritage*

With the expansion of concepts and categories within the scope of cultural heritage, the need to recognize and protect assets that do not strictly fall within the definition of architecture has arisen. In recent decades, Iphan has implemented measures to safeguard integrated cultural assets, recognizing their importance as historical, artistic and cultural documents, as well as the symbolic and affective relationships they maintain with architectural elements.

In 1986, the National Inventory of Movable and Integrated Assets (INBMI) was established, aiming to systematically identify and catalog listed movable and integrated assets, with a special focus on religious buildings. These assets, which include decorative and constructive elements of buildings, such as paintings and tile panels, remain attached to the built surface and can only be removed with careful effort, leaving a visible mark of their origin (IPHAN, 2023).

According to Costa (1987), integrated assets encompass those that are directly linked to the built structure, both internally and externally, and that can only be successfully removed through careful and planned effort. However, even when removed, these elements still leave a visible mark of the intervention carried out in their place of origin. This category covers all items fixed in architecture and that are an integral part of the monument, including the internal decoration of residences, fortresses, palaces, museums, churches and convents. All decorative and constructive elements present in these buildings, such as paintings and tile panels, are part of this category of integrated goods.

According to Dominguez (2016), there is the possibility of integrating hydraulic tiles into this categorization and including them in standards, programs and preservation instruments already established by the Brazilian state. This would allow them to be aligned with public policies aimed at disseminating information and preserving heritage, through existing legal instruments for this purpose.

In short, the integration of hydraulic tiles into historical heritage preservation policies can significantly contribute to its safeguarding and appreciation. By recognizing their importance as integrated elements, it is possible to establish specific guidelines and measures for their conservation, aligned with the principles established by existing legal instruments. This not only protects these cultural elements for future generations, but also promotes awareness of their historical and cultural relevance, enriching society's collective identity and memory.

3. Materials and methods

To carry out a comparative analysis of the colors of the hydraulic tiles at Paço dos Açorianos with the sample at Fabrica de Mosaicos de Pelotas, aiming to select the colors for the manufacturing stage, color data were acquired with a colorimeter by Delta Color (São Leopoldo/RS - Brasil) model Colorium. The Colorium colorimeter works in conjunction with the Lab7 Software (DELTA COLOR, 2023).

To validate the procedure adopted, the colorimeter manufacturer suggests that the sample be measured and stored as a “standard”. Then perform the measurement again as a “sample”. Ideally, the color difference (ΔE) between these measurements should be a maximum of 20% of the value adopted for the tolerance. If the variation between measurements of the same sample is greater than this percentage over the tolerance, then it is likely that the procedure will not be accurate or consistent (DELTA COLOR, 2023).

4. Results

To carry out a comparative analysis between the color of the Paço dos Açorianos (Fig. 1) tiles and the shades present in the Fábrica de Mosaicos color catalog (Fig. 2), the colorimeter measured a pre-determined standard (the Fábrica de Mosaicos color sampler), together with the sample in question (a tile from the Paço dos Açorianos), thus allowing the measurement variation (delta) between both to be assessed. In this way, it was possible to check whether the color of the sample was within the pre-established tolerance of 1.5.

Fig. 1. Use of the colorimeter on the tiles from Paço and the sample from the Fábrica de Mosaicos.

Fig. 2. Use of the colorimeter on the tiles from Paço dos Açorianos.

Tolerance values should be defined internally or between the supplier and the consumer and used in quality control to determine whether the sample passes the inspection process (CARBALLO-REYES et al., 2023).

According to Jara (2023), tolerance values should be defined internally or between the supplier and the consumer and used in quality control to determine whether the sample passes the inspection process. Considering that a value greater than 2 is highly noticeable, and for it to be imperceptible to the human eye, it must be less than or equal to 0.5 (FERNÁNDEZ-QUESADA; ALONSO-MUÑOZ, 2024).

The analyses conducted with the Colorium Colorimeter, using the Lab7 Software, revealed that, despite the exact chromatic match between the hydraulic tiles from Paço dos Açorianos and the sample from the Fábrica de Mosaicos, the surfaces exhibit distinct textural characteristics. While the original tiles have a slightly irregular texture, with subtle signs of aging and natural wear over time, the newly produced tiles feature a more uniform and smooth surface, a result of contemporary manufacturing processes. Therefore, although the colors are identical, the difference in texture is a factor to consider, as it directly impacts the visual and tactile perception of the material.

When performing measurements, the colorimeter provided measurement Deltas in the CIE L*a*b* color system. The CIE has developed methods to represent colors numerically and one of these methods is the Lab chromatic measurement system (Fig. 3).

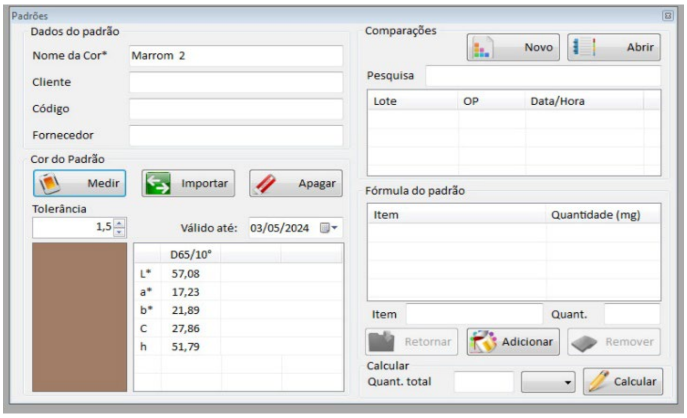

Fig. 3. Pattern data measured with the colorimeter.

Adobe Photoshop graphic editing software offers advanced automated functionalities for color conversion between different chromatic systems. Among these, the conversion from the Lab color system to the RGB system (light-based, composed of Red, Green, and Blue) and the CMYK system (pigment-based, consisting of Cyan, Magenta, Yellow, and Black) stands out. These features facilitate the transposition of chromatic information between color models used in different technologies (Fig. 4).

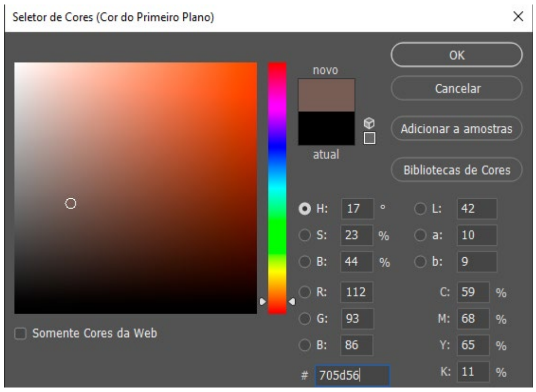

Fig. 4. Color system conversion using Adobe Photoshop.

The conversion of colors between systems proved to be crucial for obtaining the respective color codes in each model. This step is essential to ensure the correct visualization of colors both on electronic devices, which use the RGB system, and in printed media, which operate with the CMYK system. The conversion helps maintain chromatic integrity across different platforms, ensuring consistency and accuracy in the results presented in both digital and physical formats (Table 1).

The same procedure was applied to the color catalog of Fábrica de Mosaicos. The 30 available colors in the catalog were carefully measured and subsequently converted to the RGB and CMYK systems. After the measurement stage, a comparative analysis between the color standards and the samples was conducted using the Lab7 software, developed for the colorimeter, to ensure the accuracy and consistency of the obtained results (Table 2).

To understand the results obtained with the comparative analysis, it is important to understand the acronyms L*a*b* C* h*and their meanings – L* main axis (black = 0 to white = 100); a* (green [-] to red [+]) and b* (blue [-] to yellow [+]. C* represents the saturation and h* the hue. The higher the L* values mean lighter colors, consequently , smaller values indicate darker colors. L* values range from 0 to 100 and a* and b* values range from -128 to 127 (Fig. 5).

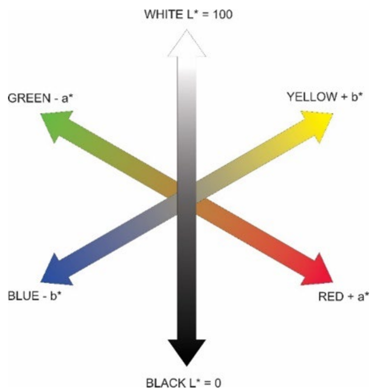

Fig. 5. CIE L a* b* color space.*

COLOR NAME	HUE	COLOR SYSTEMS									
		Lab			RGB			CMYK			
Orange		66	40	35	212	128	101	7	66	61	0
Chocolate		57	17	21	160	124	102	39	58	63	0
Dark grey		68	3	16	174	162	137	36	35	49	0
Dark blue		50	-7	-9	114	119	132	66	53	42	0
Bronze		70	15	37	198	159	107	22	43	66	0
Dirty White		99	-3	5	250	254	242	5	0	9	0
Caramel		90	0	50	243	224	133	7	15	60	0

Table 1. Colors measured with the Paço tile colorimeter and its color systems.

COLOR NAME	HUE	COLOR SYSTEMS									
		Lab			RGB			CMYK			
01 White		99	-5	3	247	255	246	7	0	8	0
02 Cream		99	-3	2	249	254	248	5	0	5	0
03 Gray		94	-3	4	236	239	229	11	5	14	0
04 Yellow		89	-3	67	239	222	98	11	13	77	0
05 Orange		65	35	28	202	131	110	14	63	56	0
06 Salmon		60	37	26	192	119	104	18	68	58	0
07 Light Red		58	44	25	190	104	98	18	76	58	0
08 Dark Red		56	27	15	166	115	109	34	66	54	0
09 Chocolate		59	13	15	160	132	116	42	52	55	0
10 Dark Gray		64	3	7	160	152	142	42	38	43	0
11 Medium Green		70	-4	19	172	171	138	39	28	51	0
12 Aqua Green		94	-21	14	216	249	210	27	0	29	0
13 Dark Green		59	-5	6	137	143	131	55	38	51	0
14 Dark Blue		64	-7	-22	133	159	191	61	31	18	0
15 Light Blue		62	2	-58	107	151	250	72	43	0	0
16 Pink		79	27	16	232	175	166	0	43	29	0
17 Terracotta		60	25	26	178	126	101	29	61	63	0
18 Bronze		76	3	30	200	183	133	25	28	56	0
19 Black		20	-2	0	50	53	52	83	77	70	44
20 Grape		63	19	3	174	139	146	33	51	34	0
21 Dirty White		99	-5	10	250	255	233	6	0	14	0
22 Caramel		86	3	55	235	210	114	10	21	69	0
23 Greenish Yellow		99	-10	34	253	255	187	8	0	37	0
24 Pastel Blue		95	-18	-5	215	252	250	27	0	10	0
25 Cobalt Blue		73	-49	-43	51	204	255	87	0	12	0
26 Strong Light Green		80	-27	17	170	211	166	48	0	48	0
27 Lead		69	-1	0	166	167	167	41	30	31	0
28 Hot Pink		73	50	21	240	138	142	0	64	32	0
29 Pastel Pink		96	5	-2	248	238	245	0	11	0	0
30 Blue-Green		66	-8	-3	148	163	164	52	28	34	0

Table 2. Colors measured with the colorimeter in the Fábrica de Mosaicos showcase and its color systems

Once you have the color difference values, it is possible to establish acceptance limit values, the so-called colorimetric tolerance. This tolerance varies for each industry, depending on the acceptance of the customer it serves (DELTA COLOR, 2023).

In this study, the CIEDE2000 method was used to calculate the color difference between the analyzed samples. CIEDE2000 is an advanced method that evaluates color differences based on human visual perception, taking into account luminance, chromaticity, and other relevant factors (SHARMA, WU AND DALAL, 2005).

The LAB color coordinates of the samples were obtained and used to calculate the initial differences (ΔL, Δa, Δb). Subsequently, the means of these coordinates were calculated and chromatic corrections were made to adjust the a and b components, considering the luminance weighting (SL), chromaticity (SC), and the rotation factor (RT). The full CIEDE2000 formula was then applied to determine the final perceptual color difference, ΔE00. These precise calculations were carried out using the Lab7 software developed by the colorimeter manufacturer.

For the present analysis, a tolerance of 1.5 was established. As the manufacturer indicates that the tolerance should not exceed 20%, the maximum tolerance value can reach 1.8. Based on the stipulated value, the standard (Fabrica de Mosaicos sample) previously measured was compared with the sample (Paço dos Açorianos tiles), as recommended by the colorimeter manufacturer. The colors of the Paço dos Açorianos tiles that were most similar to the display were: 05 Orange, 09 Chocolate, 10 Dark Grey, 14 Dark Blue, 18 Bronze, 21 Dirty White and 22 Caramel.

When comparing color 05 Orange, the tolerance scale was 2.5, 1 point above the established percentage. Reading the data, it was found that the sample had a lighter L* value and a redder a* value. b* has the same tone. C* had a more vivid color, that is, more saturated (Fig. 6).

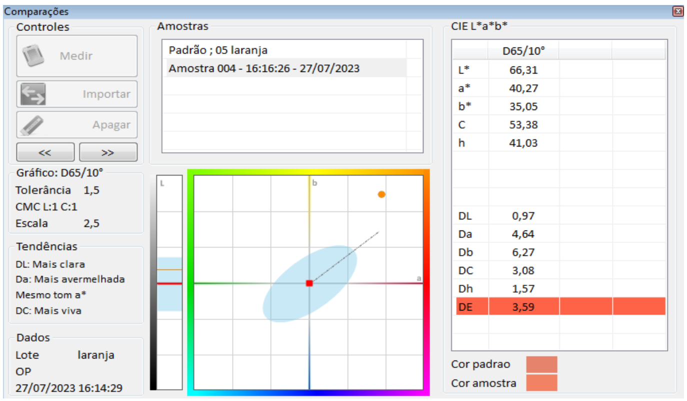

Fig. 6. Laranja color comparison chart.

When comparing the color 09 Chocolate, the value obtained exceeded the tolerance scale, scoring 5.25. However, given the colors on the factory display, this is the one that most closely resembles the color of the tiles at Paço dos Açorianos, which is why it was selected. Reading the data, it was found that the sample had a lighter L* value compared to the standard and a redder a*. B* introduced himself with the same tone. The C* that represents saturation showed that the sample had the most vivid color (Fig. 7).

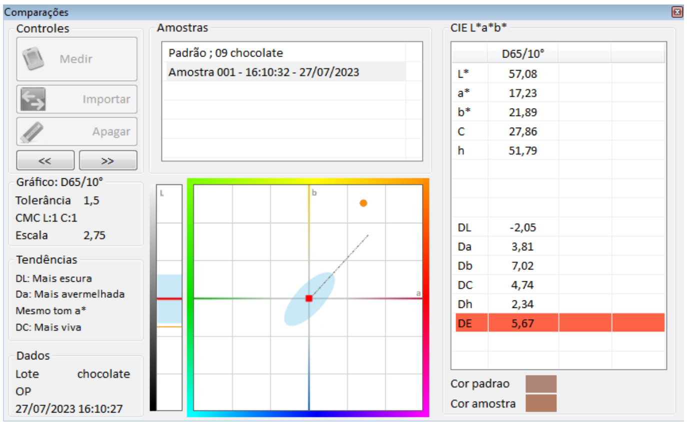

Fig. 7. Chocolate color comparison chart.

When comparing the color 10 Dark Gray, the tolerance scale was 3.5, 2 points above the established percentage. Reading the data, it was found that the sample had the L* value lighter, a* more reddish, b* the same tone and C* more vivid (Fig. 8).

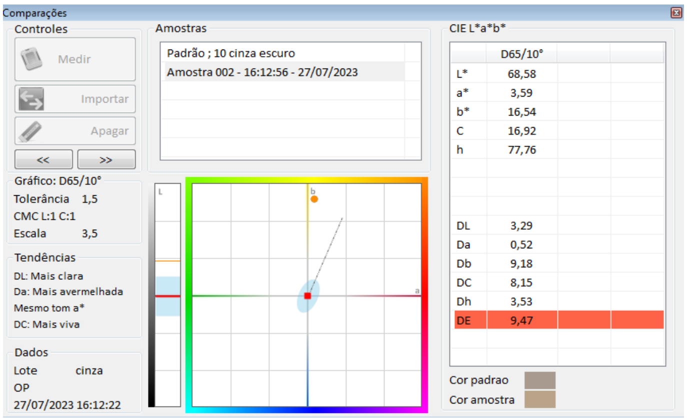

Fig. 8. Cinza Escuro color comparison chart.

When comparing the color 14 Dark Blue, the tolerance scale was 9. Among the colors selected, this was the shade in which the value obtained exceeded the tolerance scale too much, however, compared to the colors on the Fábeica de

Mosaicos display, it is the one that most It resembles the color of the tiles at Paço dos Açorianos, which is why it was selected. Reading the data, it was found that the sample had the L* value lighter, a* more reddish, b* with the same tone as a* and C* more opaque (Fig. 9).

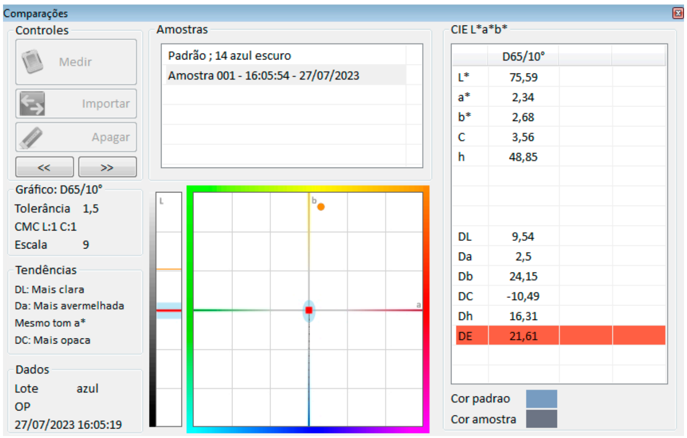

Fig. 9. Azul Escuro color comparison chart.

When comparing color 18 Bronze, the tolerance margin was 4.5, exceeding the stipulated percentage by 3 points. When analyzing the data, it was found that the sample exhibited a darker L* value, a more intensely reddish a* tone, a b* with the same tone as a*, and a more vibrant C*, as demonstrated in image (Fig. 9). This set of observations highlights the specific nuances of color and its variations in relation to established standards.

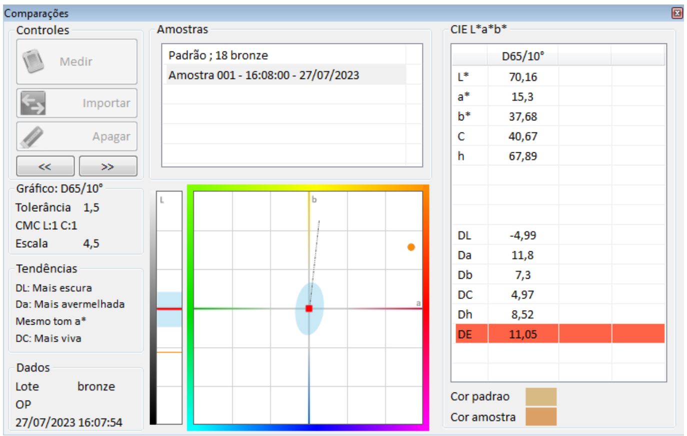

Fig. 10. Bronze color comparison chart.

When comparing the color 21 Dirty White, the tolerance was 1, within the acceptable percentage. This was the only highly compatible shade. The luminosity (L*) and red tone (a*) values were the same, with a more yellowish tone (b*), and the same chroma (C*). (Fig. 11).

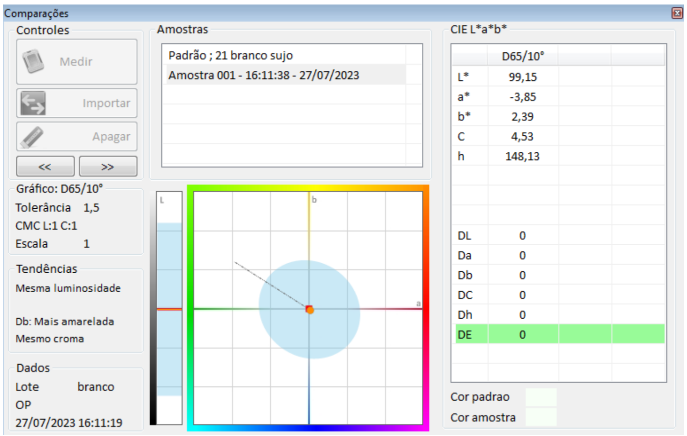

Fig. 11. Branco Sujo color comparison chart.

Finally, when comparing the color 22 Caramel, the tolerance scale was 3, being 1.5 above the established percentage. Reading the data, it was found that the sample presented a lighter L* value, a* more greenish, b* the same tone as a* and C* more vivid (Fig. 12).

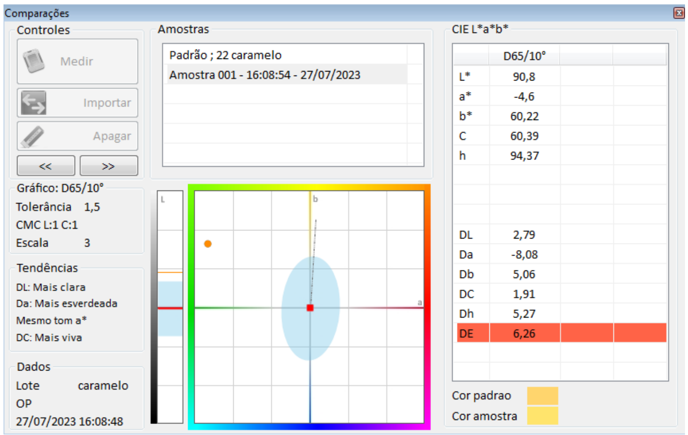

Fig. 12. Caramelo color comparison chart.

5. Discussion

According to the standard ASTM (2017), brightness can influence color perception and result in very costly errors. Likewise, the effects of geometric metamerism, if not taken into account in assessment observations, will result in color mismatches.

Therefore, it is understood that measuring and evaluating the colors of the city hall's tiles proved to be a complex task, since the damage caused by yellowing, dirt and excess shine from the waxes applied over the years to polish the surface, can cause imprecision in the color, which can make hues more saturated and less luminous (Fig. 13).

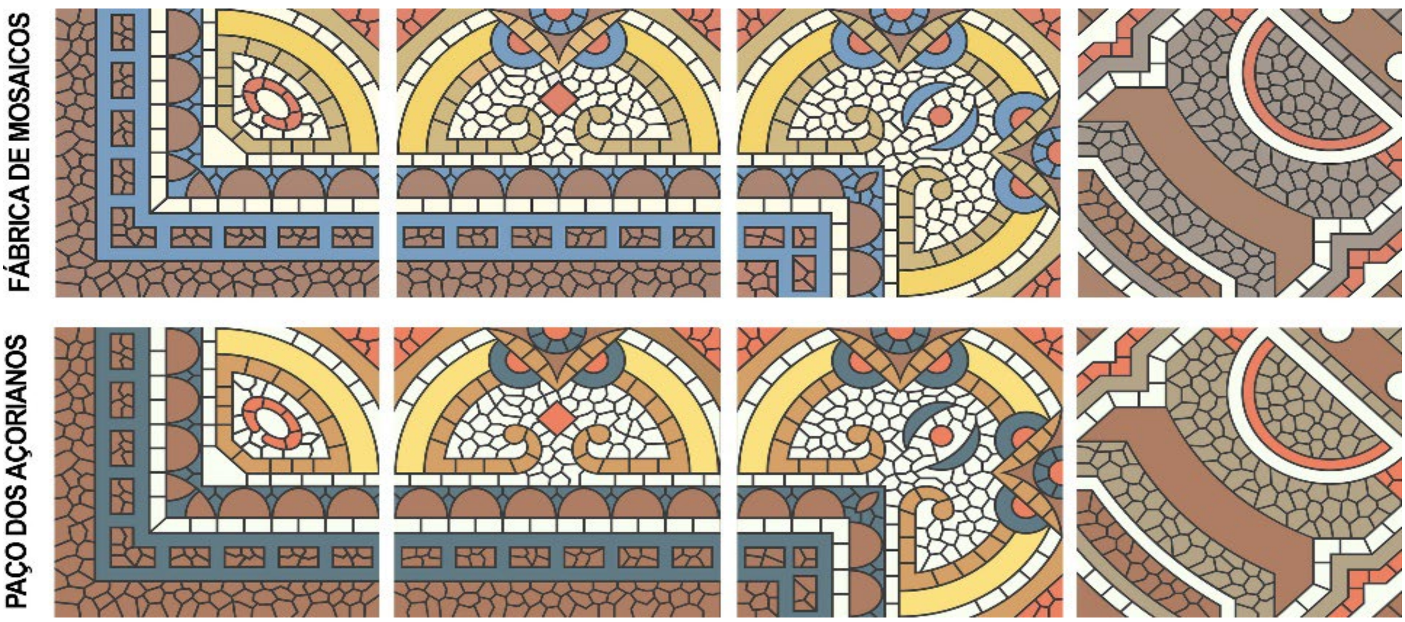

Fig. 13. Demonstrative illustration with the colors applied to the tiles made by Fábrica de Mosaicos and those at Paço dos Açorianos.

To obtain the exact color, it would be necessary to carry out a sanding process to reach a deeper, damage-free layer. Therefore, it would be possible to carry out a study with the preparation of various test bodies based on mixtures of pigments from the Fábrica de Mosaicos, to then achieve the most compatible tone, however, as we are dealing with an asset integrated into a listed heritage property, such action is not viable the decision to use a colorimeter reinforces the choice to use indirect data capture methods that do not cause further damage to property.

6. Conclusion

Conceptually interdisciplinary research, combining design, architecture, new technologies and cultural heritage, provides, through its results, the potential to promote the conservation of hydraulic tiles, contributing to the advancement of scientific knowledge in these areas. By combining academic research in partnership with Fábrica de Mosaicos de Pelotas, innovative strategies for manufacturing were developed.

In this context, the use of a colorimeter proved to be a viable and effective alternative, allowing accurate measurement of colors without compromising the physical integrity of the tiles. This choice reflects the commitment to preserving cultural and historical heritage, while at the same time enabling advances significant in the understanding and conservation of hydraulic tiles.

The research reaffirms the cultural and heritage importance of hydraulic tiles, highlighting the collaboration between science and industry in the preservation and valorization of this element in the Paço dos Açorianos. This partnership paves the way for future restoration interventions on the pavement, ensuring its conservation for future generations. Furthermore, cooperation between the institutions involved allowed the sustainable and replicable incorporation of research results by Fábrica de Mosaicos, suggesting new directions for future restoration and conservation projects. By combining scientific methods with the practical expertise of the Fábrica de Mosaicos de Pelotas, the aim was to contribute to a better understanding and conservation of this integrated asset. In summary, the research results have the potential to assist other researchers and professionals involved in the conservation of tiled floors, highlighting the crucial role of the colorimeter in the manufacturing process of these coverings. By demonstrating the effectiveness of this tool in accurately measuring colors, this study contributes to the development of more efficient practices in colorimetry.

Regarding the developments of this research, it is suggested to investigate the development of specific shades of pigments for hydraulic tiles intended for heritage properties. This would involve researching and testing pigment formulations that meet the aesthetic and preservation requirements required for such historic spaces

7. Conflict of interest declaration

The authors declare no conflict of interest.

8. Funding source declaration

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