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Built Heritage Research and History of Architecture: Light and Acoustic in the Cistercian Monastic Church of S. Bento de Cástris (Portugal)

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Abstract. The research on the Cistercian legacy in Portugal is an innovative multidisciplinary study. Consequently, the results achieved in this research have many different approaches: the former monasteries and their architecture are the main subjects concerning morphology, architectonic rehabilitation but also acoustics, thermal comfort, or natural light. This research, carried out at the Department of Civil Engineering and Architecture of the University of Beira Interior (DECA-UBI), was developed in connection with two other research centres - Lab2PT (Landscape, Heritage and Territory Laboratory) and CIDEHUS (Interdisciplinary Centre for History, Culture and Societies). In 2015, the curriculum of the Integrated Master Degree in Architecture of the University of Beira Interior underwent revision. Consequently, it was needed to allocate more time to the teaching of History of Architecture and the requirement to assign specific syllabus to the Portuguese History of Architecture, which is emphasized by the specific and multidisciplinary research performed linking with other sciences of engineering. The natural light in the Cistercian churches is closely linked not only with the liturgical requirements at the officium but also with the canonical hours based on the "ora et labora" dictated by the Rule of St. Benedict. The Cistercian Monastery of São Bento de Cástris (13th-19th centuries), in Évora, Portugal, includes a church, at the south-eastern corner. This church presents an unusual space setting with two choirs which seems to favour different positions for coral groups supporting liturgical and musical expression activities within the research scope of a Research Project. As the light in the Cistercian Monasteries, mainly, in their churches, is mostly related to the fulfilment of liturgical needs, this paper analyses the relationship between daylight conditions within the monastic choirs located within the monastic church. The chant was a very important way of oration and thus of the liturgy. This was the ORFEUS Project – “The Tridentine Reform and music in the cloistral silence: The Monastery of S. Bento de Cástris” which was based on a multidisciplinary approach around the Tridentine Reform with reflexes in the musical Cistercian feminine matrix between the 16th and 18th centuries on Cistercian Monasteries. This paper describes the objectives and methodology applied to the case study thus linking Built Heritage Research and History of Architecture, i.e., Research and Education.

1. Introduction

The Cistercian Monasteries were located out of any urban settlement. However, with time, many of these constructions were integrated into a contemporary ever-growing urban space which changed



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drastically its boundary conditions. Due to the architectural legacy of these historical buildings and the economic stimulation that moves public and private attention towards rehabilitation, there is an incentive to undergo multidisciplinary studies in order to understand these monastic buildings. Modern life also requires new standards of living which can be applied to heritage buildings. Some questions may arise to the contemporary way of life in order to reuse these impressive constructions [1], [2], [3], [4].

2. Built Heritage Research and History of Architecture

The University of Beira Interior is one of the most recent Portuguese universities. Since 1986 it has been developing multiple education and research centres, now structured in five faculties. One of these faculties is the Faculty of Engineering which incorporates the Department of Civil Engineering and Architecture (DECA-UBI). The main degrees at the Department are the Integrated Master degrees in Architecture and in Civil Engineering [5].

Martins [6] carried out a study about the Integrated Master degree in Architecture at DECA-UBI and brought to debate the redesign and enhancement of the History of Portuguese Architecture curricular units underlining the importance of an integrated teaching of General History of Architecture, History of Portuguese Architecture and Theory of Architecture as basis for Architectural Design [6]. The History of Portuguese Architecture I and II, related transversally to the courses of Theory and History of Architecture, will enable the students to pursue the review and analysis which is essential to the Architectural Project. The aim of the History of Portuguese Architecture courses is to relate the students with the particularity of Portuguese Architecture since the beginning of the Country as a nation until the contemporary Portuguese Architecture and its Architects [6].

Nevertheless, the interdisciplinarity and interrelation, which link both research and education, are the basis to produce knowledge at DECA-UBI. Among the different research themes, particular attention is devoted to the built heritage in Portugal, and its connection with the engineering sciences as thermal comfort, acoustics and daylighting [1], [2], [3], [4], [5]. Built heritage is a very important cultural asset as evidence of any development in the society. It refers to all aspects of the man-made environment such as houses, places of worship, commercial and office buildings, monuments and other places of historical significance. Built heritage helps to define a sense of place and identity for communities. It is not only about monuments of exceptional value but it also includes small modest vernacular buildings that represent other equally important historical, social and cultural values. Furthermore, the actual technical requirements are not always compatible with the former building. Regular maintenance of these buildings may include preservation, rehabilitation, restoration, reconstruction, adaptation and interpretation. A balance needs to be achieved, i.e., the future of built heritage conservation is focused on the sustainable built environment. Conservation does not require buildings to be preserved in their original condition to accept contemporary use. It may change over time as community values evolve. However, it is important, as a cultural asset, to retain its original heritage features. While heritage conservation is a key player in sustainability planning, interdisciplinary skills that are needed to deliver the heritage studies and projects of the new generation architects which combine aspects of cultural heritage with the best preventive conservation, projects, methodologies and practices. For this purpose, the link with engineering sciences is important [5].

The research on the Cistercian legacy, carried out at the Department of Civil Engineering and Architecture of the University of Beira Interior (DECA-UBI) was developed in connection with two other research centres - Lab2PT (Landscape, Heritage and Territory Laboratory) and CIDEHUS (Interdisciplinary Centre for History, Culture and Societies) - is an innovative multidisciplinary study [1], [5]. Consequently, the results achieved in the research of the Cistercian legacy in Portugal have many different approaches: the former monasteries and their architecture are the main subjects concerning morphology, architectonic rehabilitation but also acoustics, thermal comfort, or natural light as referred by Martins and Carlos in previous studies [1], [4] and by Martins, Carlos and Nepomuceno

[5]. Cistercian Monasteries were the target of numerous renovations, extensions and improvements [1], [7], [8]. The research projects are also a way of connecting education and research as it is considered an important output in thematic dissertations concluded within its scope. The “ORFEUS Project (EXPL/EPH-PAT/2253/2013) - The Tridentine Reform and music in the cloistral silence: The Monastery of S. Bento de Cástris” is based on a multidisciplinary approach around the Tridentine Reform reflexes in the musical Cistercian feminine matrix, between the 16th and 18th centuries, on Cistercian Monasteries [1], [4], [5]. This research, guaranteed by historians, architects, engineers, musicologists made possible to achieve the proposed results and accomplished much more than the results previewed initially with a significant International dimension [1], [5].

3. Monastery of S. Bento de Cástris: the monastic church and its choirs

The Monastery of São Bento de Cástris (13th - 19th centuries) has been a National Monument since 1922 and it is located in the region of Alentejo, on the hill of São Bento, about two kilometres away from Évora [4], [9]. Currently, the monastic building presents architectural features that fit within a period between late 15th century and early 16th century, with traces of the final Gothic as well as mudéjar (which is a stylistic mixture between Cristian and Islamic Art in some Portuguese regions that were under Islamic influence before, and during, the Christian Reconquest). These artistic and architectonic influences were always reconciled with Cistercian requirements [4].



Figure 1. Monastery of S. Bento de Cástris: Church wall

This monastery includes the church, at the south-eastern corner which has not only a high choir but also a low lateral choir (within the presbytery). Its unchanged exterior walls are made of solid masonry (figure 1). Although the function of the walls is primarily structural, the windows allow daylight to penetrate the space of the church. The church has two external façades facing northeast and southeast. The combined orientation effect of the church’s main axis and the sun trajectory determines how the sunlight reaches the interior of this architectural structure [10].



Figure 2. Monastery of S. Bento de Cástris: the monastic church and its choirs

The feminine Portuguese Cistercian Monasteries have always the choir separated by a grid. The nuns' access was possible usually by the inside of the monastery without having to cross the church. The nuns' choir is located at the end of the nave, opposite the apse, in a higher or lower position [4], [7]. But there are two exceptions: a) the double choir of S. Bernardo de Portalegre at the end of the nave, one above the other, this is, one high choir above the low choir, and b) the double choir of São Bento de Cástris, one lateral low choir, directly connected to the apse, and a high choir at the end of the nave [4], [7], [9].

The Church of the Monastery possesses characteristics from the 1500s, being worth highlight the Manueline ribbed masonry vault as well as the arch formeret and discharging arch which finish in half columns (figure 2). The Church has a biaxial Latin cross plan, showing a single nave and transept. The decentring of the transept in relation to the nave of the Church suggests traces of a previous building. The nave has three sections: the first two correspond to the transept and the intermediate section. The last section and part of the following are occupied by the high choir with noticeable Gothic traces. The lateral low choir appears in the 16th century which consists of an unusually low vault down on which a coating of lozenge boxes is placed (figure 2). The access to the Church is made laterally to the nave, as it would happen in feminine monasteries, part of it would open to the secular community so as not to disturb or break cloistered life. The sacristy would remain south, in relation to the apse, allowing the chaplain's access when celebrating the Liturgy. The southern arm of the transept gives access to the sacristy and the pulpit. The opposite arm of the transept has a confessional booth and a pathway which would give access to the nuns' ward and which is now sealed [1], [4], [10].

Throughout time, alterations to the building have occurred in order to adapt it to new realities and requirements. During the 18th century, new alterations appeared in the Church, especially in terms of decoration, where a Rococo Style is noticeable in gilt carvings, stucco and tiles. After the extinction of Religious Orders, in Portugal, in 1834, these buildings acquired new usages [8]. The last Cistercian Nun of the Monastery of S. Bento de Cástris died in 1890 thus becoming the monastery extinct and the building suitable for other uses in accordance with the Decree of 1834 [4], [9], [10]. After 1941, the building became part of the DGEMN - Direção Geral de Edifícios e Monumentos Nacionais ("General Directorate of Buildings and National Monuments") and in 1937, conservation works started on the referred building [9]. The Monastery of S. Bento de Cástris was used as Casa Pia of Évora - Section Baptista Rolo, which was a former orphanage until 2004 and after its abandonment, in 2006, there was an attempt, by the Ministry of Culture, to host the National Museum of Music [4], [9].

The walls of the nave which are plastered masonry and ornamented by ashlar tiles (around the Church nave) as well as sealed openings that exist on the north side of the Church and that feature a wooden grid and some gilt vegetal decorations [11]. The access openings to the Church are closed by wooden doors where an iron grid in the lateral choir stands out separating this side from the apse. The openings that allow lighting in the Church are also carried out by means of wooden frames and simple glass. There are two large windows on the south wall of the Church, one on the southern arm of the transept and two on the main chapel which an eastern additional opening is added to at the top of the apse. The Church roof is ribbed and vaulted and composed of masonry covered with stucco. A triumphal arch, composed by a perfect round arch, marks the nave of the main chapel. This demarcation is also achieved through a two-step elevation of the apse in relation to the nave's floor level. The apse features an altarpiece (three steps higher in relation to the floor of the main chapel) and an 18th century throne, in gilt, as well as an altar in the same material. The floor of the nave is of marble and the floor of the apse is a combination of marble and granite which was carpeted in the late 20th century. Regarding the floorings of lateral low and high choirs, they both consist of marble [4].

Considering the movable heritage, both high and low lateral choirs had wooden chairs. In the SIPA/DGEMN archives, photos of rows of wooden chairs with multi-coloured paintings in canvas or wood can be seen in the higher choir [4]. In the lateral low choir, due to the unique flatness, the backrest of the chairs would reach the cornice. Currently, these chairs no longer exist, and only plastered walls and ashlar tiles of a random pattern can be seen (possibly where the Abbess's chair existed). Towards the east, on the cornice, two circular openings with wooden frames and simple glass can be seen. Nuns would follow the requirements imposed by cloistered life hence being separated by iron grids and curtains both on the high and lateral lower choir (the grid of the higher choir no longer exists, having been replaced by a wooden balustrade). This prevented visual contact between the religious and secular community without, however, disturbing the hearing [4]. In the 18th century, substantial parts of the nave's walls and transept were covered with blue and white ceramic tiles, and a polychrome frame portraying scenes from St. Bernard's life [4].

4. Light in the Cistercian Monastic Church of S. Bento de Cástris

The use of natural lighting in architecture is widely accepted, yet its application in heritage buildings has been difficult to evaluate properly [12]. Simple methods were developed to quantify the level of daylight [13], even to study its influence on heritage buildings [14]. Since it is difficult to evaluate its quality and quantity through simple rules of thumb [15], the use of daylight simulation tools has increasingly become a necessity to accurately evaluate daylight in buildings. In Architecture, a daylight factor is commonly used and is based on uniform or overcast skies regardless of weather conditions. This is the ratio of a measure of indoor daylight illuminance at a given location as a percentage of illuminance outdoors [16]. Recommended minimum daylight factor for a church would be of 1% [17] while a lower daylight factor may be acceptable for secondary spaces such as circulation areas.

Some of the Cistercian monasteries denote the importance given to light in its own title: Clairvaux, Vauclair, Clairmarais [5], [9]. Natural light in Cistercian churches is closely linked not only with the liturgical requirements at the "officium" but also with the canonical hours based on the "ora et labora" dictated by the Rule of St. Benedict [4], [5], [9]. The full activities of a Cistercian day, according to the "ora et labora", were presented thoroughly by the authors in previous studies [3], [4], [14]. The chant was a very important way of oration and thus of the liturgy in all Cistercian Monasteries. The two unusual locations of the choirs (a high choir and a low lateral choir), at São Bento de Cástris' monastic Church, which worked as one, were the research objective as the levels of daylight is compared with the requirement needs of the modern world [4]. Martins and Carlos [10] carried out a study using the Velux Daylight Visualizer, a software tool dedicated to daylighting design and analysis, which predicts daylight levels and appearance of a space [4]. In order to obtain as much detailed information as possible, it was essential to obtain drawn elements such as plans, sections and elevations, which dimensions were

confirmed “in situ”, as well the registry of covering materials with different colours and shapes (figure 3). As effective daylight strategies have become an essential goal for any sustainable building, critical design questions of the choirs are seeking through produced trustable simulations tools [4]. The survey of all the materials present in the space was indispensable to be able to use in the 3D model as closest to reality as possible [4].



Figure 3. Monastery of S. Bento de Cástris: measure the levels of illuminance in different materials

In order to obtain the values of reflectance and transmittance value of opaque and transparent surfaces, two portable Luxometer devices were used, which measure the levels of illuminance through a light sensor that captures light on 180° amplitude. For all opaque surfaces inside the room, an illuminance measurement was carried out with one sensor in the direction opposite the surface and the other in the direction of the surface (figure 3). The quotient between these two values corresponds to the reflectance of this material. A second measurement was carried out on the inside of the glazing towards the outside, and on the outside of the glazing towards the outside [4], [5].

According to the previous study carried out by Martins and Carlos [10] light has had a symbolic role related to the sacred. This role is apparent in the religious buildings in the creation of worshipping and aesthetic forms. Therefore, it is one of the key architectural elements which introduce the visitor to a sense of inner harmony resulting in the spiritual relation between believers and religion [4], [10]. The spiritual transformation leads to a different perception of light that provides the necessary visual condition for the religious acts and to evoke mystical and spiritual feelings [18]. Martins and Carlos contextualized the importance and close connections of natural light within the Cistercian Monasteries architecture [1], [4], [10], [19].

It was important to the ORFEUS Project outputs to present the qualitative and quantitative analysis of the luminous environment in the church of S. Bento de Cástris, based on the authors' perception of the effect of daylight within the different areas of the enclosed space. The appreciation of the spatial experiences was supported by quantitative daylight simulations that were carried out in selected areas within the space [10], [18]. Simulations were carried out where the level of the illuminance was obtained (figures 4 and 5). The authors' observation of the variation in spatial experience, illuminance level and luminance patterns led to the conclusion that the luminous environment in S. Bento de Cástris could be classified into direct light (both from the sun and the sky) and reflective light. On a clear day, the patch of light is an early sunbeam showing the morning hours of the day. Under an overcast sky, a soft-edged

light falls on the internal northern wall while in the afternoon, the west end of the church recedes into darkness [4].



Figure 4. Monastery of S. Bento de Cástris: church and high choir

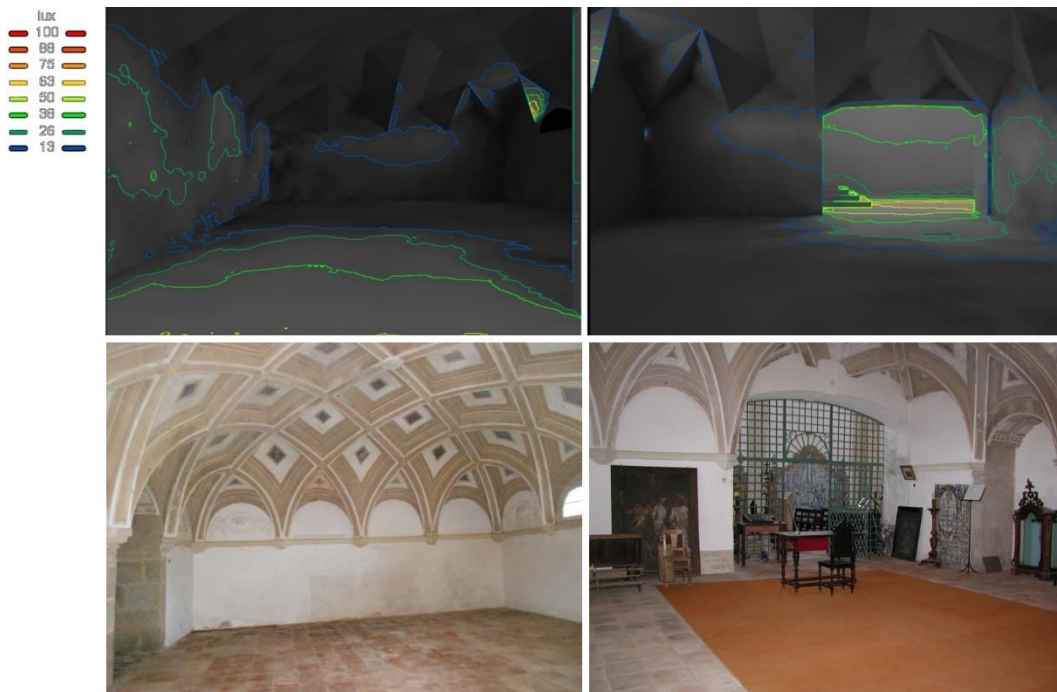


Figure 5. Monastery of S. Bento de Cástris: lateral choir

5. Acoustic in the Cistercian Monastic Church of S. Bento de Cástris

Rodrigues et al. [20] consider that acoustic heritage results from soundscapes with relevance to the characterization of the cultural identity of a place. It is an element that characterizes the cultural identity

of a place and allows featuring a social and historical context. In the case of religious buildings, the acoustic heritage acquires a cultural dimension which results from the typology layout, form, the construction materials, but also from the liturgy [20]. In the Portuguese context, there is a diversity of Cistercian monastic churches, so their characterization allows the acknowledgement of the interaction between the Cistercian liturgy and the regionalism present in the country, resulting in a great diversity of soundscapes. The acoustics in Cistercian spaces is characterized by a strong resonance, with high values of reverberation time. This resonance results from an austere decoration and the use of materials of the region, according to the principles established by the Rule of St. Benedict [20].

According to Martins and Carlos [1], it was necessary to provide the ORFEUS Project team with information on the actual acoustics of the Church of the Monastery of S. Bento de Cástris and to establish knowledge regarding the architecture and the duality of its choirs. Consequently, results obtained must be compared with the current recommendation for this type of space. In Portugal, an acoustic study was carried out at the Cistercian monastic Church of St. Bento de Cástris [11], [20]. In this study, high Reverberation Times (RT) were confirmed, including subsequent changes. This feature suggests a lack of intelligibility of speech. However, considering that the church was built in a period when the religious ceremony was essentially sung, a higher RT in this space is expectable (in later Cistercian's monasteries, wood carvings, decorations and even panelled ceilings were used). As such, greater intelligibility of speech can be intuited. These cases are in accordance with the evolution of the liturgy, for which intelligibility acquires greater importance and justifies less reverberation [11], [20], [21]. The existence of reverberation, on the other hand, also suits the use of the organ in Church, which use is justified for being an instrument of choice on a significant period of history. The organ accompanied the plainchant which, due to its characteristics, was more intelligible in reverberant spaces when compared to other religious chants [20].



Figure 6. Monastery of S. Bento de Cástris: measuring reverberation time

Lanzinha et al. [11] carried out a study which revealed the interest in measuring reverberation time (figure 6) in this type of enclosed space and discussed it. The measurement results of the reverberation

time were presented and analysed for the different spaces of the Monastic church of S. Bento de Cástris [1], [11].

Finally, the findings of the study presented some hypotheses for future work in terms of acoustic analysis of Cistercian spaces and for a better understanding of the architecture and music relationship, in its different expressions. Acoustic comfort levels must be guaranteed in all usable spaces in order to optimize the transmission of sounds and listening conditions which are essential for all audience members. Therefore, such studies should be continued [1], [11] as it is the case of Rodrigues et al. [20].

6. Conclusions

The contribution of the History and of the Theory of Architecture, in general, and of the History of Portuguese Architecture, in particular, are of great importance for the education of Portuguese Architects. The interpretation of the past, not only in terms of ideas but also in terms of monuments and common architecture, as well as researching the architectural language presented in each epoch is crucial for tackling the architectural profession. Thus, materializing ideas into buildings or research, in comparison with other studies, carried out at a European level allow the completion of the research and knowledge about the performance of the Portuguese architectural spaces.

It should be noted that the monastic architecture is a comprehensive and transversal research niche which is taking its first steps in terms of research in Architecture and Engineering in Portugal. In fact, this research aims to provide Architecture students with a very aware and complete education. Through this specific research carried out at UBI and supported by the ORFEUS Project, within the Cistercian Heritage, as a system, allows reaching some conclusions. This knowledge is transmissible not only through scientific articles but also through the outputs of project research as it is the case of the project ORFEUS. Ultimately, built heritage research and education are deeply linked to multidisciplinary research carried out and provide a distinctive framework for the Dissertation/Project of the Integrated Master degree in Architecture which allows connecting Architecture with other sciences of Engineering, thus linking Built Heritage Research and History of Architecture, i.e., Research and Education.

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