



Azulejos as an architectural element within the scope of design and conservation

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Abstract

The research question is shaped on the axis of how the current state of azulejo applications is positioned in terms of design and technique and how it can be carried to the future. The aim is to provide a framework for the follow-up, mapping and strategy development steps necessary for the preservation and development of azulejos practices. In this context, a brief history of glazed ceramics, related restoration perspectives and views on how these techniques can be carried into the future are discussed with a common view. The scope consists of the steps of façade identity developed through azulejos, current studies to improve material properties, mathematics and discourse in azulejo applications, and evaluation of near future potentials. The method of the study is based on the comparison of the data obtained through the literature review on these topics. The findings were shaped on the axis of the importance of systematizing the studies. In addition to extending azulejo applications to areas such as engraving and iconography work, a base must be created that will allow researchers to leverage larger structures and broader projects on a collaborative basis. The use of contemporary modeling techniques, the application of contemporary mapping methods, the use of high-quality images will allow this design heritage to be recognized by the masses and to be carried into the future as one of the most important parts of the urban identity.

1. Introduction

Focusing on how azulejo practices can be preserved and how they can be carried into the future is an essential part of contemporary architectural practices. The aim of the study is to provide a framework for the follow-up, mapping and strategy development steps necessary for the preservation and development of azulejos practices. In this context, a brief history of glazed ceramics, related restoration perspectives and views on how these techniques can be carried into the future are discussed with a common view.

Azulejos are decorative ceramic tiles with a long history and cultural significance in the Iberian Peninsula. These tiles were first introduced in the 8th century and have since become an important part of the decorative arts in Portugal and Spain. The history of glazed pottery goes back to ancient China, where the technique was first developed about 8,000 years ago [1]. It includes the application branches of traditional ceramics, raw materials, porcelain, glazes, glass and vitreous ceramics, pigments, restoration, tiles, tableware and works of art [2].

Over time, the glazing technique became more sophisticated and new materials were added to create more diverse and colorful glazes. The use of glazed pottery spread throughout Asia and Europe and became a common technique in the Middle Ages for creating objects that are both decorative and functional. During the Renaissance, glazed ceramics were highly prized for their beauty and technical prowess and were used to create elaborate dinnerware and decorative works of art [3].

Bosh and Niepce states that the glazing process begins with a baked ceramic object that is left to cool. The glaze is then applied to the surface of the object in liquid form using a brush or spray gun. The glaze should be applied evenly to the surface of the object and any excess should be removed to prevent drips or run-off. After the glaze is applied, the object is fired again at a high temperature in an oven, causing the glaze to melt and fuse to the surface of the object. The end result is a smooth, glass-like surface that is both durable and visually appealing [4].

There are several different types of glazes used in ceramics, each with its own unique characteristics and

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properties. Some of the most common types of glazes are: Earthen glazes are made from a mixture of clay and other materials and fired at a relatively low temperature. They are often used for decorative ceramics such as vases and figurines. Stoneware glazes are fired at a higher temperature than earthen glazes, making them more durable and water resistant. They are often used for functional ceramics such as plates and bowls. Porcelain glazes are fired at the highest temperature, making them extremely durable and water resistant. Some of the most common types of glazes include fine porcelain and decorative art [5].

Although glaze is an effective preservative, historical changes cause various deteriorations on the surfaces of glazed ceramics. In this context, azulejos applications, which are one of the areas of interest for restoration and one of the areas where the deterioration of the facades is seen most, provide an effective basis for contemporary studies on how glazed ceramics can be carried into the future. On the other hand, at this point, it is necessary to consider the restoration works related to azulejos practices not as interventions aiming only visual improvement, but as a tool to ensure the continuity of cultural sensitivities. It is known that design practices that aim only to improve the physical conditions of the space, focus only on spatial conditions and do not take into account human activities are problematic in terms of restoration. The importance of investigating the effects of restoration projects applied to buildings on intangible cultural heritage values should be emphasized [6]. This requires creating a comprehensive system that can offer implications for the future of azulejos applications on contemporary facades. Because azulejos is one of the most concrete reflections of cultural heritage and collective memory on the facades.

2. Method

The study covers the comparison of data obtained through literature research and the development of strategies for carrying azulejos applications into the future. In this context, the basic methodology of the study includes the steps of following the steps of creating a facade identity developed over basic azulejos, listing the place of azulejos applications in the literature in a comprehensive manner, examining current studies on the improvement of material properties, mathematics and discourse in azulejos applications, and evaluating azulejos application and protection potentials in the near future. In this context, it is also important to examine the background of azulejos practices in existing historical buildings (Figure 1).

3. Current needs and assessment of near future potentials

3.1. Facade identity evolving through azulejos

With the growing international appreciation of Portuguese tiles (azulejos), encouraged not only by the recognition of Portuguese tiles (azulejos) as a unique heritage for their integration into Baroque architecture, but also by their continued use to the present day,

azulejos have become a subject of interest and research. The characteristics, production technologies, deterioration forms and restoration materials and techniques of the azulejos before the 20th century were examined. Although manufacturing technologies of the early 20th century have identified some industrial production techniques, degradation patterns, and major restoration techniques, current knowledge is far from complete for modern azulejos. More than 100 modern panels of azulejos have been identified in different parts of Portugal. Twelve factories are determined according to their operating periods in different regions of the country where Viúva Lamego, Constância and Sant'Anna have higher production. The composition of modern azulejos may differ from that of pre-industrial azulejos, and therefore unknown forms of decay can sometimes be observed. It is important to know the characteristics of these azulejos in order to be able to recommend appropriate restoration approaches. Identifying the most important production plants and production technologies of the 20th century in the field of production technology is the most basic step in tracking deterioration [7].



Figure 1. Porto Cathedral Façade

Helvacıkara [8] mentions that the use of ceramic tiles is also common in other countries such as Spain, Italy, Netherlands, Türkiye, Iran or Morocco, but it gains special importance in Portugal with its widespread use and contemporary practices. At this point, he emphasizes that although Azulejo is not of Portuguese origin, it forms an important part of the culture with its continuous use for five hundred years. It gives information about the diversity of its use, from religious places to tomb structures, from palaces to fountains and urban furniture. From the point of view of continuity and efficiency of access to information, Bank of Materials in Porto offers a meaningful pattern to follow this whole historical process and to read the contextual relationship between azulejo pieces (Figure 2).

Salema de Carvalho shows that azulejos can be found in tapestries, textiles, illuminations, jewelers, etc., as well as models spread through engravings. He investigates what can be called Digital Art History today, by accepting Art History as his main research area and following an inventory tradition dating back to the last quarter of the 19th century. It also reminds us that the azulejos offer a

very suitable workspace in the fields of documentation and data visualization methods and automatic image comparison with computers. In this context, it is important to aim to continue to adopt a collaborative approach with other institutions related to or having specific responsibilities in the field of tile decoration. Producing inventories that fit clear and verifiable strategies and creating the conditions for the actual sharing of data also support this approach. Moreover, this exchange should not be limited to tile decorations only. It should be extended to other areas of research, such as the study of engraving and iconography, allowing researchers to leverage larger structures and broader projects on an open and collaborative basis. The use of high-quality images allows not only to document this heritage more effectively through the creation of future-proofed documents, but also to consult tools, such as provided applications, that can explore their potential. At this point, it should not be forgotten that the most basic purpose is to provide information about a heritage whose importance is widely accepted and to allow it to be used for different purposes [9]. As well as tools for high-resolution zoomable images The Mirador application, which enables the comparison of multiple images from multiple warehouses, is among the tools that Carvalho mentioned in this context. The interior design of Sao Bento is an effective example of the diversity of uses emphasized by Carvalho. Azulejos is not only a wall covering element, but also a historical descriptor (Figure 3).



Figure 2. Bank of materials

He evaluates Francisco de Matos in terms of both his painting skills and the technical quality of the tiles on the panels, while also considering his relationship with

azulejos. While two different painting styles emerged in the panels, the analytical results did not distinguish between them. Artistically, it appears that there was a demand for azulejo slips with blue ornaments on a yellow background in Portugal in the 16th century. It is also known that the sketches of the panels are usually made on paper and the lines are punched with carbon black so that they can be transferred onto the raw glaze [10]. One of the best examples of this subject is the Grande Panorama de Lisboa, exhibited at the National Azulejo Museum (Figure 4).



Figure 3. Sao Bento Station interior



Figure 4. Grande Panorama de Lisboa, c. 1700, National Azulejo Museum

3.2. Current studies on the material properties and their improvement

Pereira et al. [11] emphasizes that the glaze and in-glaze pigments of the nineteenth-century historic glazed tiles from the Pena National Palace are characterized using an analytical approach. In this system, in which the chemical composition and microstructural characterization were determined by μ -PIXE, μ -Raman, optical microscopy and VP-SEM-EDS, it was seen that the production technique and color palette were close to the ceramic pigments used in traditional majolica. It is known that the purple colors are caused by cobalt oxide and manganese oxide, respectively. While a mixture of Pb-Sn-Sb yellow with cobalt oxide and iron oxide is used for green and dark yellow, respectively, gray tones are composed of a complex mixture of cobalt oxide, manganese oxide and Pb-Sn-Sb yellow in different proportions. When all these are evaluated together, it can be clearly seen that the obtained results allow the determination of the production techniques as well as the oxides and elements used in the pigments by resorting to traditional majolica production, although it was produced at the end of the nineteenth century [11]. The related differentiation of azulejos can be seen on facades (Figure 5).



Figure 5. An exterior in Porto with Azulejos

Examining a series of old azulejo mortar preparation samples from the Portuguese towns of Lisbon and Coimbra from the 16th to the 19th centuries, Damas et al. emphasize that all mortars consist of siliceous aggregates with the addition of air lime and usually clay. He emphasizes that the results show a clear difference between the azulejo fees in Lisbon and those in Coimbra. The knowledge that Lisbon mortars have a calcite airlime binder containing siliceous aggregates and traces of clay minerals becomes important when evaluated together with the knowledge that Coimbra mortars have a dolomitic airlime binder containing siliceous aggregates and, in most cases, a significant amount of clay minerals. The main conclusion of Damas' work has developed that these mortars do not follow a chronological pattern, but differ from region to region, certainly due to the use of local materials in the mortar formulation as well as the experience of the practitioners. In addition, the differentiation of the results obtained according to the building type also provides clues that the professionals preparing the air-lime coating mortars adapted the formulation according to the type of building to be used and the available resources. Azulejos are frequently found in military and religious buildings and then in other public buildings such as hospitals, and the correct selection of coating mortars plays a major role in this [12]. This relationship will also diversify the strategies of carrying the identity of the existing structures to the future in terms of the balanced coexistence of the old and the new (Figure 6).

Mimoso emphasizes that the differences between the monogrammed panels are mostly related to the morphology and composition of the varnish. It is essential to find such clear differences to study the early

production of majolica azulejos in Portugal. With regard to the Si/Pb ratio, the composition of the glazes was largely dependent on the firing method, which was dependent on the available kiln technology. The constancy of morphological features suggests that cooking conditions did not change substantially during this period, and perhaps the oven used was always the same. When a new furnace or improved technology was introduced, possibly allowing faster firing at a higher temperature, the Si/Pb ratio was increased to save lead cost and the cycle time was shortened, which resulted in sharp interfacial crystal growths to save both time and fuel [13]. Different styles which occur by different chemical combinations and artistic reflections can be seen on facades of city (Figure 7).



Figure 6. An exterior in Porto with Azulejos (Figure 6)



Figure 7. Two different styles of exterior in Porto with Azulejos

The addition of unusually finely ground minerals to a smalt used to paint outlines, possibly to give them body and prevent the color from flowing as they cook, can characterize a single painter or workshop. The dark lines remain protruding from the glaze with little diffusion of the blue or purple pigments into the glaze underneath [14]. The results presented here suggest that it was the collective qualities that allowed grouping the 16th century azulejo produced in Lisbon workshops within

what we might call the João de Góis circle. They shared a common technique (glaze compositions and the baking cycle) that defined the circle. The results showed that there were significant differences in the composition of the biscuits, perhaps due to the fact that ceramic pastes were produced from marl or clay obtained from different pits and varying depths. However, the composition of glazes remains constant throughout the period, possibly representing a reasonable assurance of good results when firing tiles according to a series of cycles involving a single kiln. The very distinctive morphology of glazes, particularly with regard to the development of neoform crystals at the glaze-biscuit interface, is probably a result of the firing cycle rather than the composition of the glaze itself. This point should be kept in mind when evaluating later productions that do not have the same interface development: different glaze morphologies may result from different firing cycles in different kilns rather than characterizing a single workshop. The morphology of glazes will likely be affected immediately if a different baking cycle is adopted, but the basic composition of glazes and biscuits does not change significantly when using a different oven. However, when a higher firing temperature is achieved, the Si/Pb ratio can be increased to save lead cost. Once again, the results are available, these and similar considerations can help establish the progressions and chronological sequences that determine the spread of faience azulejos production in Portugal [15].

3.3. Mathematics and discourse in Azulejos practices

Leitao and Gessner emphasizes that the glazed tiles in Coimbra, appear to be the only example of mathematical properties and scientific motifs used as decorative elements in buildings widely used in Europe, especially in areas constructed by the Society of Jesus. Panels of azulejos using ornate mathematical motifs are well known in Portugal and elsewhere. But the mathematical azulejos of Coimbra are unique in that they are not only decorative works but real didactic aids to the teaching of mathematics. It is also seen that azulejos are usually cut into squares of 14×14 cm. As decorative tile panels were applied to the walls of several Jesuit colleges in Portugal in the early eighteenth century, it seems clear that at one-point teachers in Coimbra ordered the production of an azulejo collection displaying geometric diagrams of all the propositions needed. This provides a striking visual impact while avoiding using the blackboard and drawing a diagram when a demonstration needs to be worked out. In the following years, a program for the development of mathematics courses was established, which may be regarded as the first large-scale reform of mathematics education in Portugal. The production of mathematical tiles must be understood in the context of this particular training. However, it is not known exactly why and when these azulejos were removed from the wall on which they were applied. It is possible that they were deliberately exterminated when the Jesuits were expelled from their schools. However, some tiles have survived as silent but tangible witnesses of an ancient mathematical tradition [16].

Salema de Carvalho recalls that over the centuries, changes in taste affected different types of framing, often seen as a minor part of decoration and therefore more open to the introduction of new artistic styles. In the light of all these, it is clear that frames are not just a finishing element, but an important tool in the design of architectural spaces and structuring of tile decorations. Moreover, frames are often the vehicle of a visual and textual discourse that is part of the iconographic program they contain. As such, they play a decisive role in the history of Portuguese azulejos, which are highly relevant for today's international frameworks and the dialogue between images and words [17]. The process is based on the cataloging procedure, and the rhythmic and formal visual analysis of the models. Then, by looking at this digital heritage, the consistent preservation of many elements such as plasticity and design in the tiles to be renewed is possible with a systematic archiving [18].

3.4. Institutional approaches for the preservation of Azulejos

The details of the 1989 edition of UNESCO's journal Museum, which focuses on conservation practices in Portuguese-speaking geographies, are as follows: While the exhibition examples of the period are mentioned, it is mentioned that simple, large photo-montages were used to describe the evolution of ceramic tile in Portugal. Specific details on the authenticity of Portuguese tile work, in particular, are supported by a twentieth-century diaporama. In addition to all these, the special issue of the magazine mentions the development of a series of display systems for how clay and tile were shaped, painted and fired [19]. From the past to the present, it is understood that the discussion and exhibition experiments, which are considered contemporary for their own period, are insufficient today. Knowing that collective memory is directly related to the cultural heritage that includes memory and transfer may contribute to the preservation process of similar historical elements. It takes part in technological applications, cultural institutions and international UNESCO projects that ensure the sustainability of tangible and intangible cultural heritage in the 21st century. For example, the World Memory Registry developed by UNESCO in 1997 is within the scope of documentary heritage [20].

In the relevant topics published by ICCROM (2003), it is seen that in Portugal, the removal of glazed tiles for conservation applications is sometimes due to poor condition of the mortar and sometimes due to the disproportionate size of the joints between the tiles. The application differences in this regard show that all materials should be evaluated separately. The intervention methods to be used for the tiles to be exhibited in the museum may be quite different from those for the tiles on the walls of the buildings, which are part of an architectural element. Glaze, ceramic body, mortar and masonry should be included in research and development studies as four separate components. The most basic step to be taken for this is to maximize the protection process by cutting the relations of these four components with water [21].

Another example of the discussions about the practices of ICOMOS and related exhibition forms is as follows: The letter that Architect Urioste wrote to Careaga, the President of ICOMOS Uruguay, regarding the renovation and exhibition of the ceramics he donated for exhibition is remarkable. With the help of comparative examples, this letter shows how original azulejo pieces were re-exhibited with deformation [22]. The main deficiencies in azulejos practices and the problems related to the insufficiently contemporary display represent a much narrower field than the field represented by today's technological sensitivities. Therefore, topics on how ceramics can be transferred to future generations through technological innovations gain importance.

Santos et al. [23] state that mobile augmented reality (MAR) applications help users navigate and explore their real environment by displaying virtual content corresponding to real-world objects and scenes. In this context, it should also be remembered that despite the increasing popularity of these applications, users may not be satisfied with some experiences when they cannot accurately recognize the Points of Interest (POI), objects or places they want to visit, or get more information. Emphasizing that spurious recognition may occur due to imprecise Global Positioning System (GPS) data or the absence of QR codes for interaction, Santos et al. offers a proposal that combines pattern recognition in images with geolocation information to improve the accuracy of identifying POIs. The associated project is the identification of azulejos on the facades of historic buildings in the city of Belém, Pará, Brazil. It is also important that the methods used to extract the properties of azulejos are the occurrence matrix combined with the color percentage and global positioning data. Since the tests will be performed using six machine learning algorithms with different paradigms (neural network, decision tree, k-nearest neighbors, pure Bayesian, random forest and support vector machine), a method whose accuracy is tested and validated in many steps is followed [23]. Relatedly, neural network and Bayesian analysis can be used to transfer the azulejos practice on the Chapel of Souls facade to future generations with contemporary museum techniques and similar iconic structures can thus be preserved semantically and contextually (Figure 8).

Almendra and Ferreira state that the Anti-Amnesia project is a design research and mediation process dedicated to the recovery and maintenance of traditional knowledge systems embedded in Portugal's four typical industrial practices – hand weaving, shoe making, Azulejos tile work and typography. The research focuses on recovering and interpreting elements of relevant identities, traditions, knowledge and material culture to develop a scientific infrastructure for society and culture that can help build on their tangible and intangible values. Seen in relation to this, actions include ethnographic documentation, archiving and interpretation in art and design, as well as pedagogical interventions aimed at addressing tactical objectives associated with the preservation of industrial and cultural heritage. Despite its importance for Portugal's architectural heritage, the existence of a collective aiming

to save, maintain and promote the heritage of traditional Azulejos tile work, which is facing the attack of theft, insensitivity and invalidation, is not enough, and it should be emphasized that it should be developed and expanded for similar historical legacies and façade characters [24].



Figure 8. Chapel of Souls Facade (Archive of Author).

Cruz [25] states that facades in current standards are defined as non-structural elements and adds. Generally, only static loads such as dead loads, wind, limiting forces are assumed in the calculation of required anchors. Whereas, facades can have different loads like azulejos. Facades have two main functions in building constructions: It is part of the aesthetic design of the building like an envelope and it is part of the insulation. Facades consist not only of external cladding, but also of an adequate layer of insulation and optional ventilation, in order to have an effective effect on the building physics. The respective task of fastening structures is therefore to safely introduce loads into the building construction and provide sufficient space for all necessary components [25].

In the example of Anemurium, one of the important ancient port cities in the south of Anatolia, the necessary protection and repair works were started on the buildings in the ancient city with poor physical condition and the mosaic flooring and wall frescoes in these structures without dissipation of time. Thus, the ruins were prevented from facing the danger of extinction in the following periods, and their lifespan was extended, and this very valuable immovable cultural heritage was protected and kept alive. In addition, necessary studies have been carried out to ensure that the items produced from materials such as terracotta, metal, glass, bone,

which are unearthed during the excavations and are called movable cultural assets, are protected under appropriate conditions by cleaning, conservation and restorations, and that they can be seen by future generations [26].

It is very important to develop and implement a similar process for Azulejo applications. In the context of transferring the Azulejo culture to future generations, it should be emphasized that the maps obtained through Geographical Information Systems tools will also make a direct technical contribution to the conservation and restoration processes. Geographic Information Systems offer many innovative technical tools in terms of both classifying historical data and presenting it in the most effective way [27]. All these sections are the details necessary to preserve the structures that contribute to the extreme identity and turn them into an open-air museum in the city. Considering that the protection of cultural protection is directly related to tourism, the importance of a special strategy structure for the cultural heritage road that needs to be protected in terms of tourism and the city border becomes evident once again [28].

4. Discussion and Conclusion

The absence of sufficient data to examine the characteristics, production technologies, degradation patterns, and restoration materials and techniques of pre-20th century azulejo makes historical mapping difficult. It does not seem possible to examine the development of azulejos practices detached from the historical context. Azulejos practices are treated not as one of the main restoration techniques, but as supporting decorations, which causes them to be read and treated only as one of the local civil folk arts. Taken together, the results show that traditional majolica production, although produced at the end of the nineteenth century, allows the determination of the production techniques as well as the oxides and elements used in the pigments. The lack of technical traceability also applies to math and discourse topics in Azulejos practices. The mathematical azulejos of Coimbra, for example, are unique in that they are not only decorative works but real didactic aids to the teaching of mathematics. In addition to their artistic values, another important issue that should be mentioned is that tile panels have obvious advantages as protective elements in schools, hospitals or other public buildings caused by intense human circulation. Looking more broadly, a system that will be implemented using six machine learning algorithms with different paradigms (neural network, decision tree, k-nearest neighbors, pure Bayesian, random forest and support vector machine) in order to maintain the systematic adjustments to be made about azulejos in the near future. It is seen that a series of steps should be followed. In addition to pedagogical interventions aimed at addressing tactical objectives related to the protection of industrial and cultural heritage, actions must also include ethnographic documentation, archiving and interpretation in art and design. Therefore, azulejo pieces need to be evaluated with studies that update the

load calculations before they are manufactured and considered for new chemical compounds.

In conclusion, azulejos as one of the most known applications of glazed ceramics are an essential part of ceramic art and have a rich history and diverse applications. The most critical details about the application, design and organization processes of azulejos are listed below:

- Azulejos has a very important place in Portuguese identity. The use of detailed mapping methods not only in traditional housing patterns but also in all cities will increase the incidence of azulejos applications in different functions.
- Emphasizing the properties of mortar, presenting comparative analyzes on ceramic fragility values, evaluating the most efficient firing temperatures can contribute to the spread and perfection of this art.
- The fact that mobile augmented reality applications help determine the new character of tourist routes will also offer ideas about how the use of azulejos can be diversified.
- Azulejos should be considered not only as a facade cladding element, but also as a matter of static and safety. The patchy image due to missing azulejos on many fronts shows that the necessary security measures and tracking systems for azulejos have not been established. A comprehensive mapping and archiving system have not yet been established to have a separate identity and inventory of each piece of azulejo.
- On heavy façades, fastening elements must bear high point forces on large wall openings. This necessitates compliance with a number of technical documents, not only for azulejos designs, but also for how these designs are applied to facades.
- While there is no collective that aims to save, maintain and promote the heritage of Azulejos tile work, there is an urgent need for activities to be disseminated for similar historical legacies and façade characters.
- The proportions of all binders, together with siliceous aggregates, clay minerals and dolomitic air lime, have been developed by random trials in the past and it has been observed that a chronologically consistent durability result has not been obtained. In contemporary azulejos applications, it is necessary to make these technical applications according to certain recipes and to create a substrate to be developed by following the moisture and durability properties together in the recipes.
- Identifying, comparing and evaluating the mathematical patterns in the Azulejos pieces in the context of prominent motifs will also play a contextual role in associating the symbols in Portuguese cities with each other. Similar motifs in the pieces can be traced to help the city function like an open-air exhibition, and certain mathematical repetitions can work as pieces of a design puzzle traced in the city.

When all information is evaluated together and how azulejos applications contribute to the identity of the city

as a design object, the importance of systematizing the studies becomes evident. In addition to extending the practice of azulejos to areas such as engraving and iconography, a base must be created that will allow researchers to leverage larger structures and broader projects on an open and collaborative basis. At this point, the use of contemporary modeling techniques, the application of contemporary mapping methods, the use of high-quality images will allow this design heritage to be recognized by large masses and to be carried into the future as one of the most important parts of urban identity.

Conflicts of interest

There is no conflict of interest between the authors.

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