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Essence of Daylight in the Cistercian Monastic Church of S. Bento de Cástris, Évora, Portugal

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Abstract. 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 architecture, in its beginnings (12th century forward) is characterized by austerity, simplicity and the play of light and shadow that gives value to the monastic architectural space itself, making it perfect for a contemplative experience. In the Cistercian Monastery the church is the central piece of the monastic building. Nave, transept and apse are the main architectural components to which is added the choir. This paper contextualizes the importance and close connections of natural light, within the Cistercian Monasteries architecture. Thus the essence of daylight is analysed within the Church of the Monastery of S. Bento de Cástris, in Évora, Portugal. This former Monastery (13th - 19th centuries) 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. Although the function of the walls is primarily structural, the windows allow the 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. This study presents the qualitative and quantitative analysis of the luminous environment in the church of S. Bento de Cástris, being the first based on the authors’ perception of the effect of the daylight within the different areas of the enclosed space. The appreciation of the spatial experiences was supported by quantitative daylight simulations that were conducted in selected areas within the space. With this paper is intended to contribute to the debate about the specificity of daylight, in the context of Cistercian architecture.

1. Introduction

The Cistercian Order was introduced in Portugal, in the 12th century and its monasteries from the beginning associated with the development of the nation and the objectives of occupation and administration of the territory [1, 2]. The new monasteries were deployed to the image of the Monastery of Clairvaux, branch from which they provide, defining a typology of place. However, in 1567, the separation of the Portuguese Cistercians from the obedience to Clairvaux occurs, with the creation of the Autonomous Congregation of Alcobaça [1].



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 visitor to a sense of inner harmony resulting in the spiritual relation between believers and religion. The spiritual transformation leads to different perception of light that provides the necessary visual condition for the religious acts and to evoke mystical and spiritual feelings. According to Antonakaki [3] the main differences in the lighting of religious buildings arise from the different spiritual content, beliefs and rituals of each religion.

The monastic space is the reflex of an ideal, a vision of the world, a system of values that models everything. Reasons of spiritual and material order play a decisive role in the choice of the building sites for each Cistercian monastery [1]. The church plan was sometimes called Bernardine Plan to translate St. Bernard's ideas: latin cross, deep sense of orthogonally and alignments based on a square module. Villard de Honnecourt on his notebook (1230) drew a model church plan with the title "this is a church made of squares for the Cistercian Order" in which he does not represent the thickness of the walls, this indicates the existence of an ideal plan, probably based on the unity that characterizes the cistercian architecture [1]. As Fergusson says, architecture embodies ideas, reflects identity, and gives physical form and expressive meaning to values [4].

The daylight enhancement and availability also guarantee the maintenance and exhibition of frescoes [5]. Although the use of natural lighting in architecture is widely accepted, its application in heritage buildings has been difficult to be properly evaluated [6]. Simple methods were developed to quantify the level of daylight, [7] even to study its influence on heritage buildings [8]. Since it is difficult to evaluate its quality and quantity through simple rules of thumb, the use of daylight simulation tools has become increasingly as a necessary to accurately evaluate daylight in buildings. For the present study the Velux Daylight Visualizer was chosen [9]. It is a software tool dedicated to daylighting design and analysis, which predicts daylight levels and appearance of a space. As effective daylight strategies have become an essential goal for any sustainable building, critical design questions are being sought through trustworthy simulation tools.

This paper presents a qualitative and quantitative approach to natural lighting for the S. Bento de Cástris church. Daylight is a combination of sunlight, skylight and the reflected light from the facades and the ground. In architecture, a daylight factor is commonly used and is based on uniform or overcast skies regardless of weather conditions. Thus it is the ratio of the light level inside a structure to the light level outside the structure [10].

2. Cistercian Monastic Architecture

2.1. Portuguese contextualization

The Romanesque and then the Gothic, adjusted to the characteristics of the place, are the answer to the demands of the Cistercians, translating their spirituality. We must highlight the importance of the Cistercian Order, not only in Romanesque proliferation but also in the introduction of the Gothic, in Portugal, through the Monastery of Santa Maria de Alcobaça (1153). Portuguese Cistercian monasteries became worthy examples of the European Cistercian architecture, although over time they have been adapted, enlarged and transformed according to the styles of each epoch [1]. After the extinction of the Orders (1834), they underwent numerous transformations and the Cistercians moved out from Portugal but to return. However, their architectural legacy, object of recoveries and rehabilitations, evoking the ideals and the Cistercian spirituality, does not let us forget the importance of the Cistercian Order in Portugal. Currently, Portugal is part of the 'European Charter of Cistercian Monasteries and Sites' since 2009. Consequently, the Portuguese Cistercian architectural heritage is also part of the 'European Route of Cistercian Abbeys' to which it was assigned in 2010 the mention of 'the Council of Europe Cultural Itinerary' [1, 2].

The building, while Cistercian Monastery, dates back to the 13th century if we consider it in full exercise of its functions and with complete construction of the Church, the chapter house, the Nuns' ward and all other facilities supporting community livelihood such as refectory and kitchen. The monastic building that remains today presents architectural features that fit within a period between late

15th century and early 16th century, traces of final Gothic may be found as well as mudéjar (which are stylistic mixtures between Cristian and Islamic Art in some Portuguese regions under Islamic influence before and during the Christian Reconquest). Through time alterations, to the building, 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 decorations where a rococo style is noticeable in gilt carvings, frescoes and tiles [11]. After the extinction of Religious Orders, in Portugal, in 1834, these buildings acquired new usages. After 1941 the building becomes part of the DGEMN (Direção Geral de Edifícios e Monumentos Nacionais) “General Directorate of Buildings and National Monuments”. 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 to host the National Museum of Music by the Ministry of Culture [1].

2.2. *The cyclical life in a Cistercian monastery*

The time is cyclical, so it is cyclical the life in a Cistercian cloister, followed summer and winter, sunrise and sunset hours, as well as the play of light and shadow that value the architectural space making it perfect for a contemplative experience [1]. As Le Corbusier states on the Cistercian Monastery of Le Thoronet: “...witness to the truth. Stone is man's friend; its necessary sharp edge enforces clarity of outline and roughness of surface (...). Light and shade are the loudspeakers of this architecture of truth, tranquillity and strength. Nothing further could add to it” [12].

As Martins [1] explains the Cistercian day according to the Rule of St. Benedict, exploring the relation between the monastic spaces and Cistercian canonical hours, thus the Cistercian work and prayer as it is known as “Ora et Labora” also Carlos and Martins [8] explore the natural light connected to the Cistercian canonical hours. These researches are the aim of a multidisciplinary approach to the Portuguese Cistercian Monasteries Architecture [2].

The day of a Cistercian, begins at the Church with the Vigils at 2h or 3h in the morning, depending on the time of year, and these last about 1h to 1h30min. At dawn the Lauds begin, and the Eucharist is celebrated around 7h in the morning. After this, the *Officium*, called the Prime, takes place in the Chapter-house. Later, in the chapter house, a chapter of the Rule of Saint Benedict is read aloud, it is the *Capitulum*. Then the *Lectio Divina* follows and the next *Officium*, is the Terce. After that, each Cistercian Nun performs the tasks assigned by the Abbess, and around noon, work stops and the Sext *officium* takes place. Then, it comes the moment to eat in the refectory. At about 2 o'clock in the afternoon it is time for the None *officium* followed by 2h to 2h30 min. of work depending on the season. At about 5 o'clock in the afternoon the Nuns must be at the church for Vespers. The *Officium* of the Compline is introduced by a small reading, outside the Church, continuing into the Church [8].

3. The Monastic Church of S. Bento de Cástris

3.1. *Architecture*

The church of S. Bento de Cástris has two main perpendicular axis, defining different areas. It is located about 2.5 km northwest from Évora (38.5841 N, 7.9341 W, altitude 325 m). The church sits on the east-west axis, deviated about 28 degrees from east due north, allowing the nave to receive the rising sun. It has characteristics from the 1500's, being worth to highlight the Manueline ribbed masonry vault as well as the discharging arch which finishes in half columns. The Church has a biaxial latin cross plan, common in the Cistercian churches, showing a single nave and transept. The last section is occupied by the Upper choir with perceptible Gothic traces. The lower lateral choir appears in the 16th century which consists of an unusually low vault down on which a coating of lozenge boxes is placed [11]. 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 distract or break cloistered life. The sacristy would remain south in relation to the apse allowing the chaplain's access when celebrating the Eucharist. 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 [11].

The layout of the church is simple, with two rows of stalls occupying the west end (nave) with a few public seats and the altar standing on a raised platform. A transept is the space between the nave and the apse and has a transition element, between both spaces, named triumphal arch. A lower and lateral choir is located immediately northwest of the main altar and the upper choir is located at the immediately west end of the nave on a higher level (Figure 1). The longitudinal axis has about 25 meters and the transversal axis about 15 meters. The width of the nave was defined by the necessity of having two small rows of stalls on each side and in the middle a space large enough to allow passage and performing the services.

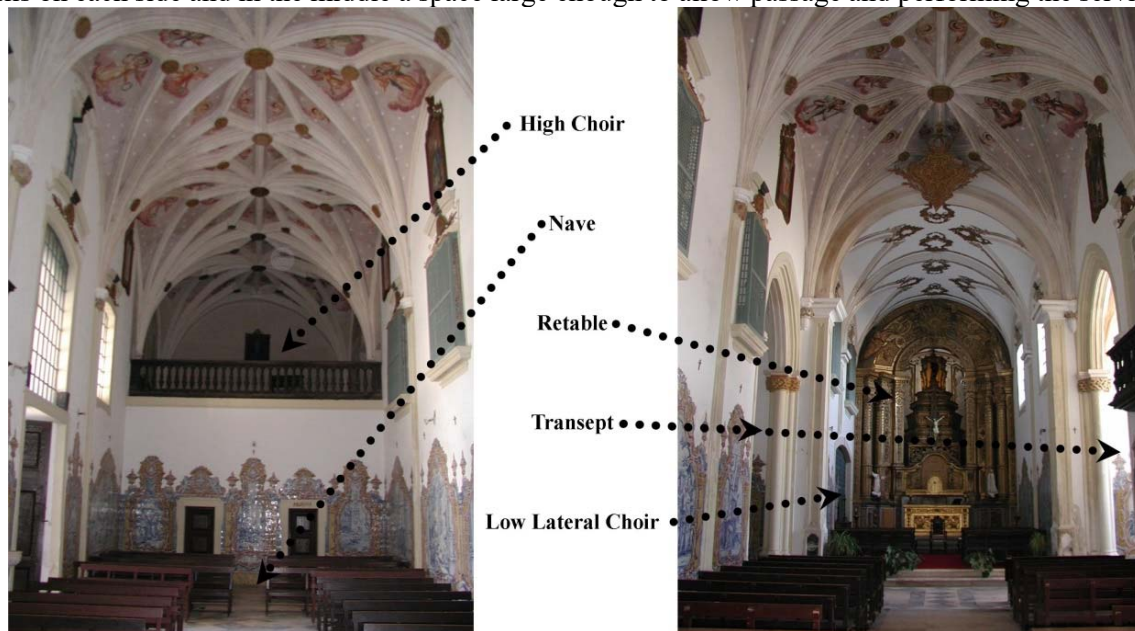


Figure 1. The different spaces along the longitudinal axis

Entering directly from outside, the church seems an ambiguous enclosure. The visitor has to stop to adjust to the low light levels and to comprehend the space. The contrast between inside and outside, sacred inner and profane outer world is noticeable. The walls of the nave are of plastered masonry and ornamented to mid-height by ashlar tiles, 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. 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. In the lower lateral 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 east, on the cornice, two circular openings with wooden frames and simple glass can be seen [13].

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 upper choir no longer exists, having been replaced by a wooden balustrade). This prevented visual contact between the religious and secular community [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 to which an eastern additional opening is added at the top of the apse. The Church ceiling is ribbed and vaulted and composed of masonry covered with frescoes. 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 church and choirs is of marble [13].

3.2. Light levels

Light levels in Cistercian churches are generally associated to the creation of a divine environment where the worshipper could have carried out his religious needs, establishing visual connections with the daylighting design, rather than to regulate visual comfort. This study presents the qualitative and quantitative analysis of the luminous environment in the church of S. Bento de Cástris, being the first based on the authors' perception of the effect of the daylight within the different areas of the enclosed space. At the first hours of the day, light shafts penetrate the interior and provide the intended visual appearance of the space. The sun is low in the sky and the modifications of the light patterns in the interior of the church occur in a fast way due to the rising angle of the sky. Due to the rotation of the longitudinal axis, at mid-afternoon, where the sun is going down to the sunset (Figure 2), the darkness takes over the space.

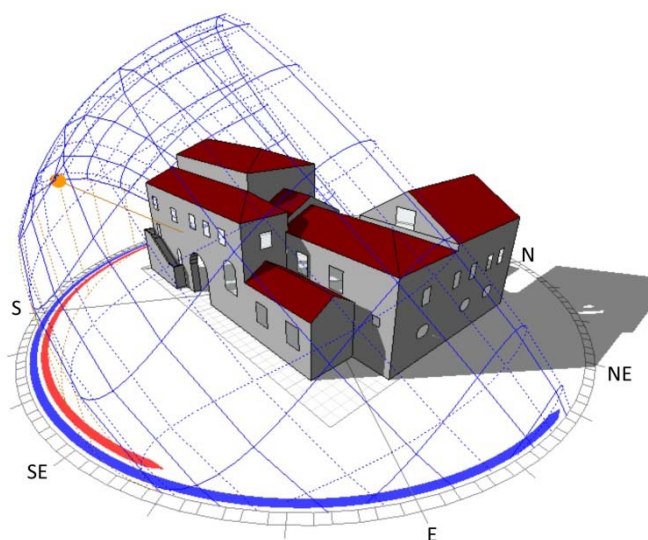


Figure 2. Annual sun path

Table 1. Optical characteristics of the church.

Space	Surface	Reflectance
High choir	Walls and ceiling – colourful paint	0.32
Nave and Transept	Walls – colourful tiles	0.60
	Walls – white paint	0.75
Apse	Ceiling – Colourful frescoes	0.32
	Retable – Golden	0.39
	Walls – colourful	0.60
	Ceiling – white paint	0.75
Low lateral choir	Altar - wood	0.25
	Walls – white paint	0.75
Other	Ceiling – Colourful	0.54
	Doors – wood	0.18
	Floors – marble	0.36
	Stones – granite	0.40

The study began with an exploration of the subjective experience of the church through observation and registration throughout photography with an aim to identify daylighting domain. The pictures had shown an approach of understanding the meaning and effects of daylight. The appreciation of the spatial experiences was supported by quantitative daylight simulations that were conducted in selected areas within the space. Simulations were carried out where the level of the illuminance was obtained. The authors' observation of the variation in spatial experience, illuminance level and luminance patterns led to a 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 overcast sky, a soft edged of light falls on the internal northern wall. In the afternoon, the west end of the church recedes into darkness.

4. The luminous environment of the church

4.1. *The perceived quality light in the church*

There are three distinct spaces within the church: the nave, the transept and the apse. Each one of these spaces offers a sense of tranquillity and perception of peacefulness due to the absence of contact view to the exterior and the balance of light. These three areas of the church (nave, transept and apse) are lit differently, although always from southeast openings. As one enters through the main door, from the exterior environment directly to the nave, the light spills into the church softening the abrupt transition between light and shadow with a sense of arrival. This entrance is under a vertical window at the centre of the southeast wall of the nave (Figure 1 – left). Through a shadowy atrium is the entrance to the church, from outside the monastery, towards the prayer space at the southwest end of the nave.



Figure 3. The main entrance of the church

At the western end of the church, the darkness is scattered by two openings that delivers reflected light. These openings are concealed from the exterior environment by a massive external wall (Figure 3) that creates a corridor between the exterior and interior ambiances. There is no view to the sun and sky, reason why it delivers only reflected light. The reflected light falls on the opposite wall and floor which regulates the dimly luminous environment in the nave. The sidelight coming from these openings also enhances the assembly, the space and form due to the low brightness zone. The area under the big window of the transept is perceptually the brightest part of the church. There is a noticeable increase of luminance due to this biggest window of the church. Its form is revealed by the nearly noon direct sunlight on the equinoxes. The light intensity alters with the movement of the sun and is strongest in the late morning, especially in the transept, creating a constantly changing luminous environment also in the nearby spaces, from dawn to dusk. The relative strong light coming from the transept of the church is balanced by the direct light penetrating through the openings at the southeast wall of the apse accentuating the outline of the elements it contains, as the altar and retable.

The apse with the altar and the retable is the vital core of the church which is located on the northeast wing being emphasized by the harmony of light. It is lit by the shafts of light through two windows of the south east wall of the church. This light draws attention to the altar and the chorus wall which is pierced by large aperture that admits light into this enclosed almost squared space. The light from the two openings spills into this zone of the altar, creating lateral lighting while leaving the opposite zone (right side) in shadowy light. The rays of light strike the apse at intervals ruled by the seasons where the statue of the St. Benedict or St. Bernard is embedded. There is also diffuse light coming from an opening behind the retable that penetrates through the gap on the northeast wall of the golden wall of the altar appearing to call for the divinity of the space.

The enclosure of the lateral choir is dimly visible in silhouette, with the mass wall separating the church and the chorus. The diffuse light openings of the lower choir cut through the northwest wall of the church (Figure 4). The brightly sills of the windows hold the light within it and reradiate the light to provide illumination for the Cistercian Nuns to read without dazzling. Light entering through these semi-circular shaped channels with reduced light intensity is softened as it travels down the wall surfaces arriving as a filtered light at the flat, open space of the choir.



Figure 4. View from the lower lateral choir to the apse rendering

The emptiness and the darkness of the upper choir at the southwest end of the church (Figure 2 – left) do not distract, but rather force to the possible connection with God shown by the contrast of brighter lighting of the apse and the altar ahead. This space is free from openings and it looks like a cavern on the top of a hill protected and reserved.

4.2. The quantitative study of the light in the church

The light distribution patterns obtained from the simulations revealed that three daylight typologies (direct, diffuse and reflected) were introduced to light the church. Daylighting is captured through the southeast side of the church with different geometric and exposed openings, and the transept capturing most daylight through the biggest window of the church. The asymmetrical balance of light enhances visual perception of the space by eliminating excessive brightness contrast in dimly lit space. This also emphasizes the three dimensions of space and form (i.e. nave, transept and apse). Although the geometry of the light and differences on the illuminance patterns are identified, the light intensity and ambience created are never static. The luminous environment in the church under overcast sky conditions is characterized by uneven distribution. The isolux contour map of the daylight factor contour, as shown in Figure 5, indicates an irregular horizontal distribution of light. Several distinctive light zones are identified, with highest daylight zone found close to the southeast end of the transept with the biggest window.



Figure 5. Daylight factor of the church

The light source (sun and sky) along the nave is concealed, being baffled by external construction of the monastery. Therefore, the windows only capture reflected light from the ground and the surrounding walls. The illuminance level is low (below 60 lux) with a light zone close to the light slot of the transept, reaching 100 lux on a clear day (Figure 6). Under overcast sky conditions the average daylight factors is around 0.5% with low contrast around the nave. The low uniformity of 0.01 also suggests the same result. The maximum daylight factor is reached near the southeast end of the transept with big windows.

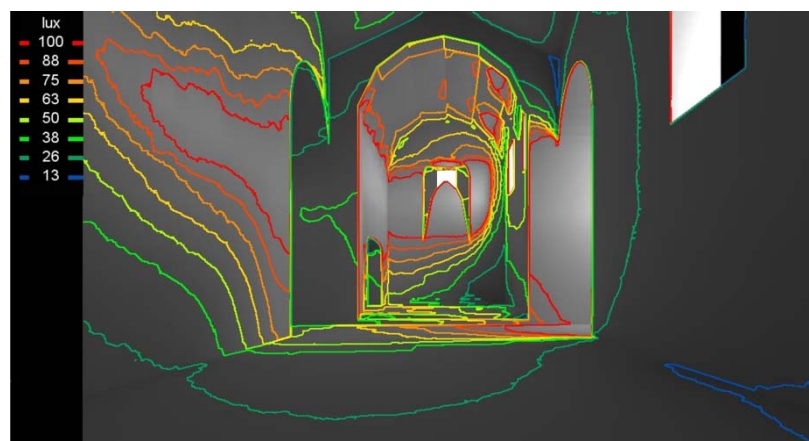


Figure 6. Isolux contour

It is evident that there are two distinctive types of luminous environment in the transept of the church: the dynamic and static light co-exist describing two distinct zones. The first with higher dynamic light is near the southeast wall under the direct influence of the biggest window in the church. The maximum daylight factor exceeds 2% with an average value of 1%. The highest contrast is observed within this area with a uniformity value of 0.35. On the opposite side is the area of the transept with low dynamic light and a preponderance of static light which has obtained the maximum daylight factor of about

0.75%. The uniformity value of 0.03 also shows a low contrast light environment of this most remote area of the window.

The apse has its own distinctive luminous environment under overcast sky conditions. The northwest side of the space is capturing most of the daylight through the southeast facing two windows at high level from the floor. The window behind the retable does not improve much the quantitative light that reaches the altar. The average daylight factor is around 1% and the maximum daylight factor around 2%. Even though, there is little light contrast as the low uniformity values of 0.05 support the analysis. The light intensity gradually increases towards the northwest side where a big opening to the lower choir is located. On a clear day the sun path is drawn in the altar, where the dynamic characteristics of the light impose constant changes on the light environment. This is especially significant in the late afternoon when the sun sets and where illuminance on the altar table can reach up to 350 lux.

The northwest adjacent low lateral choir of the church benefits from the illuminance produced by two light cannons. These two façade openings deliver only diffuse light onto this space. Nevertheless, the choir benefits from the significant daylight contribution from the vertical openings of the altar. With an asymmetrical arrangement, the openings produce a relatively uneven light distribution with a uniformity value of 0.05. Here again, a minimum of two light sources direction create dynamic balance of light, however with a low DF value of 0.1. As in the transept, both dynamic and static luminous environment co-exist here.

At the southwest end of the nave and at a high level from the floor is the upper chorus. This is the most shadowy space within the church. The interior wall and ceiling painted with low reflectance colours and the absence of external openings create very low daylight factors (0.01% to 0.05%). This is mainly caused by the low surface reflectance of the walls, ceiling both around 36% and floor (around 24%) reflecting little light, but it tends to help emphasize the candle light in this space. The overall illuminance is low (average horizontal illuminance: 20 lux) with a light zone close to the wide opening balcony to the nave from where only interior reflected light reaches.

5. Conclusions

The church is a completely enclosed space, with the access of light rigidly controlled by fenestrations only on the southeast façade, serving the collective sense of the Cistercian way of praying. The church of S. Bento de Cástris is a composition of spaces (nave, transept and apse) aiming to create an atmosphere of privacy and meditation, having different lighting which enhances both the division and the composition. The orientation of the church was done in accordance with the path of the sun on the horizon. The dynamic luminous of the church is not clearly delimited. The directional light is channelled onto the opposite wall of the fenestrations, while the non-directional light is captured from different angles to vary the light intensity throughout the different spaces. In conclusion, the church daylighting design satisfied the spiritual and celebrated light criteria. The duality of light/darkness enhances the notion that light provides feelings for spiritual and mystical greatness. Following a multidisciplinary approach to the Portuguese Cistercian Monasteries Architecture as it was presented earlier by Martins and Carlos [2] is an additional confirmation of interest and contribution to the Portuguese Cistercian Architecture knowledge.

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