Bioclimatic Strategies and Energy Saving in Residential Spaces. The Case of the Former Colegio de Propaganda Fide de Nuestra Señora de Guadalupe in Zacatecas

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Abstract: ***The main purpose of the following paper is to carry out the analysis of some constructive features of the old Colegio de Propaganda Fide de Nuestra Señora de Guadalupe located in the municipality of Guadalupe, Zacatecas, their relationship with the principles enunciated by the bioclimatic architecture, and the solutions that they provide in order to save energy in residential spaces. Although the Franciscan complex was made up of several rooms that included a temple and chapels, the analysis carried out here focuses essentially on the spaces where the friars performed their daily tasks that are common to current homes, such as resting, eating or sleeping. To this end, the document addresses issues such as the impact that energy generation through fossil fuels has on the natural environment, the beginnings of the bioclimatic architecture movement and some of its postulates that are used like the basis to carry out the analysis of the main construction elements that make up the living spaces of the old building complex. This work pursues the intention of showing the value of the architecture that was erected in past times, when it was necessary to respond to the limitations that the climate of the different regions imposed and at the same time to solve the requirements of daily life, when it had to be carried out without dependence on energy generated through the use of fossil fuels.***

Keywords: Bioclimatic strategies, architecture, energy, construction materials, thermal comfort

1. Introduction

The energy that currently supplies most of the needs of daily life, is generated in a way that in itself entails repercussions, due to the emissions of greenhouse gases and other waste that are inevitably produced and deposited in the natural environment in the process. This issue has generated debates that revolve around the current world's dependence on fossil fuels and the pollution that occurs when we use them, among other things, for the generation of electrical energy. The situation has also encouraged the rise of research work from a variety of disciplines focused on finding solutions that reduce anthropogenic impacts on the natural environment, including architecture. The following writing initially addresses these issues to immediately focus on some of the strategies proposed by the so-called passive solar or bioclimatic design, which promote, among other things, energy saving in living spaces. In this search for solutions that minimize the impact of the building on the natural environment without sacrificing thermal comfort, bioclimatic architecture experts have recommended the analysis of traditional and vernacular construction. This means focusing attention on constructions that were erected in the past, among which stands out the old Colegio de Propaganda Fide de Nuestra Señora de Guadalupe located in the municipality of Guadalupe, Zacatecas. The analysis of this Franciscan complex is carried out from the point of view of bioclimatic design.

1. Power generation and its impact on the natural environment

According to recent research, even in the first decades of the 21st century, the main sources of energy on the world are oil and natural gas. Generation alternatives such as sun and wind, hydrogen, biofuels or the force produced by seawater currents when they move, have not managed to significantly reduce the demand for fossil fuels (Dyatlov. *et. al*., 2019, p.3). This implies that most of the means of transportation and the requirements of daily life needs are solved through energy sources that ultimately impact and pollute the environment.

In Mexico, it is the Federal Electricity Commission (CFE) the one that is in charge of generating, transmitting, distributing and marketing electrical energy. The question about how electricity is produced in the national environment has been clarified by researchers such as Ramos-Gutiérrez (2012), who explains the following:

The installed capacity in 2011 was integrated through a diversification of generation sources, being the thermoelectric plants the ones that have a greater participation with 45.1%; hydroelectric 21.9%; coal power plants 5.1%; the only nuclear power plant in the country 2.7%; two more sources with renewable resources, geothermoelectric, with 1.7%, and wind power with

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0.20% of the country's total power. The rest of the percentage, 23.3%, constitutes a special case, called independent producers (IEP's). The generation in 2011 was made up as follows: thermoelectric plants, with a greater participation, 43.77%, through the use of hydrocarbons (diesel, fuel oil, etc.); hydroelectric, with 12.84% (6.23% through the use of coal, 3.58% through nuclear power); geothermal, with 2.30%, and wind power with only 0.04% of national electricity generation. The remaining percentage of generation is provided by independent producers (IEP's), who maintain a better use of their respective sources and represent 31.24% of production, mainly using thermoelectric plants (p.197).

The above figures make it clear that thermoelectric plants are the ones that still generate most of the electricity, whether they are managed by the CFE itself or by independent producers. They are joined in third place by hydroelectric plants that also use hydrocarbons for their operation, with the consequent emission of products from their combustion into the environment.

Although the greenhouse effect is a phenomenon that occurs naturally and even helps the planet to keep a certain temperature, the anthropic element has altered this process and contributed to climate change and global warming. Human activity has increased the presence of greenhouse gases (GHG) on the planet, which has caused a predisposition to warm of the lower part of the atmosphere and terrestrial surface. Changes in the temperature lead, in turn, to alterations that consequently bring about an increase in climatic phenomena of great proportions. It has even been determined that since 1991, more than seventy percent of natural disasters could be associated with changes in the climate. Effects on agriculture and even a factor that promotes the appearance and spread of infectious diseases, have been linked with global warming (Del Río and Aburto, 2018, pp.7, 8).

Other issues have been found in this regard: developed countries consume around two thirds of the energy produced in the world; cities are among the entities that most require natural resources to survive and they are the ones who pollute the environment from which they obtain them to a greater extent, to whom they also return the waste they produce; due to the above, the urban area is largely responsible for the depletion of resources and environmental pollution. The interest in reducing the anthropogenic impact on the natural environment is what has encouraged the arisen of the sustainable development model, which among other things proposes to provide alternatives for when renewable resources are finally exhausted, in addition to generate waste at a speed and level that the natural environment can absorb. As part of these solutions some researchers have proposed the generation of energy through renewable and less polluting sources; they also have suggested the use of construction materials that require less energy consumption when they are manufactured and when they are used to build spaces, beside the creation of buildings that involve less energy expenditure both to erect and to make them work (Cedeño, 2010, pp.101, 102).

This dissertation focuses precisely on the design process of residential-type buildings and the way this can contribute to the requirement of a lower amount of energy to maintain them and make them work. Before getting into the matter, it is worth doing a little history about how was born the movement in architecture that first proposed adaptation to the climate and the proper use of construction materials as alternatives to reduce the dependence of buildings on the use of fossil fuels, with the consequent benefit for the environment.

2. Bioclimatic architecture and thermal properties of construction materials

Although the terms "climatology" or its adjective "bioclimatic" were already used around 1930, the dissertation "Bioclimatic Approach to Architecture" carried out in 1953 by the Hungarian Víctor Olgyay, was innovative because it managed to bring together the work of various disciplines such as physiology, climatology and building physics. The researcher then created the so-called "bioclimatic map", a tool that shows how some atmospheric variables such as relative humidity, air movement and solar radiation affect the surrounding temperature and as a result, the human comfort. It was Olgyay who coined the term "bioclimatic design", which synthesizes the ideology of architects who are worried about the degradation of the natural environment and disdain formal concerns. Among his postulates, stands out the idea that the purpose of architecture is the human being, who is exposed to climatic factors, which are not always favorable. The main aim is to create a "filter" between the two, which should not be thought of as a barrier that entails the need for enormous amounts of energy to cool or heat spaces, but rather a tool that excludes harmful elements (wind, rain, cold) and that at the same time integrates those that are desirable such as daylight, solar radiation in winter or fresh air in summer. In this wayare built constructions adhered to ecological principles: obtaining the least amount of resources from the natural environment and returning the least amount of waste (Szokolay, 1998, p.111).

Among the background of what is also known today as bioclimatic architecture or passive solar design, there is also the "Bioclimatic Design Manual for Architects and Urban Planners", published by Olgyay around 1963, a writing that is relevant for many reasons. It explains that adaptation is a remarkable and common principle that generally havethe constructions carried out by the indigenous people who initially began to inhabit the territories of the American continent. When Olgyay analyzed the buildings erected in the northern parts of the territory, he observed that the first settlers used, in addition to their ingenuity, the resources of the different regions and the natural factors of the site-sun, wind, snow, soil-, at the time of erect their living spaces. He paid particular attention to the igloo, a low and hemispherical shelter that takes advantage of the insulating characteristics of the snow, in addition to the fact that its shape helps to divert the strong winds that blow in the north of the continent. Temperatures inside the igloo can be kept at 15.56 Celsius degrees even though the outside is minus 45 degrees. Olgyay emphasized that regional character of the shelters built by the natives wasn't observed by the immigrants who later settled the territory known now as the United States of America and came to form most of the population: they established a typology of uniform dwellings that is finally what characterizes today the housing developed in North American territory. The need to develop and use mechanical technology to heat and cool spaces it is among the consequences of the above (Olgyay, 1963, pp.5, 7).

As in this case, a wide variety of contemporary buildings located at various latitudes use air conditioning to ensure proper temperature and humidity, which in turn requires large amounts of energy to function. On the contrary, bioclimatic architecture proposes, among other things, the adequate use of construction materials and the use of renewable energies, as well as the need to maximize the use of sunlight to ensure proper interior lighting and, if possible, even eliminate the electrical expense dedicated to the artificial type. It recommends avoiding overheating of spaces, and ensuring thermal comfort through other strategies that do not require excessive energy expenditure, which means savings for the user and less polluting in the natural environment (Widera, 2015, p.568).

The objective of architecture based on bioclimatic design is to plan and erect buildings adapted to the climatic conditions of a site. All of its constructive elements (ceilings, walls, windows, floors, eaves) must be used in order to ensure minimum energy consumption. When all these components are considered it is possible to reconcile the form, matter and energy, in addition to achieve constructions appropriate to the physical characteristics of each region (Gaytán, 2009, p.107).

Olgyay and other researchers found that vernacular architecture has characteristics that make it worthy of study, such as the adaptation to the place where it is developed, in addition to the fact that it preserves a constructive knowledge transmitted by generations that implies multitudes of trials, trial and error that led to results that should be analyzed, especially if we consider that it was generally produced under different conditions from the ones nowadays we experience: when daily life did not yet depend almost entirely on energy generated through the burning of fossil fuels.

Helena Coch points out that are limited the studies on vernacular construction. This situation has contributed to the fact that contemporary architecture does not pay attention to the interaction between form and energy or to the bioclimatic approach. Perhaps the limitations arise from the latter, since energy is not something material and it is difficult to capture it in an image. Hence the difficulty of finding basic knowledge concerning the aesthetic and functional possibilities of bioclimatism among architects today. It must be added to this the little value that is given to popular architecture, in many ways anonymous in comparison with that built by the established powers and whose ultimate goal is to impress those who observe it, which is completely far from the natural environment and it also sometimes destroys it, excessively focused on the aesthetic concern of creating artificial environments instead of integrating itself into the environment. The current constructions, generally wrapped in glass as an emblem of their contemporaneity, require artificial light during the day while the weak skin that separates them from the outside makes it essential to use air conditioning practically the whole year, even when the conditions outside are acceptable and even pleasant. Vernacular architecture, however, is created by the people in response to their values and needs; it respects the environment; it is far from aesthetic demands; it uses local materials and techniques, as well as centuries-old wisdom that contemplates the limits imposed by the natural environment; and finally, it preserves teachings on how to assimilate the bioclimatic approach in the practice of architectural design. Undoubtedly, one of the greatest teachings that it entails are the lessons about the relationship that the ancients had with the climate and that contemporary architecture has unfortunately lost (Coch, 1998, p.67).

It was previously mentioned that bioclimatic design is also known as passive solar. In general, active solar systems such as photovoltaic panels are well known. However, it is necessary to understand how passive solar energy is used and how the systems that use it for its operation are categorized, which in turn are determined by direct gain, indirect gain or isolated gain. Direct gain is the simplest way of using passive solar energy, that is, when the spaces of a building are directly heated by sunlight, which enters through the openings located in a south-facing façade (in the case of buildings located in the northern hemisphere). What is proposed in this approach is that the materials inside the space can absorb and store heat, while the cold air from the lower parts distributes it in the room. Likewise, the variations of the angle with which the sun enters in the different seasons of the year must be taken into account, and the way in which elements such as the eaves can be contemplated in the design of the building to achieve greater temperature control. In the case of indirect gain, sunlight is frequently received by a wall also oriented to the south. The heat received is transmitted from the wall to the living space. To control the interior temperature, ventilation openings are placed at the top and bottom of the wall or another thermal mass, which help to regulate it (Baber, 2012, pp.2, 3).

Regardless the kind of accumulation, passive solar provides heat for free, as well as opportunities for variations in building construction and design. Among the elements that can be used to store solar energy in addition to the walls, are greenhouses, ponds on the roofs or the so-called convection cycles. When walls are used, they can be covered in black or dark colors that contribute with absorption. Even the walls can be built with water placed between stone or other materials that serve as containers for the liquid. Regardless of the material, the essential purpose is to absorb heat and release it into the room. This helps to control the temperature and to avoid extreme changes in it. The ponds on the roofs are based on the capture of heat from the sun through the covers, although they use insulation that prevents its accumulation, especially in the summer months. This solution benefits both cooling and heating by removing or placing insulation in the summer and winter months, day and night or as required. The convection cycle uses water circulating machine, or thermosiphon, to move heat from the collection point to an area where the liquid is collected. This is the principle used by solar water heaters, which is reliable and economical. Furthermore this, kind of systems doesn't require controls or pumps. In air-based convection cycles, are generally combined passive storage and active distribution, resulting in a simple but effective system for temperature control in buildings (Baber, 2012, pp.8, 9).

For the case that concerns this article, it must be paid attention essentially to the way in which the construction elements can contribute or not to the thermal comfort conditions inside the living spaces. The proper choice of materials helps in many ways: the changes in the temperature inside the buildings are less extensive and also favors the use of solar radiation, which implies significant energy savings, especially in the case of climates with extreme variations. The elements and construction materials have physical properties that allow them to transmit, absorb and accumulate energy, in addition to being used as temperature control and regulation devices. The "absorption" refers to the proportion of solar radiation that reaches the material and is captured by it, while that which is not retained is reflected; the transfer of heat through it is known as "thermal conductivity" and its counterpart is the so-called "resistivity".

It must be understood that heat always tends to move from the hottest to the coldest place, therefore, for energy transmission to occur, there must be a difference in temperature between two bodies. The thermal conductivity increases or decreases according to the characteristics of the material (almost 400 units higher in the case of metals, compared to insulating elements), and it is the most significant reason in the total heat losses experienced by a dwelling. Density may be related to conductivity: dense materials generally have high conductivity, unlike other porous materials that keep air inside, so their conductivity is lower. Elements such as cork, bamboo, fiberglass, dry wood, mineral wool or tezontle have low thermal conductivity. The heat flow through a material is called "thermal transmittance" and this value is analyzed only in the case of construction elements. (Cedeño, 2010, pp.103-105).

Another issue related to the physical properties of materials is their ability to accumulate heat. Those that can store large amounts of heat energy guarantee that the temperature variation propagated through them will be less. The delay that occurs during the transmission of heat is known as "thermal inertia", and it involves the ability to store the energy charges that are produced at times of greatest heat during the day to release them at times when low temperatures occur. In this way it is possible to reduce the magnitude of the thermal impact. Materials with great thermal inertia are generally dense, so their effect is related to their weight (Gaytán, 2019, p.111). This property determines how long it will take for the stored heat to flow through a roof or wall. Inertia, therefore, expresses "the magnitude of the effect that a material has to dampen and retard the maximum temperature indoors in relation to the outside temperature", in addition to being the most outstanding advantage of the walls used in traditional architecture, unlike other construction systems that are based on smaller thicknesses and lightweight walls (Cedeño, 2010, p.105).

Glass is one of the materials that are commonly used for construction, and nowadays it covers the exteriors of many buildings. In order to understand how it behaves thermally, it must be explained that when solar radiation reaches any element of the building, part of it is reflected and another is absorbed, which causes it to heat up. The radiation that is absorbed is equally re-radiated inward and outward. Incident radiation is known as the sum of all those that occur in a material or a body: transmitted, reflected and absorbed. The construction elements are affected by short (solar) and long (terrestrial) radiations, and as a result, they will present two types of absorptivity. What is known as a perfect black body is one in which all incident radiation of any wavelength (short or long) is absorbed and re-radiated. On the other hand, in the perfect reflecting body, all incident radiation is reflected and thus the radiation exchange is zero, as its absorptivity and emissivity are zero. Reflecting bodies therefore, have difficulty losing their thermal energy by radiation. Emissivity measures the ability of an element to emit thermal radiation. With the exception of the metallic surfaces, all those belonging to the constructive elements behave practically like black bodies in relation to long radiation, regardless of their color or finish. This is what happens for example, with a wall that has just been covered with lime against infrared radiation. In relation to short (solar) radiation, the behavior of the construction elements' surfaces will depend on their color and finish. Infrared radiation is that one irradiated by bodies that have been exposed to sun's action (such as roads, hills, etc.). The masses of vegetation manage to absorb this radiation, who later dissipate it by convection and evapotranspiration (Tudela, 1982, pp.185-187).

It might be said that glass is practically transparent to (short) solar radiation and behaves like an opaque body in relation to long radiation, which promotes the so-called greenhouse effect. Through the glass solar energy penetrates easily; it is then transformed into long (infrared) radiation and encounters resistance as it attempts to pass through and leaving the space through the material. This is what causes the temperature of the interior environment to rise a lot in relation to that of the exterior. It must be added to what has been described, the fact that conventional glass is not very insulating: it is a constructive element in which strong energy transmission occurs by conduction (Tudela, 1982, p.190).

As was said before, the study and observation of vernacular architecture provides the opportunity to find in it passive techniques, which were previously considered an integral part of the constructions and even of the way of life of the inhabitants. In the past, for example, multiple passive ventilation systems were used. Among them, there were those based on pressure's changes to boost the circulation of the air inside the building; the wind towers; also the one that used the "chimney" effect, reinforced by the action of hot air that tends to rise. There have been modifications to these three basic solutions according to the environment in which they have been used: cross ventilation in the spaces combined with structures on stilts, or that one which favors the cooling of the surfaces through the use of near water ponds. Many of these techniques are based on ancient knowledge (Widera, 2015, p.569).

In cold climate regions, adequate ventilation and cooling along the hottest seasons are equally necessary, although it is required to put more attention to the issue of indoor heating during winter. The factors used by passive systems to achieve thermal comfort in this case are thermal concentration and proper insulation that is achieved by using thick roofs and walls, elements that store heat during the day and release it at night. Another fundamental issue for spaces located in the northern hemisphere is the reduction in the number of openings in certain parts of the building. If some windows are placed on the north-facing façade, they must be insulated in some way to prevent heat loss through them. The large windows are generally located on the south façade, to take advantage of solar radiation during the winter, a matter that contributes to energy savings. The insulation of the interiors is an issue that should be prioritized for residential houses that are located in temperate climates and high latitudes. The applied solutions generally vary according to the climatic conditions, resources and materials available in the locality, traditions and customs of the users (Widera, 2015, p.570).

It was necessary to carry out the previous analysis focused on the thermal properties of the materials that are commonly used in construction, since one of the main debates related to ensuring thermal comfort inside living spaces revolves around the use of air conditioning or central heating and the enormous energy expenditure required to operate this type of air conditioning system, with the consequent impact on the natural environment. As it has been explained, there are other solutions that combine knowledge about the shape of the building, the relationship between the behavior of energy (heat) and the different materials that are used to build it, as well as different strategies provided by passive systems to manage the solar radiation that the construction elements receive.

The conclusion reached by Víctor Olgyay after the investigations he carried out around the first half of the 20th century, on the relevance of observing the architecture developed in antiquity, is what motivates the present analysis of the Colegio de Propaganda Fide de Nuestra Señora de Guadalupe located in the city of Guadalupe, Zacatecas. As the researcher pointed out, the adaptation to the site and its climatic conditions is a matter that determined the type of constructions built by those who inhabited the American continent in the past. It is believed that especially today, when the debate on the use of fossil fuels to produce the energy that sustains daily life grows, it is convenient to look back and observe the solutions that were previously given to the challenges and limitations imposed by the climate of the different regions, in those years when daily life depended on ingenuity to solve issues such as comfort, ventilation and heat preservation in interior spaces. The following section provides some historical data on the convent complex, as well as details of its location.

3. The Colegio de Propaganda Fide de Nuestra Señora de Guadalupe in the city of Guadalupe, Zacatecas

When the rich mines of the city of Zacatecas were discovered, the conquerors who decided to settle in these territories were joined by various religious orders. For the Spanish crown it was of particular interest that the Franciscans extended their ministry. As a result, centers of doctrine were founded. The Iberian monarchs were convinced that religion was vital to achieve peace with the Indians who originally populated the Great Chichimeca, well known by being robbers and their fierce character. By doing so, the religious orders would contribute to the extraction of the mineral, the main interest of the conquerors. In the city of Zacatecas, it was established the convent complex of what would later become the custody of San Francisco de Zacatecas, which achieved great notoriety at the beginning of the 16th century and spread over several territories located between Nueva Vizcaya, Nueva España, Nueva Galicia and the Nuevo Reino de León (Morales, 1997, pp.19-24, 167-170).

The custody of San Francisco de Zacatecas was surrounded in the region by seven monasteries, which propagated the Catholic teaching and doctrine. It was among them the Colegio de Propaganda Fide de Nuestra Señora de Guadalupe, which was founded around the year 1702. The evangelizers generally left this convent complex on foot, mainly to the northern territories of the American continent. José Arlegui in his book *Chronicle of the Province of N. S. P. S. Francisco de Zacatecas*, pointed out that five missions also were founded from the school. The first president of the school was Fray Antonio Margil de Jesús. Among the founders was also Pedro de Urrutia, who had previously worked on the conversion of the Lacandon Indians and later returned to Spain (Arlegui, 1851, p.48, 49).

The convent complex was originally established in an area of 25 square kilometers. After the promulgation of the Reform Laws, the friars had to leave the convent around 1859. As a result, the building began to perform various tasks: stable, housing and even a match factory. Some friars returned years later, after their exclaustration. In 1862, the Guadalupe School of Arts and Crafts was established in part of the building. Around 1878, the children's hospice was also founded in the complex. In 1908 the Colegios of Propaganda Fide were suppressed, although not the Franciscan seminary. The building acquired a new function around 1917, when a museum of antiquities was opened in it. This one was declared a national monument around

1939. By 1971 the hospice was closed and its dependencies were incorporated into the museum. The complex obtained the declaration as Cultural Heritage of Humanity by UNESCO in 2010 (Mediateca INAH, 2022).

Figure 1 shows the layout of the current distribution of the Museum of Guadalupe. In it you can see what originally used to be the living spaces of the Franciscan monks. Figure 2 provides a view of the main entrance to the architectural ensemble.

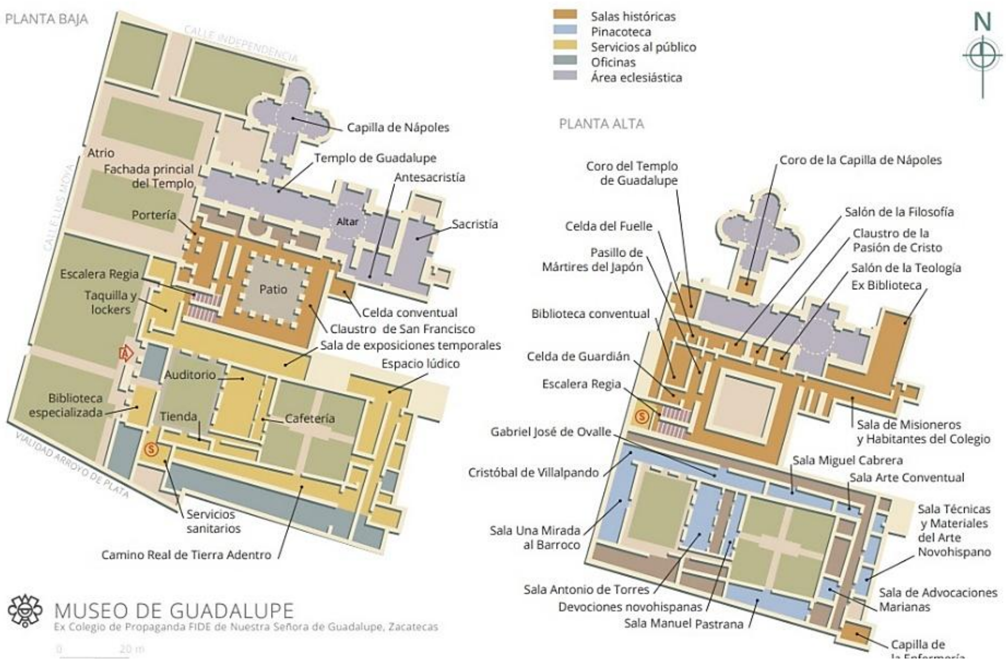

Figure 1: Layout of the Museum of Guadalupe, a space that was created to house the Colegio de Propaganda Fide de Nuestra Señora de Guadalupe located in the city of Guadalupe, Zacatecas.

Source: https://mediateca.inah.gob.mx/repositorio/islandora/object/museo%3A1263, accessed on October 11, 2022.

Figure 2: View of the main entrance to the Museum of Guadalupe, a space that was created to house the Colegio de Propaganda Fide de Nuestra Señora de Guadalupe, in Zacatecas.

Source: Inés delRocíoGaytán Ortiz (IRGO), October 2022.

The next section focuses on the relationship between some of the strategies proposed by the bioclimatic design that were discussed previously, and the solutions that in ancient times the Franciscan monks used when they erected their living spaces, an issue that makes worthy of study their convent ensembles.

4. Bioclimatic strategies used in the convent complex

In order to understand where is located the Colegio de Propaganda Fide de Nuestra Señora de Guadalupe, it should be mentioned that the city of Zacatecas is crossed from east to west by a road known as Boulevard Adolfo López Mateos, which was extended from 3 to 17 kilometers to cover the conurbation that now exists between it and the city of Guadalupe. Its construction implied that an old vaulted wall that began to be erected over the Arroyo de la Plata in the last third of the 19th century was extended by 10 kilometers. Due to processes such as the suburbanization of the population and decentralization of employment, the cities of Zacatecas and Guadalupe were finally joined together (González, 2009, pp.95, 101). The map shown below (figure 3), shows the border between the municipalities of Guadalupe and Zacatecas, as well as the conurbation that exists between both locations. Number 1 indicates the delimitation of the historic center of the city of Zacatecas and number 2 shows the historic center of the city of Guadalupe. The blue circle within the polygon of the historic center of Guadalupe indicates the location of the Colegio de Propaganda Fide de Nuestra Señora de Guadalupe.

Figure 3: Cities of Guadalupe and Zacatecas: delimitation, conurbation and historic centers.

Source: website of the Centro de Inteligencia Territorial, Secretaría de Desarrollo Agrario, Territorial y Urbano del gobierno de Zacatecas (CITE-ZAC), available in: http://cit. zacatecas. gob. mx/, accessed on October 7, 2022. The numbers and annotations were made personally. The municipal limits and polygons of the historic centers were determined by the CITE-ZAC.

It is clear how close both locations are, as a result, the temperature studies carried out for the city of Zacatecas can also be used as a reference for the city of Guadalupe. It was found that if the average maximum and minimum temperatures in the city of Zacatecas are considered, the variations between them are between 18 and 21.96 degrees Celsius[5], a considerable

[5] In the study carried out on the maximum temperatures of the city of Zacatecas between the years of 2001 and 2007, the following variations were found for all the months of the year: the average in January was 19.27 degrees Celsius (°C) the maximum and -0.89 °C the minimum; in February 21.23 °C the maximum and 0.94 °C the minimum; in March 23.09 the maximum and 1.13 the minimum; in April 25.31 °C the maximum and 6.24 °C the minimum; in May 25.87 and 8.33°C; in June 25.30 °C the maximum and 9.19 °C the minimum; in July 23.86 °C the maximum and 9.53 the minimum; in August 22.33 °C the maximum and 9.46 °C the minimum; in September 21.56 °C and 8.54 °C the minimum; in October 22.23 °C the maximum and 6.60 °C the minimum; in November 21.41 °C and 2.31 °C the minimum and in December it corresponded to 19.67 °C and the minimum to 0.83 °C. With these figures, it was possible to determine that the variations between day and night are wide, since they oscillate between 18 and 21.96 °C, if the maximum temperature averages are considered. These calculations were made based on the data provided by the Comisión Nacional del Agua of the state of Zacatecas (Gaytán, 2009: 219-223).

difference. This implies that to avoid using large amounts of electrical energy in order to achieve thermal comfort inside spaces, it is required the use of materials that have a good capacity to absorb heat through radiation along the day. These materials also must be thick enough to ensure that the heat energy through them takes several hours to cross them.

Having this in mind, we proceed to analyze the constructive elements of the convent complex's living spaces, such as walls and ceilings, parts that due to their size and layout play a fundamental role in the thermal comfort of the buildings. As already mentioned, in the case of some towns located in the northern hemisphere, such as the city of Zacatecas, the temperature variations throughout the day are very wide, a matter to consider especially during the winter months when it is necessary to keep the heat inside of the spaces for as long as possible. On the other hand, adequate ventilation and cooling must also be provided in them throughout the summer months. For all this, it is essential to properly choose both the material and the thickness of the walls and ceilings that are part of a construction, with the intention that the "walking" of heat from the interior to the exterior and vice versa through them does not occur instantly, rather, gradually, which also seeks to avoid considerable energy expenditure to maintain thermal comfort in the spaces that is adequate for the users along the time they remain in them.

Before, it was explained that "thermal inertia" is the delay that occurs during heat transmission, that is, the ability of a material to store energy charges that take place when are present the higher temperatures that come from solar radiation, to then release the energy during the hours of the day when the lowest temperatures occur. Olgyay, in his "Table of total heat transmission (u) and characteristic inertia times for homogeneous walls", indicated that a 61-centimeter stone wall provides a delay of 15.5 hours, compared, for example, to a common brick wall of 20 centimeters, through which the heat manages to pass in 5.5 hours (Olgyay, 1963, p.119).

In figures 4 and 5, it can be clearly seen that the thickness of the walls in the convent dependencies are considerable, and far exceed the 15 centimeters that are generally present in the conventional residential houses that are erected today in the locality.

Figure 4: Thickness of walls in the convent.

Source: IRGO, September 2022.

Figure 5: The image allows us to appreciate the thickness of the convent walls
Source: IRGO, September 2022.

There is evidence that the Franciscans in the region used the lime and stone system to erect their churches and convents. This was recorded after the fire that the cloister of the city of Zacatecas suffered on December 7, 1648. For the following year, the reconstruction works began. The R. P. Juan Lascando, who would be the pioneer in the construction of temples and cloisters of lime and song in the region, took part in this job, as they didthe R. P. F. Martin de Urizar and Fray Domingo de Arteaga. The enclosure became the first building erected in masonry in the entire province (Gallardo and De la O, 2000, p.6).

Of all the construction elements and due to their location in the building, the roofs are the ones that receive the highest heat load, which increases when they are placed horizontally. To the previous fact, it must be added the number of hours of sunshine that they receive throughout the day, in addition to the fact that the radiation is greater on the roofs due to the fact that the sun's rays fall on them practically perpendicularly. This is the reason why they are the parts of the construction that store the most and therefore radiate heat during the night, when they release the amount of this energy that they accumulated during the day. For this reason, the selection of materials for the roof is an even more critical issue than it would be for the walls, since it is the roof that can contribute the greatest heat gain to the interior (González, et. al., 1986, p.80).

The reality is that the roofs currently held by what was formerly the Colegio de Propaganda Fide de Nuestra Señora de Guadalupe are not integrated with all the materials used to build them originally. However, as can be seen in figures 6 and 7, the spaces still preserve the wooden beams that were part of the roofs, on which other materials (tablet, dry wood) were placed, and in them, in turn thick layers of land, to constitute with so-called "terraces".

Figure 6: Interior view of the beams that were part of the roofs of the spaces
Source: IRGO, September 2022.

Figure 7: Interior view of another type of beam that formed part of the ceilings of the convent complex.
Source: IRGO, September 2022

Concerning the use of the soil as part of the roofs of the Franciscan cloister, it should be mentioned that its effectiveness as a thermal insulator has been proven since ancient humans dug their homes in soft, moisture-free soils that varied in their composition according to the chosen site. Thus, they were from sedimentary lands in regions of China, Hungary or Lower Austria; crystalline earths that when decomposed produced impermeable clays; recent soft rock sediments in parts of Fresno in California and Spain; soft volcanic debris as in Turkey; alternating layers of rock and earth as in Valencia, Spain, Chenini in Tunisia or Puy-de Dome in France; soft calcareous rocks (chalk) in regions such as Touraine, Picardy, Baux-de-Provence or the Soissonnais in France; dry silty clay terrains as in Matmata, Tunisia and Siwa, Egypt. Having used the soil as an insulating element in walls and ceilings, an excellent response was given to the extreme climates of various regions. These buried habitats used the thermal inertia of the ground itself. For this reason, the variations in the daily outdoor temperature were completely ignored since they practically did not affect what was happening inside, nor did strong winds, too much light or cold (Izard and Guyot, 1980, pp.134, 35).

Therefore, it is relevant that the builders of the Colegio de Propaganda Fide de Nuestra Señora de Guadalupe, have used wood to carry out part of the roofing of the living spaces, since among the physical characteristics of this material its low conductivity stands out, and even todayit is used as an insulator in some places. In the case of the soil, which was the final part of the roof, it has been proven that due to its physical properties it can accumulate large amounts of heat energy that favors a lower variation in temperature that is transmitted through elements made with it. It has already been explained that the delay produced while heat moves from the hottest to the coldest place is known as thermal inertia, and it implies the ability to store the energy charges that occur at hottest times during the day and then release them later, when low temperatures occur. In this way it is possible to reduce the magnitude of the thermal impact. This is the physical property that the Franciscans knew and took advantage of in order to achieve better thermal comfort in their spaces in the different seasons of the year.

Then we proceed to analyze the case of the openings of the enclosure. In the facades of the building it can be observed that the proportion of the holes that served as windows and doors in relation to the totality of the cover was not very considerable. That is, the massif predominates over the span (see figure 8). This issue relates to bioclimatic design principles in that the smaller the openings, the less energy is lost through them.

Figure 8: Proportion of the dimensions of doors and windows, in relation to the totality of the dimensions of the facades in the residential spaces of the complex

Source: IRGO, September 2022.

Another situation that must be considered, it is what was already explain about the physical properties of the materials used to make windows and frames. Many of these elements are manufactured today with materials such as aluminum and iron. Like all other metals, they are poor insulators as they have a high conductivity. This means that quick heat transmission occurs through them. The opposite is the case with wood, which, as already mentioned, is considered a good insulator since its conductivity is low. Some types, such as pine, even insulate better than cork (Guillén and Muciño, 2018, p.96). In figure 9 you can see the doors that, in addition to being solid and made of wood, have considerable thickness, thanks to which they contribute to maintaining heat inside the spaces.

Figure 9: Door that was generally placed inside the living spaces of the convent
Source: IRGO, September 2022

It was already explained that glass is a material with physical characteristics that promote the so-called greenhouse effect. This is why it is necessary to be really cautious when using it. The Franciscans along the winter were able to maintain the heat energy gained through the windows, coming from daylight, by closing the doors that were placed with them, also known as "postigos"[6]. In this way, the low conductivity and therefore insulating factor of wood was used to ensure that the heat gained during the day remained inside for longer. The windows of the convent were, so to speak, multifunctional. For example, they could be fully opened in the summer months as they were hinged, which meant that when the temperature rose, ventilation easily penetrated through them (figure 10).

Figure 10: Window with open postigos. It also can be opened as it is made up of folding elements.
Source: IRGO, September 2022.

[6] The "postigo" is a panel fastened with hinges in the frame of a door or window to cover the glazed part when appropriate, source: Diccionario de la Real Academia Española.

The window also could be partially closed, so that only a certain amount of light could enter. This was facilitated since the postigos were made up of two doors, which at the same time were divided into small sections or boards that opened and closed independently, in this way, the desired amount of lighting could be decided (see figures 11 and 12).

Figure 11: Window with one of the doors that make up the postigo, closed.
Source: IRGO, September 2022

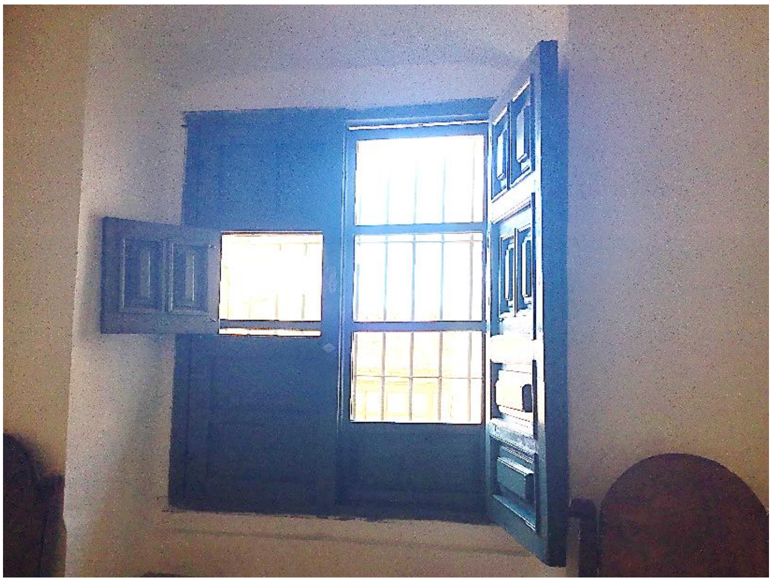

Figure 12: Options for opening the postigo and for the entry of light and heat into the interior.
Source: IRGO, September 2022

In this way, the penetration of light into the interior of the spaces was achieved. Furthermore, the short-wave energy from the sun easily entered and was trapped inside by becoming infrared or long-wave radiation when reflected by the constructive elements as the floor. This passive strategy was especially useful during the winter months, when the postigos were likely opened throughout the day to let light and heat into the rooms. Through the glass the greenhouse effect was produced, which is beneficial when temperatures are low. At night the thick postigos were closed to ensure that the heat did not escape (see figure 13).

Figure 13: Window with fully closed postigos

Source: IRGO, September 2022.

It must be emphasized that the construction elements are affected by short (solar) and long (terrestrial) radiation, in addition to the fact that they obtain heat energy gains; unless they are metallic, their surfaces, regardless of their color or finish in relation to long radiation, behave like black bodies, that is, they tend to capture and re-radiate it. The masses of vegetation, however, are able to absorb infrared radiation (which is irradiated by bodies exposed to the sun) and later dissipating it by evapotranspiration and convection. The Franciscans again used a passive air conditioning technique when they planted vegetation in large patios around which rooms and other functional spaces were organized, thus, it was possible to achieve better temperature management (see figure 14).

Figure 14: View of one of the patios of the complex.

Source: IRGO, September 2022

2. Conclusion

By exposing some strategies proposed by bioclimatic design and the different ways in which Franciscan designers applied them several centuries ago, the relevance of the study of architecture that was carried out in past times is understood. This kind of architecture, most of the time is recognized for its historical and patrimonial value; although it is believed that it is equally remarkable for the lessons and solutions that it offers in other areas. Today, proposals for buildings that use innovative technologies are made in order to find energy saving alternatives given the need to maintain the thermal comfort of living spaces. However, it is worth to study the building complexes that were erected in the past, because as evidenced in this writing, their builders paid attention to the thermal properties of the materials they used to erect them, and the importance of using the most appropriate materials for the various elements of the construction such as roofs and walls. They equally understood the way ordinary glass behaves and therefore came up with creative solutions to deal with the challenge that using this material poses.

Although the final aim is not to urge to build completely as was done in the past, it is undeniable that the time has come to contemplate monuments such as the Colegio de Propaganda FIDE in the city of Guadalupe from another point of view. This space has generally been recognized for the fundamental role it played in the process of evangelization in northern Mexico. However, through this analysis it was shown that the architectural enclosure requires to be observed from other perspectives, since it still preserves information that could be studied in greater depth. Until now, for example, there has been no reflection on the fact that the convent complexes were conceived to be practically self-sufficient and sustainable spaces, qualities sought by those who today try to reduce the damage done to the natural environment through building construction and that includes returning to it the least amount of waste possible. The study of the way in which eco-technologies were applied in this space remains pending, an issue that surprises those who visit it when they contemplate the two large cisterns that still stand out for their design and solidity, in which the water from of rain was stored and cleaned.

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