Daylight & Architecture

The role of daylight in modernist architecture
-- history thesis--

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Figure 1 (front cover) | The temple of three religions. (Idealni Magazine, 2018)

Abstract

In this history thesis, the role and use of natural light in European modernist architecture is explored. Natural light has always played a major role for humanity, as we evolved underneath the sky. Daylight shapes spaces through creating contrasts between light and shadow. Although daylight is a fundamental source and a predictable factor, it differs over time and also in latitude (Ramos, 2019). This causes a different approach to the organization and shaping of a building. Architecture is therefore dependent on geography, culture and climate. It is to say that architecture and daylight are inseparably linked.

The utilization of daylight in buildings and the cultural meaning has changed over the centuries. Until the twentieth century, daylight was mainly used functionally and decoratively, particularly to illuminate specific elements in a room. A major shift took place in the twentieth century, when new building techniques became possible and new insights into healthy architecture were obtained, resulting in the architectural style Modernism, which is characterized by the application of simple forms and the use of fresh air and sufficient daylight (Berman, 2013). The possibilities resulted in more differences between the north and south, where the design can be consciously tailored to the local climate. Local architecture was adapted to the amount of daylight, geography and culture. This is also reflected in the differences between the villas and churches in Scandinavia and the Mediterranean.

Northern modernist architecture is characterized by the extra attention to reflections, use of colours, contrast, direct light and the raw, lightly treated materials, while southern modernist architecture is characterized by the emphasis on solar radiation, obtaining indirect daylight, the minimal use of bright colours and the architectural solution to block solar heat. Besides that, this research shows the similarities, such as the internal experience that determines the design, the orientation, elaboration of the smooth surfaces of the buildings, the connection of the villas and their surroundings and the effect of obtaining light from above in religious buildings. The utilization of daylight within modernist architecture was dependent on the local culture, geography, movement of the sun, brightness of sunlight, surrounded colours, reflections and solar heat.

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Introduction

Mankind has always been connected with the abstract and intangible 'material' called light. Since the origin of humanity we have been dependent upon daylight. Moreover, our evolution proceeds underneath the sky of this planet. We perceive a space through contrasts between light and shadow, which makes daylight a fundamental source of orientation within a building. If light changes, it influences the spaces around us and also our behaviour. Studies over the last decades have shown the great effect of daylight on humans in order to exist and to support our health and well-being (Münch, et al., 2017). Therefore, the most optimal result often seems to bring as much daylight inside a building as possible. However, the quantity of daylight within a building does not imply a pleasant visual environment (Mathiasen, 2015).

Daylight changes throughout the day and year, hence it plays a leading role in giving us a better understanding of place and time (Ramos, 2019). Besides that, daylight does not only differ during a 24 hour period but also in latitude. These differences produce a particular daylight with its own atmospheric characteristics and contribute to a specific local architecture. The Scandinavian pale light, which varies in shades of grey and whiteness, is the exact opposite of the Mediterranean bright light, which is mainly characterized by the strong contrast between light and shadow. Both pale and bright light create different atmospheres and environments through which buildings are revealed in different ways. Thus, the design of the apertures of a building in a certain area has to be approached differently so that daylight can be optimally utilized within the building (Mathiasen, 2015; Millet, M. 2009).

The argument that is cited above is that different latitudes cause a different approach to the organization and shaping of a building, which results in a specific type of architecture that is dependent on the location, culture and climate, or in other words 'place' and 'time'. This leads to the close connection between architecture and daylight that can also be found within the building style Modernism in which the use of light was reinvented and applied. Modernism was a result of innovative possibilities through new building technologies and new scientific insights into health, which led to the realization of healthy architecture (Berman, 2013). In this research the role and use of natural light in European modernist architecture of the modernist era (1920-1980) will be described. The purpose of this research is to answer the following main question: 'How is natural light utilized in modernist architecture in northern and southern climates within Europe during the twentieth century?'.

This thesis contains three sections and is conducted through desk and comparative research. The first section highlights how the use and role of daylight within European architecture evolved over time, starting with the classical age. This section addresses the following questions: 'How has the utilization of apertures in European architecture developed during the centuries?', 'How have the knowledge and motives of past architects about the use of daylight in buildings changed over the centuries?' and 'How did modern architects treat daylight in buildings during the twentieth century?'. This information generates new insights and knowledge of what key influences and motives have been used for the utilization of daylight in buildings.

The second section is aimed at the impact of climatic, geographical and cultural variations on daylight utilization in buildings at different latitudes. In this section the following question will be addressed: 'Why is light vital to our perception?', 'What is the influence of location on the perception of daylight?' and 'To what extent does latitude influence architecture in North Europe and South Europe?'. This section provides a better understanding of how the nature and use of daylight are affected by time and place. Differences between the climate conditions and architecture in North Europe and South Europe are described, as well as the different approaches it requires.

The last section is a comparative research and is aimed at both Scandinavian and Mediterranean climate. This is done through different case studies of modernist architecture in Scandinavia and the Mediterranean. The case studies aim to analyse and compare how apertures are utilized within different buildings of the modernist

era in these areas. The selected building types are residential buildings and religious buildings, because daylight is of exceptional importance for the specific activities that take place in these buildings. The comparative research examines the specific light in Scandinavia and the Mediterranean, the motives of architects and the effects of modernist architecture on the interiors in these regions, so that an answer can ultimately be given to the main question.

Although much research has been done regarding the relationship between daylight, buildings and human well-being, little research has focused on the quality of daylight in modernist buildings at different latitudes, especially the contrast between North Europe and South Europe. This research will offer a deeper understanding in, the background of, the utilization of daylight in modernist architecture in Scandinavia and the Mediterranean, taking into account the geographical, climatic and cultural circumstances and the expressive implementation in colour and material.

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Section I – History of daylight

"There is no architecture without light and there can be no building where the presence of natural light, either in part or as a whole, will nog benefit those who use it."

Derek Philips, 1997

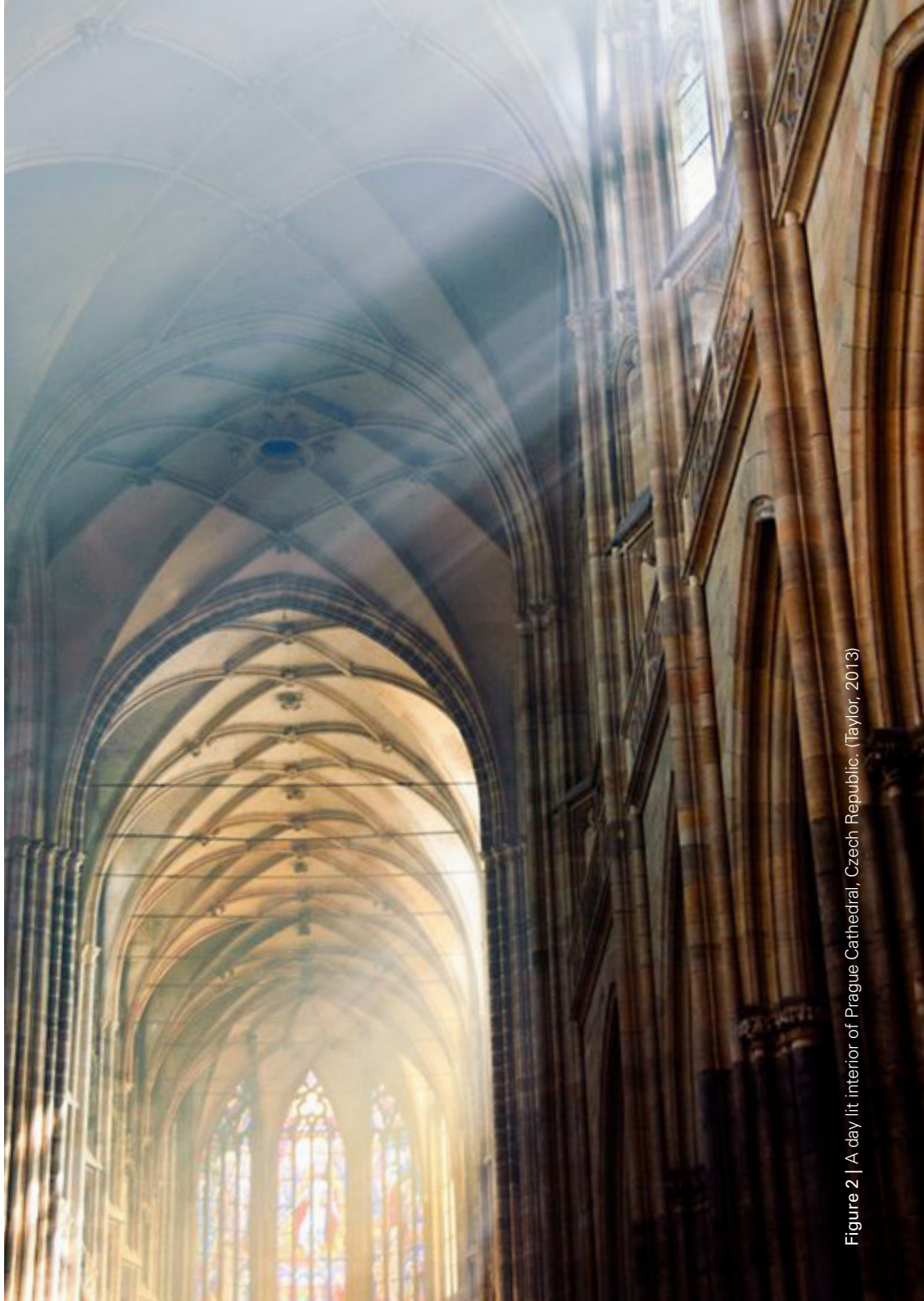

Figure 2 | A day lit interior of Prague Cathedral, Czech Republic. (Taylor, 2013)

This section defines how the use and role of daylight evolved over time in European architecture to give a general overview of the most important phases and inventions. Furthermore, the change in knowledge and purposes of past architects is investigated. Finally, the motives concerning daylight in architecture of modernist architects are examined to find out how natural light in modernist buildings of the twentieth century is treated. A broader and comprehensive overview of the history of daylight in European architecture is shown in the timeline in Appendix 1.

Daylight distribution

For centuries daylight has been the only efficient primary source of light in buildings. Until the seventeenth century, architecture was shaped by the ambition to create wide spaces and thereby make openings large enough to allow sufficient daylight into the building to illuminate the interior spaces (Chepchumba, 2013). Depending on the climate and its variations, the size of apertures was examined and solutions were devised to generate diffuse light from bright light, such as translucent materials, glazing, grills, porches and cantilevers. Hence, daylight was only admitted in the building where it was needed, which resulted in the great prominence of apertures within the design. For example, daylighting in Ancient Rome was always associated with the warmth from outside, which resulted in arcades to protect the facade from heat and, as a consequence, softened the incoming light to the interior. The illumination differences within the building and also within a space were significant in denoting special functions or elements within a space.

Conveyors of light

Windows provided direct qualitative sunlight and shadow and gave information of the weather, time, season and the world outside. Until the seventeenth century, the proportion of windows was mainly influenced by the structure, available height and the desired form of the building. Especially vertical windows were used in high interiors and, therefore, it was made possible to receive daylight deeper into the interior. If walls were very thick, a common feature was to splay the wall openings to allow wider light diffusion. Derived from structural innovations, horizontal windows were made possible. Especially in spaces with a reduced ceiling height, it was necessary to generate alternatives. Horizontal windows on both sides of narrow buildings allowed sufficient daylight into the interior. Clerestories were provided at a higher level to smooth the direct sunlight at lower levels by illuminating the ceiling combined with interreflection of different surfaces. This resulted in a gentle light distribution in the space and a deeper reach of light (Philips, 1997, pp. 14-23).

Although the first evidence of glass made by human was found in 3000 BC in Egypt, it was not until the Roman Period that it became of use as the infill of windows (Philips, 2004, pp. 3). The small panes were held together by bronze frames, but the size of a window was limited. It was in the late sixteenth century when in England the innovation of larger panes of glass in windows were introduced and became universal. Until that moment various materials were used to modify the external weather conditions in the indoor environment, such as animal horn, thin slabs of marble, oiled paper or sheets of mica (Philips, 1997, pp. 14-23; Philips, 2004, pp. 19-24).

The role of daylight in history of European architecture

The external conditions led to the internal appearance, influencing the building's form, floor plan and structure of the building. Architects and builders were eager to understand the geometry and variability of daylight, which led to the urge to create buildings with a strong influence of natural light. Depending on the function or use, architecture was designed to distribute daylight into the building. Besides the practical use of daylight in the building, there was also a symbolic value of purity, knowledge, heaven and divinity attributed to light. This positive connotation was especially present in Gothic cathedrals, where the height symbolizes the capture of the heavenly light and reaching of the sky and where the light through stained glass displays the enchanting colours of this holy atmosphere (Solt, et al., 2017, pp. 25). Daylight was thus first used for functional purposes, but was later supplemented with the decorative effect (Philips, 1997, pp. 1-4). This is also evident from the following selected historical moments.

Figure 3 | Natural light beam in Abu Simbel Temple, Egypt. (Egypt Forward, 2020)

Figure 4 | Natural light through the oculus of Pantheon in Rome, Italy. (Cohen, 2018)

Figure 5 | Rays of light crossing through the Cathedral Sainte Cécile, France. (Sargent, 2014)

Ancient Egypt

In the third century BC daylight was introduced to the interior of Egyptian temples with gaps in the roof, which were established by the different heights of the roofs, creating light shafts onto statues. The apertures were incised and the walls were decorated, which ensured diffused light in the temple. The appearance of the buildings was a derivative of the interaction between sun, sky and mass (Philips, 1997, pp. 1-4; Ramzy, 2013, pp. 220-225).

Ancient Rome

A few centuries later, top light was provided through clerestories in the Roman public baths, expressing an impressive appearance of the interior. In addition, the Pantheon in Rome was also an innovative example of the provision of top light, where an eight metre wide round opening in the centre of the dome was made through which weather and light can be perceived. This opening, or oculus, was a tribute to the gods for whom the Pantheon was built in 120 AD. The sun pattern through the oculus on the circular walls gives a constantly changing appearance to the interior of the Pantheon. Originally, the dome was finished in bronze. The circular shape of the space emphasizes the strong beam of light (Philips, 1997, pp. 1-4; Ramzy, 2013, pp. 220-225).

In addition to the public buildings, new insights into domestic buildings were generated by Vitruvius, an important and known architect of Ancient Rome. In the sixth book of his book series 'De architectura libri decem' (De Haene, pp. 20), he wrote that certain rooms, such as bedrooms, have to be exposed to the east, because these rooms require morning light. It was the beginning of solar design.

Byzantine

In 537 AD, the Santa Sophia Church in Istanbul was built, which is well known of the golden cladded dome that is penetrated by 40 windows over the entire perimeter, creating a specific incidence of light. Procopius, the principal Byzantine historian of the sixth century, describes the church as: "singularly full of light and sunshine; you would declare that the place is not lighted by the sun from without, but that the rays are produced within itself, such an abundance of light is poured into this church…" (Lethaby & Swainson, 1894, pp. 24). This citation indicates the importance of daylighting to the form of a building. In addition to its functional role to provide light to the interior, the reflection of sunlight from the decorative surfaces illuminates the space.

Gothic

Gothic cathedrals between the twelfth and sixteenth century were based on the renewed structure, which led to a new and open building typology, also known as 'architecture of light' (Philips, 1997, pp. 4). The flying buttresses allowed walls to be filled with enlarged windows, which made it possible to penetrate light at all levels. With the provision of stained glass and tracery of stone, the development of these tall spaces embodied the cathedrals with a suffusion of light (Philips, 1997, pp. 1-4; Ramzy, 2013, pp. 220-225).

Baroque

A characteristic of the baroque architecture is the concealed and recessed windows, where the light reflects on the golden and white surfaces of the interior and determines the unique atmospheric effects. The ceiling paintings are illuminated by the high windows. The play of perspective and light is the main feature of the Baroque architecture and led to a complex structure emphasizing light of the higher levels to emulate the heavenly ambiences in the domes (Ramos, 2019, Chapter 2; Philips, 1997, pp. 1-4).

Industrialization

In the seventeenth and eighteenth century light from above was obtained by means of glass domes and laylights, which cleared the floor plan and permitted deeper buildings. The illumination of spaces was till then provided by daylight, dependent on the shape, positioning of the window, location of the space and climate and in case the natural light was not sufficient, oil lamps or candles were used. The only connection between exterior weather conditions and interior light and heat conditions was thus the building envelope. A major turnaround in the provision of light in buildings took place when daylight was supplemented with artificial lighting

in the nineteenth century and the free layout of floor plans was made possible. The introduction of sheet glass, iron, steel and new techniques caused a lot of possibilities within the building design, for example the transparent Crystal Palace in London (Philips, 2004, pp. 3-5; Baillieu, 2003, pp. 16).

Early twentieth century

After the introduction of electricity and air-conditioning, alternatives for natural light were available and windows were no longer needed for cooling or fresh air. This offered new opportunities to consciously design where and how daylight enters the building based on aesthetic reasons rather than functional purposes (Philips, 2004, pp. 4). In the early twentieth century the modern movement emerged in response to the historic architectural styles of the late nineteenth century, which refer to history using modern materials, causing a radical break from traditional design principles. Modernist architecture was characterized by the simple, functional, undecorated and industrially producible type of architecture with a clean aesthetic using simple forms, shapes and lines (Design Buildings Wiki, 2021). Within Modernism, the historical principles of natural light, natural ventilation, orientation and form were retained, while new insights have emerged in the realization of healthy architecture.

In the late nineteenth century, urban areas had to deal with the unpleasant rise of tuberculosis (Landes, 2019). The increasing growth of the population in cities and the insufficient hygiene facilities led to the high rates in deaths caused by this disease, especially among the poor. Different studies showed that the mainly indoor nature of humans way of living had a negative effect on their well-being (Norton, et al., 2017, pp. 4-5). The scientific research declared the benefits of fresh air, sunlight and exercise, which resulted in new needs within the building, such as windows facing south, balconies and verandas. Le Corbusier and other modernist architects used this to define a house as 'a machine for living in', which could change the well-being and health of the inhabitants. Due to the new advantages in the building technology, these ideas could be made possible. Function became key in the design of the building (Landes, 2019). The awareness of modernist architects of the advantages of a healthy living environment was reflected by using daylight and air not only as a necessity, but as "a symbol of the new era" (Solt, et al., 2017, pp. 25). The relationship and freedom between the exterior and interior was expressed by the use of glass walls and a slim structure without load-bearing facades. The building style includes the open floor plan by creating a grid of pilotis, deep flat roofs that act as a garden and function as a retreat from the hurried modern life, continuous horizontal glass panes along the facade, and also the use of the elevator and electronic devices (Philips, 2004, pp. 3-5; Landes, 2019).

Late twentieth century

The development of electric sources, among which is the elevator, and the growth in demand of workplaces resulted in larger, deeper and taller buildings, causing the increase of distance between the occupants and the building envelope. The insufficient daylighting due to long horizontal windows and the lowered ceilings by virtue of the economic benefits resulted in an artificially lit environment

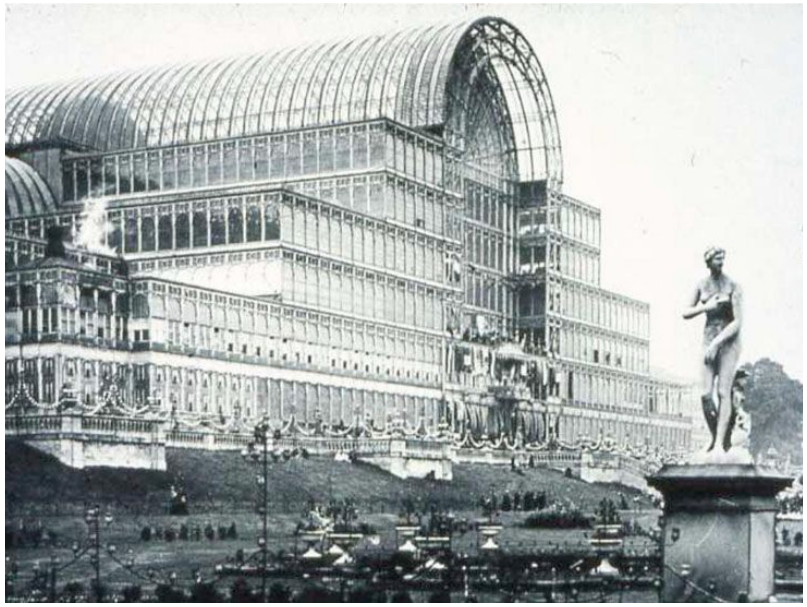

Figure 6 | Crystal Palace in London, United Kingdom. (Ismail, 2019)

with the slowly losing direct awareness of movement outside, the position and presence of the sun or any other connection with the natural environment (Solt, et al., 2017, pp. 25). In the 1960s the natural lighting was seen as luxury and artificial light became the inevitable primary source of light. It was the energy crisis in 1973, when people became aware of the consequences of energy consumption and started to think about energy efficiency and the use of daylighting in architecture. As a result of scientific research into light in buildings, daylighting provided enormous benefits in the health of the building's occupants as well as energy savings (Philips, 2004). Thus, knowledge has been shared to redefine daylight principles within architecture.

Conclusion

The light appearance and cultural meaning, focusing on the emotional and rational interpretation, has been changed over the course of centuries. For a long time, daylight was only used for functional and religious purposes. While new possibilities in construction technology continued to develop, this goal changed and daylight also acquired a decorative value. The first noticeable change in the utilization of apertures was the renewal of building structure in the gothic era by the implementation of buttresses. A major shift took place in the late sixteenth century and early seventeenth century when the industrialization provided new innovations in materials, which resulted in more possibilities within architecture. Meanwhile, the negative effect on the well-being of humans caused by the indoor living and the benefits of sunlight, among other things, were studied. This resulted in new needs within the building and the modern architects responded to this. Daylight became a symbol of modernist architecture and, because of the new innovations, all kinds of glass surfaces were made possible to implement in the building design. Since the end of the modernist period, the fluctuations between rational significance of light, meaning the bright white light, and emotional significance of light, preferring soft and subdued warm light, have been decreased and the design of daylight openings nowadays focusses on the health and well-being of building's occupants combined with energy efficiency of the building.

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Section II – Light, time and place

"Architecture is the thoughtful making of spaces. It is the creating of spaces that evoke a feeling of appropriate use … To the musician a sheet of music is seeing from what he hears. A plan of a building should be read like a harmony of spaces in light."

Louis Kahn, 1967

Figure 7 | Creo Hall, Toyoma in Japan. (Matsumura, 2005)

This section focusses on how nature and use of daylight are affected by time and place. First, the perception of daylight is discussed. Subsequently, the influence of location on our perception will be described. At last, the difference of latitude between Scandinavia and the Mediterranean is explained and consequently, the influence of latitude on architecture is defined.

Light perception

The sun is the only instrument that gives us a sense of place and time. Through the interplay of shadow and light, we experience the predictable rhythm of a day or a season. Blue light is associated with morning and golden light is connected with the evening and this condition of light differs between winter and summer. Our body is regulated by daylight and temperature and responds to the exposure and level of light. Because of this, the body is informed when to rest and when to be active. We perceive the pattern of light two-dimensionally, and in order to see this flat image three-dimensionally, we have to abstract it and understand its variations in light and shadow. Depending on the situation, such as colours and the intensity of light, we interpret that information in a different way. This makes seeing more a psychological activity than physical (Ramos, 2019, Chapter 1; Miller, 2009).

Light and shadows also clarify the visible and invisible characteristics of a place. Some places are characterized by the dramatic shifts in weather, while other places are well known for their subtle and slowly changes in weather and light. Capturing an image of this setting with the quality of the changing light is almost impossible, you can only experience it when you are there. Besides that, the exposure of light is dependent on the latitude of a certain place, which results in different ways of living over the world (Millet, 2009). The light of the revolving sun is transmitted into the interior by the use of apertures, creating different atmospheres. These changes in daylight cause a dynamic appearance of the interior and make every building unique.

Modernism can be regarded as the golden age of daylight, in which the elements 'sunlight, air and space' became the new order in architecture. Each of these intangible elements are connected to the interplay of shadow and light on which a space can be perceived (Millet, 2009). Until the nineteenth century, space was not considered in terms of fine-art and had always been an abstract idea in metaphysics and philosophy or a subject of natural sciences. Also, light was viewed differently. Although the knowledge of the properties of light was already theorized in the third century BC, including the straight lines, refraction and reflection of light, scholars claimed light was emanated from the human's eye and that this enabled human to see. Later, scholars believed it was the object that was able to lighten itself and informing human of its qualities. In 1000 AD, light was described for the first time as 'originated in luminous sources'. Subsequently, Leonardo Da Vinci was the first one with the idea of the 'radiant pyramid', which showed that objects express fragments of itself in straight lines in different angles, becoming smaller as the distance between the object and the fragments increases. He also described darkness as the absence of light (Ramos, 2019, Chapter 1). In the eighteenth century Isaac Newton was the first to consider light or heaven separated from religion. Furthermore, he discovered that white light was the only light that is able to produce the difference of colours in humans and sunlight contained seven colours, as seen in the rainbow. After different discoveries the role of light changed from a medium to an instrument that describes a space in both architecture and art (De Haene, 2019).

Time and space

We perceive time through light, so it can be argued that time is the measure of alterations in light during the day, as well as the seasons. For centuries these light changes have been measured with the sundial, which was also the function of ancient buildings expressed by the well thought shape and orientation. The beautiful thing of architecture is that it combines time with space. In relation to time, we perceive architecture as we walk through a building. The quality and quantity of light in the building, including glare and colour, also contribute to the experience of a space. This is why the location of an opening affects the distribution of light in a space and the illumination of objects and surfaces. An opening in the ceiling will transform the light into homogeneous and diffuse, while an opening near a corner will provide reflections at the adjacent and perpendicular surfaces, which will lead to a concentrated illumination of the space. The same

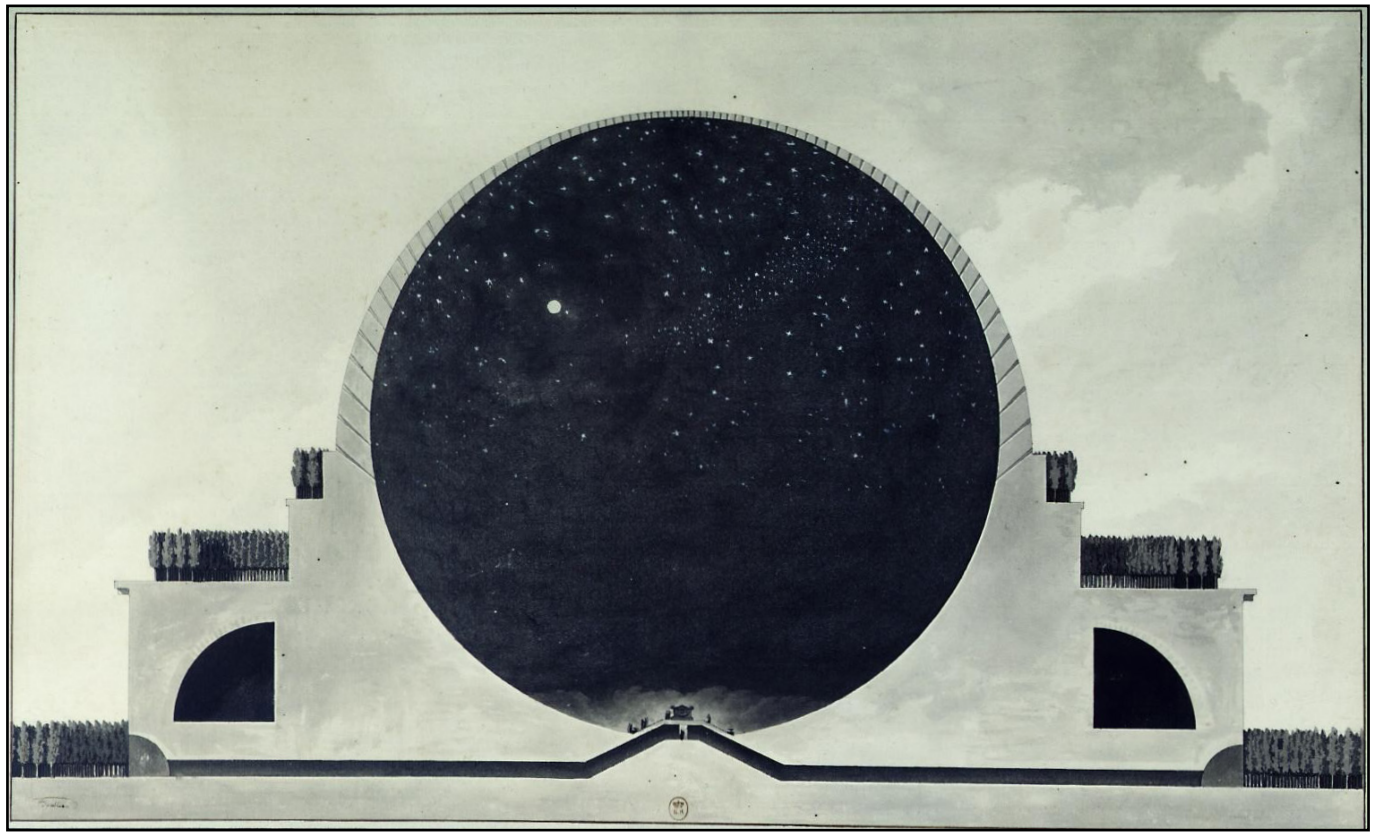

Figure 8 | Attributed to Newton, French architect Etienne-Louis Boullée designed a cenotaph with hundreds of openings in the dome, creating a heaven with the moon and constellations. (Miller, 2014)

applies to the differences between an opening in a north facade and in a south facade, where differences arise due to the contrast in climate and time of year (Ramos, 2019, Chapter 1).

Light in a space always leads to the expression of colours. Colour is caused by a combination of the reflection from an object produced by light with a certain wavelength and the absorption of certain parts of that light. In northern climates, the addition of light and reflecting colours was used to brighten the outside surfaces during the dark and gloomy winter. It alleviated the uncomfortable features of the cold climate and it increased the contrast between dark and light. In the hot southern climates, the reflection of the sunlight from vertical surfaces was too bright to look at, resulting in ornamentation in the facade to create visual relief (Millet, 2009).

Light and place

The earth tilts on its axis while it orbits the sun, which causes the different seasons over the year and also the different climates in the world. This is why at the north pole and south pole the sun during their summer never sets, while it never rises during their winter. Consequently, the way light flows into a building differs depending on its latitude and is key in understanding architecture. Buildings in climates with a high amount of sunlight require a controlled way of letting sunlight into a building by using for example a patio or inner courtyard. Buildings in climates with insufficient light contain wider openings in the building envelope and a fireplace which functions as the core of the house, bounded by a wall of darkness. The adaptation to and the management of the lack of natural light is key to survival (Ramos, 2019, Chapter 2).

Scandinavian climate

For a long period each year, the atmosphere in Scandinavian countries contains a grey sky and a white field that covers every colour of the landscape. As a consequence, this white surface can be considered precious, as the snow reflects the sparse pale light. It is also the moment when the sunlight is very strong, which is experienced as the most aggressive light in the world. Opposite of the quick sunset near the equator is the sunset in Scandinavia. It can take several hours till the sun disappears below the horizon, beginning with a yellow glow creating long shadows. The other part of the year the ray of the sunlight changes and the intensity of daylight varies, while the sun never sets. This results in a different quality of dusk where total darkness never appears. The special appearance and great contrast of daylight over the year affects the approach of life and is treated with care to get as much daylight as possible into the buildings (Millet, 2009). Therefore, the adaptation of architecture to follow the brightest light is fundamental. High windows and skylights are used to prevent the bright horizontal light and to create a sufficient daylit interior during the year. The location requires to deal with light in a very precise manner, whereby both effects of natural light are known, as well as the technical elaboration thereof. By getting to understand the nature of a place, an architect has to recognize the specific problems of each location and has to respond to them. Alvar Aalto was a Finnish modernist architect who optimally treated the maximum amount of daylight within a building. He understood the lighting requirements for the different seasons with changing lighting conditions, which challenged him to master all possible techniques and methods to control the incoming light: "Daylight through ordinary windows, even if they are very large, covers only a part of a big room. Even if the room is lighted sufficiently, the light will be uneven and will vary on different points of the floor." (Aalto & Schildt, 1978, pp. 78-79). He designed spaces carefully with a proper distribution of sufficient light or by accentuating them, using a variety of daylight openings, such as skylights and clerestories (Gruzewski, 1991, pp. 32-40).

Mediterranean light

Apart from the fact that the type of light differs from the Northern light, the combination of light and sea in the Mediterranean provides a romantic harmonised atmosphere. Le Corbusier defined this light as: "the wise […] play of volumes under light", meaning that forms play not only with light but also under this bright and overarching light (Ramos, 2019, Chapter 2). His fascination with light is also evident from how he describes it in a speech to the CIAM congress:

> In the course of years, I have felt myself become more and more a man of everywhere with, nevertheless, one strong root: the Mediterranean, queen of forms under the play of light; I am

dominated by the imperatives of harmony, beauty, plasticity. (Le Corbusier, 1933)

This led to the indispensable display of the strong light creating clear shadows in his architecture. It explains the search from modernist architects into the simplicity and harmony of different forms, but also the relationship between the geographical region and its particular light. In European regions of the southern climate, the sunrays fall almost vertical to the surface. Contrasts between shadows are therefore much greater and cause hard lines of projections on buildings. Vertical elements are thereby less effective in the utilization of daylight as an architectural instrument compared to the northern climate. In the southern climate effects and reflections of light emphasize and enliven each small element or pattern of a building, which gives a building an extraordinary, subtle and independent appearance (Ramos, 2019, Chapter 2). This is also clearly expressed by John Ruskin, who developed rules of architecture according to the region and nature of it: "If the sky is serene, architecture should be horizontal; if it is grey and cloudy, as in the north, architecture should be vertical and linear" (Zevi, 1993, pp. 170).

Conclusion

Of all natural sources, the sun is the only instrument that gives us a sense of time and place. We evolved under the sun and as a result our body reacts to the exposure and level of daylight. This makes daylight fundamental to our perception. Architecture combines time with space. The interplay of light and shadow are key in understanding architecture. Because architecture is sited at a certain location, it also belongs to this place. Local architecture is adapted to and responds to the light, climate and geography and contains specific references to this location. The great contrast of daylight in northern Europe is treated in a way to optimally use the amount of available light, while in southern Europe the clear shadows shape architecture. Different modernist architects are therefore looking for simplicity and harmony of different forms in combination with the conditions of light. It is to say that architecture is an attempt in understanding the nature of a place and finding the best solution to these natural conditions.

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Figure 9 | The Dómadalur daylight series of thirty five photos, facing north, shows the time-lapse of the Dómadalur Icelandic landscape over a twelve-hour period. (Eliasson, 2006)

Section III – Case Study

"It is possible in a scientific way to ascertain what kinds and what quantities of light are ideally the most suitable for the human eye, but in constructing a room the solution must be made with the aid of all the different elements which architecture embraces."

Alvar Aalto, 1940

Figure 10 | Villa Girasole, 1935, rotates during the day via the rails of the garden, following the movement of the sun, Italy. (Hidden Architecture, 2020)

This section consists of a comparative research, focussing on two building typologies in Scandinavia and the Mediterranean, namely religious buildings and residential buildings. Firstly, the requirements and parameters of the comparative research that frame the comparisons are described. The comparison will start off with an overview of the four analysed projects of the religious building type, after which the case studies are executed. Each case study will consist of an introduction and an analysis based on the parameters. After the four case studies, a conclusion will be generated. Subsequently, the same will be done with the four residential buildings.

Comparative research framework

In this research a distinction has been made between residential buildings and religious buildings. Each of these typologies will contain two buildings per region. The selection in typology has been made based on the modernist requirements and the exceptional importance of daylight for the specific users of these buildings. In addition to the fact that daylight enhances human well-being, it is also beneficial to other aspects. Daylight in churches emphasizes the holy ambiance, where mostly daylight and light beams from above are used to create this type of atmosphere. In residential buildings natural light is important, because a house has to give a person the feeling of home, safety and security. Besides that, it is the place where we spend most of our time, which makes it very important to create a comfortable environment. Considering the different cultural meanings of living in Scandinavia, where people are mainly inside their home and therefore live in larger houses, and the Mediterranean, where people live in smaller houses and are mainly outside their home, this research will only focus on villas. Conclusions will be made based on documentation, articles, drawings and photos of these projects. A building can only be analysed and compared if it complies with the following principles:

- A religious building or residential building.
- A building built between 1920 and 1980 (comparing a building from the same time period).
- A building designed by a modernist, preferably local, architect.
- A building according to the modernist standards and principles.

Parameters

In the analysis of the case studies nine different parameters, divided in four paragraphs, are used to get new insights in the utilization of daylight of modernist architecture in two specific regions. Other parameters may not be discussed, such as the size of the building, information of the architect and the building's context, although this may affect the comparison. It is therefore not an exhaustive study.

Orientation, form and organisation

The orientation, organisation and unique composition of a building determine what kind of daylight enters in the different spaces within the building and could also lead to new insights of the purposes of the architect.

Positioning openings

The positioning of windows is closely related to the orientation and location, which will give information about the type of light and the perception of it.

Materials and colours

Materials are recognized by their colours and textures. The extent of irregularities determine a texture and also influence the reflection of light. A rough surface will change the incoming light into diffuse illumination by reflecting light rays in different angles. Smooth surfaces reflect light in the same angle, which is called specular reflection (De Haene, 2019, pp. 62). Colours can be distinguished in the level of hue, lightness and saturation, whereby these features say something about the absorption and reflection of a surface. Light colours are used in interiors to maximize the penetration of daylight and uniformity. It will also bring in light from many directions derived from the sun (De Haene, 2019, pp. 54).

Sun, light and shadow

Dependent on time and place, the predictable sun path forms both light and shadow. This offers opportunities in architecture. It evokes the rhythm within the building through apertures, which creates atmosphere but could also cause glare. Most of the time, we look at an overcast sky, which causes diffuse light and, in contrast to direct sunlight, no specular reflection (De Haene,2019, pp. 28, 36).

Comparisons

For the comparison, the following projects will be analysed:

Religious architecture
- o Orivesi Church by Kaija and Heiki Siren
- o Bagsværd Church by Jørn Utzon
- o Nostra Signora della Misericordia by Angelo Mangiarotti, Bruno Morassutti and Aldo Favini
- o Chiesa di San Giovanni Battista by Carlo Scarpa and Edoardo Detti

Residential architecture
- o Villa Stenersen by Arne Korsmo
- o Villa Schreiner by Sverre Fehn
- o Casa al Villaggio dei Giornalisti by Luigi Figini and Gino Pollini
- o Vivenda de verán by Carlos Meijide

In Appendix II a detailed collage of the projects is rendered.

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De Haene, R. (2019). *The Design of Daylight Perception* (Master's dissertation). Retrieved from: https://lib.ugent.be/nl/catalog/rug01:002786240

Figure 11 | Map of Europe with the locations of the analysed projects.

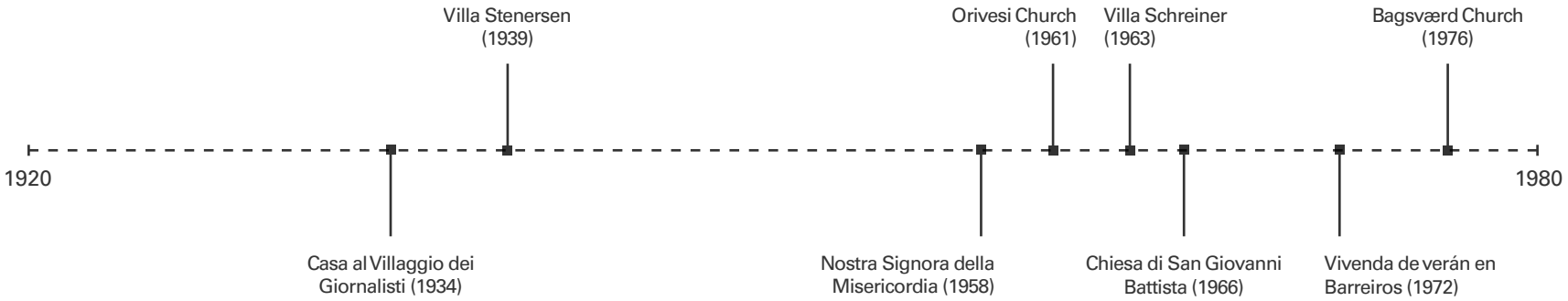


Figure 12 | Timeline of the modernist period with the construction dates of the analysed projects.

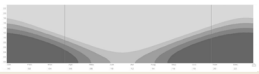
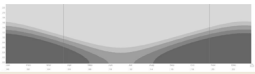
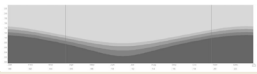
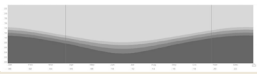
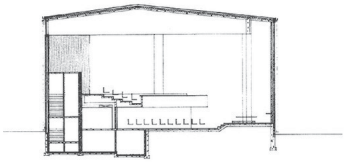
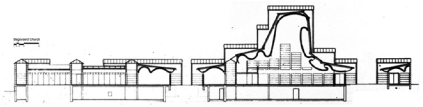
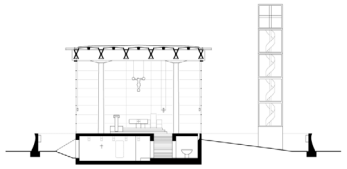
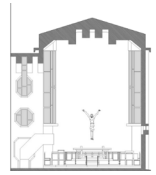
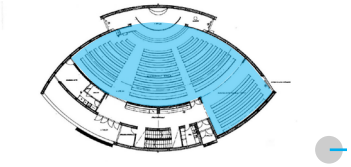
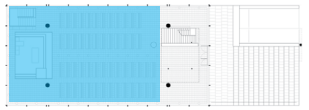
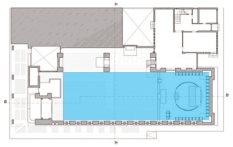
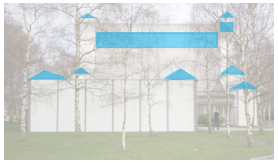
Overview religious buildings	**Orivesi Church (1961)** Kaija and Heikki Siren 61°40'24.6"N 24°21'29.6"E	**Bagsværd Church (1976)** Jørn Utzon 59°56'21.0"N 10°41'55.1"E	**Nostra Signora della Misericordia (1958)** Mangiarotti, Morassutti and Favini 45°31'41.6"N 9°06'51.7"E	**Chiesa di San Giovanni Battista (1966)** Scarpa and Detti 44°07'06.9"N 11°22'46.1"E
Annual sun graph				
Exterior				
Interior				
Colour palette				
Section				
Form and organization blue - central space				
Positioning openings blue- opening light blue- translucent opening	 E	 NW	 S	 SW
Sun, light and shadow blue- perimeter	 N	 N	 N	 N

Figure 13 | Overview of analysed religious buildings in Scandinavia and the Mediterranean.

Case Study - Scandinavia
Orivesi Church

Architect: Kaija and Heikki Siren
Built in: 1958 - 1961
Location: Orivesi, Finland
Context: Rural, residential
Coordinates: 61°40'24.6"N 24°21'29.6"E

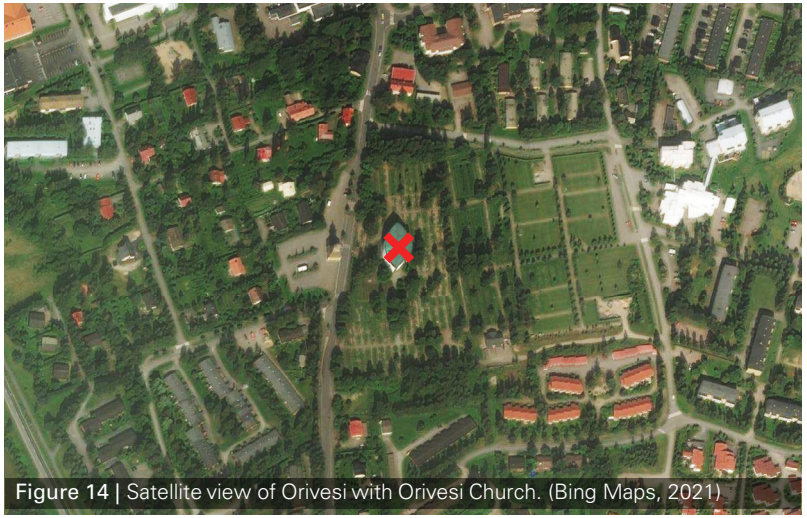


Figure 14 | Satellite view of Orivesi with Orivesi Church. (Bing Maps, 2021)

Orientation, form and organisation

The arch church in Orivesi was a replacement for the old wooden church that burned down in 1958 (Oriveden Seurakunta, n.d.). The special shape is the result of an overlap of two circles. The entrance of the building is located on the west side of the building. Instead of the altar being on the short side of the building, it is located on the long wall of the arch. The building is made up of five vaulted support walls, giving the impression of an intimate and safe space. This is also emphasized by the large curved concrete beams that almost seem to float above the walls, although many vertical lines have been used in the interior to accentuate the height of the building (Finnish Architecture, n.d.).

Figure 15 | Orivesi Church and surroundings. (Jäntti, 2020)

Figure 16 | Interior Orivesi Church. (Hietanen, n.d.)

Figure 17 | Exterior with entrance of Orivesi Church. (Hietanen, n.d.)

Positioning openings

The large number of windows that are recessed in the space between the various arched walls ensures a lot of light on the light surfaces without causing glare to the users of the building. In addition, windows have been used in the upper part of the facade over the entire perimeter of the building, which provide the sacred light that enters from above.

Colours and materials

The five support walls are made out of two layers of bricks and are painted white. The windows consist of a black steel frame, which creates a great contrast with the bright incoming light and the white colour of the facade. The dark brown wooden colour of the furniture gives the interior a warm appearance. The slightly pitched roof, which partly consists of a cantilever, contains a wooden structure in combination with concrete beams and is covered with zinc (Finnish Architecture, n.d.). The concrete is painted white, resulting in a smooth line between the walls and ceiling.

Sun, light and shadow

The use of different vaulted walls creates an interplay between light and shadow. It also highlights certain features of the church, such as the altar. The altar is located on the south side of the building, with openings from the east and west, which makes it the natural illuminated spotlight. Besides that, the windows over the entire perimeter ensure the distribution of daylight into the building. The overhang is located above the entrance on the north side and does not block any daylight or solar heat, so that it can be used optimally.

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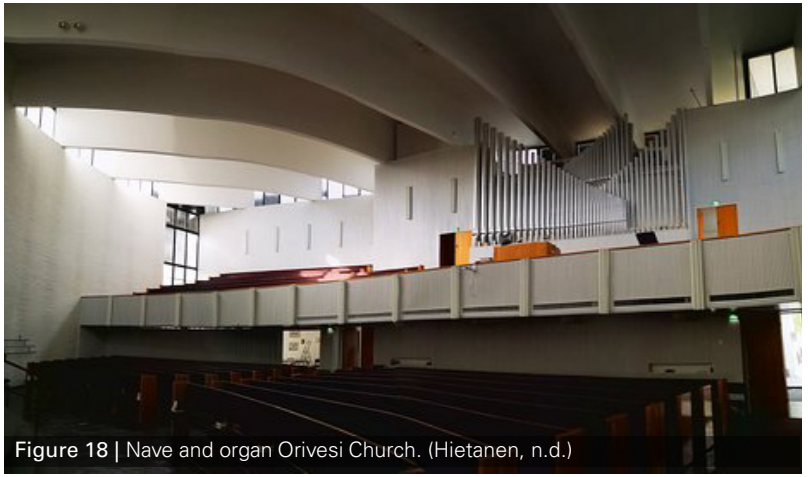

Figure 18 | Nave and organ Orivesi Church. (Hietanen, n.d.)

Figure 19 | Exterior Orivesi Church during winter. (Hietanen, n.d.)

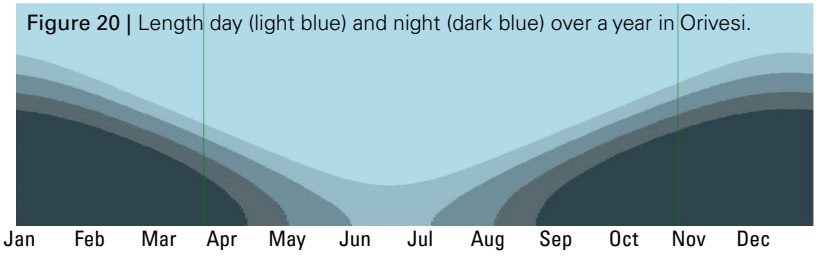

Figure 20 | Length day (light blue) and night (dark blue) over a year in Orivesi.

Case Study - Scandinavia
Bagsværd Church

Architect: Jørn Utzon
Built in: 1973 - 1976
Location: Bagsværd, Denmark
Context: Suburban, residential
Coordinates: 59°56'21.0"N 10°41'55.1"E

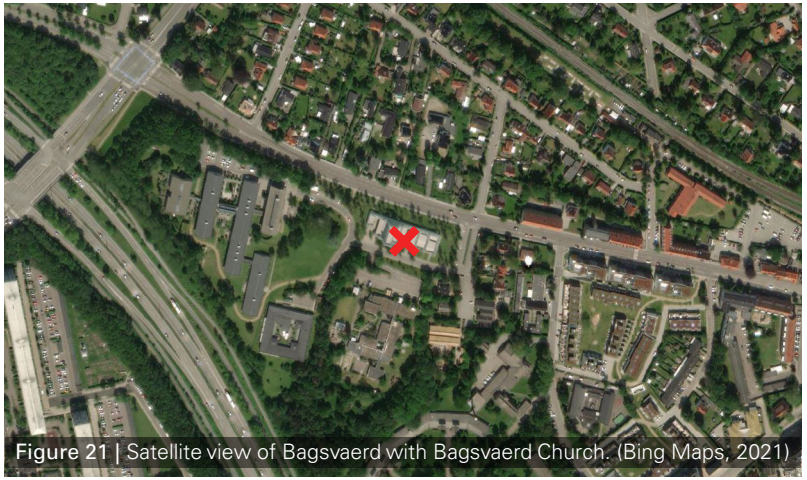

Figure 21 | Satellite view of Bagsvaerd with Bagsvaerd Church. (Bing Maps, 2021)

Orientation, form and organisation

The Bagsværd Church was commissioned by the Bagsværd community. The building consists of a geometrical floor plan of three sections. The circular geometry of the roof made it possible to freely shape the shells. The shells reflect the clouds over the sea, where sunlight through the clouds illuminates the area. The hall of the church is surrounded by the corridors. The building also houses a number of offices, classrooms and a meeting room, which can be reached via the surrounding corridors (Arch Eyes, 2021). The outside of the church is modest with a simple orthogonal shape. The entrance is located on the southwest side of the building and the back is oriented to the street. The great contrast between the inside and outside results in a secluded and protected atmosphere in the church (Fracalossi, 2011).

Figure 22 | Exterior Bagsvaerd Church. (seier+seier, 2011)

Figure 23 | Interior Bagsvaerd Church. (seier+seier, 2011)

Positioning openings

The roof openings of the central hall are facing west. Daylight is penetrated from the highest point of the building and is reflected and softened by the curves of the ceiling. The side aisles are provided with skylights, which transfer the sunbeams to the outer walls into the central space. The adjacent corridors are naturally lit by the glass roof that also illuminates the central space through sidelights in the walls. The incidence of light forms a separation between these spaces.

Colours and materials

The interior is expressed in concrete rounded vaulting combined with concrete walls, white tiles and pale wood. Other vertical wood pieces demarcate the sacred space. The cold grey colour of concrete emphasizes the coldness of the material and provides bright lighting. Nevertheless, the wooden furnishings and accents in the interior on the lower level create a warm ambience. The combination of both colours provides a special incidence of light. The sober exterior is finished with white glazed tiles, white concrete panels, and an aluminium roof. The simple tiles relate to the concrete curves of the vaulting (Divisare, 2016).

Sun, light and shadow

The soft curves are designed to control the incoming daylight. The white colour on both ceilings and walls make it possible to use the sparse daylight in the building. All surfaces are lit and come into their own. The combination of white surfaces and the grey floors provide reflections that generates the optimal intensity of natural light within the building. To avoid glare and create a peaceful light, the outer wall of the living areas is provided with an overhang. In contrast to the corridors with varying light, these areas are filled with diffuse light.

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Figure 24 | Nave of Bagsvaerd Church. (seier+seier, 2011)

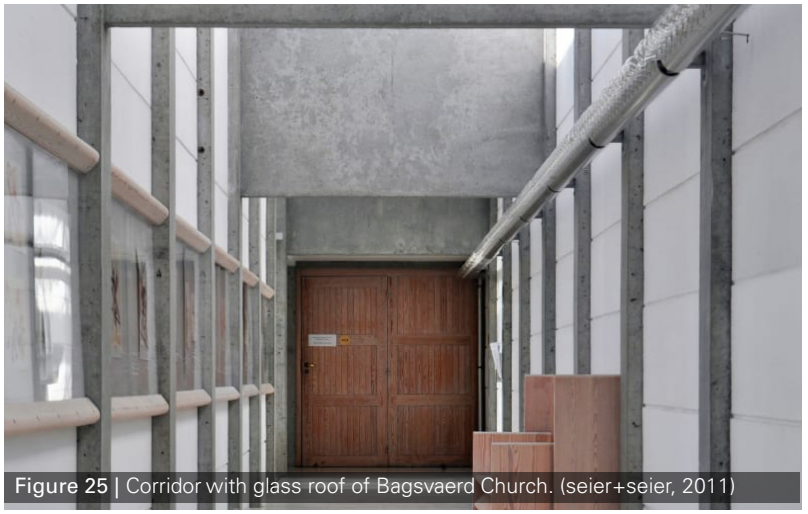

Figure 25 | Corridor with glass roof of Bagsvaerd Church. (seier+seier, 2011)

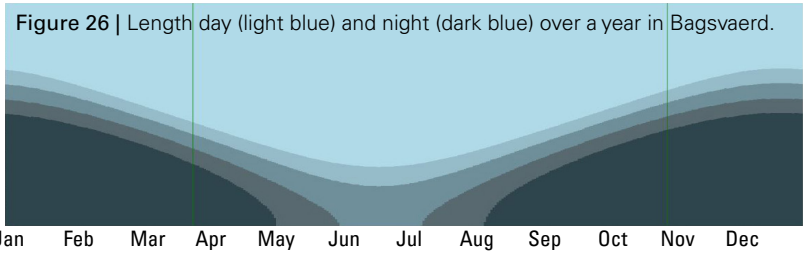

Figure 26 | Length day (light blue) and night (dark blue) over a year in Bagsvaerd.

Case Study - The Mediterranean
Nostra Signora della Misericordia

Architect: Angelo Mangiarotti,
Bruno Morassutti and Aldo Favini
Built in: 1956 - 1958
Location: Baranzate, Italy
Context: Suburban, residential
Coordinates: 45°31'41.6"N 9°06'51.7"E

Figure 27 | Satellite view of Baranzate with the church of glass. (Bing Maps, 2021)

Orientation, form and organisation

The 'church of glass' can be seen as an icon of the construction techniques and new design features of Italian churches. The building stand out for its roof structure, the linear surfaces, the pre-compressed reinforced concrete structure and the absence of ornamentation and thus, its simplicity (Borsotti, n.d.). The main entrance of the rectangular block can be reached via an upward slope from the south. The central space is provided with the altar on the north side and the organ on a raised platform consisting of a steel construction with wooden finish. Two stairs lead from both sides of the building to the basement, where a number of meeting rooms can be found (Divisare, 2014).

Figure 28 | Daylight utilization of church of glass. (Divisare, 2014)

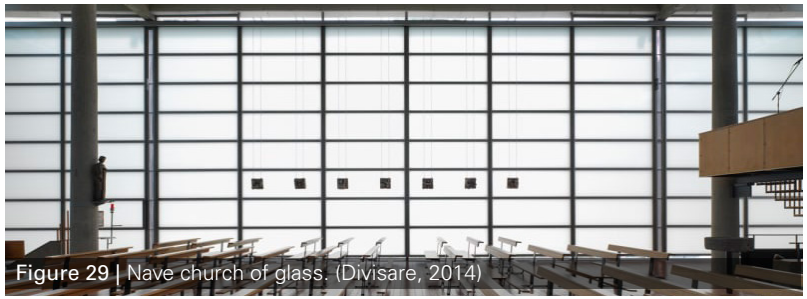

Figure 29 | Nave church of glass. (Divisare, 2014)

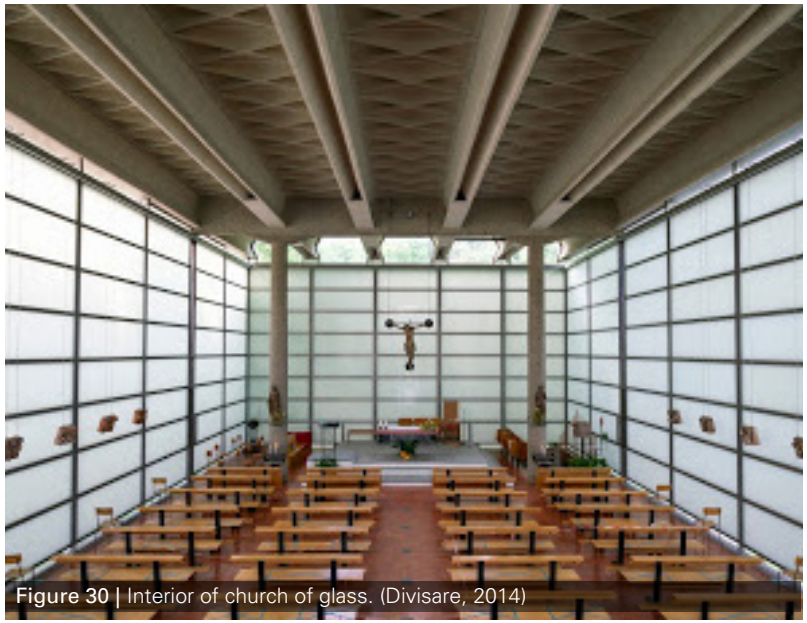

Figure 30 | Interior of church of glass. (Divisare, 2014)

Positioning openings

The transparent openings above the curtain wall, at a height of about seven meters, provide a special and concentrated incoming light, while the translucent curtain wall creates a diffuse ambiance. This combination results in a bright indoor environment. The four facades all have the same distribution of transparent surfaces and translucent surfaces.

Colours and materials

The facade is made out of a curtain wall of glass panels with polystyrene sheets rendered translucent and a steel frame. The eight meters tall concrete columns consists support the concrete X-shaped beams of the roof (Design daily, 2016). The cool grey colour of the concrete and soft white colour of the facade contrasts with the warm terracotta colour of the floor and the warm colour of the wooden furniture. The varying colour of the trees and the shadows of outside objects are reflected on the facade and change the appearance of the facade from the inside during the day. The tiled floor slightly reflects the incoming light.

Sun, light and shadow

In this church, light can be considered as the main material of the building. The constantly changing appearance of the building during the day results in diffuse light, while by night it is experienced as an object that radiates light. The way daylight enters the church emphasizes the religious atmosphere. The polystyrene panels in the facade function not only as a distributor of reflecting and refracting light, but also for thermal purposes to moderate the indoor temperature.

References

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Figure 31 | Front view of church of glass. (Divisare, 2014)

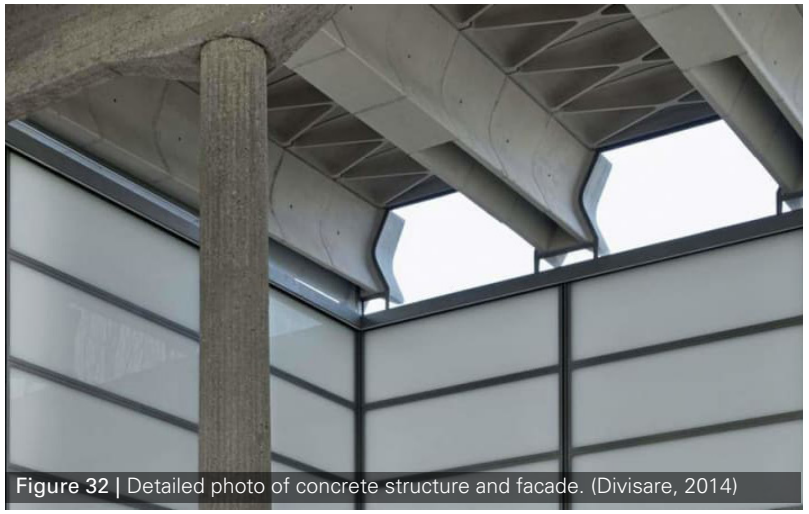

Figure 32 | Detailed photo of concrete structure and facade. (Divisare, 2014)

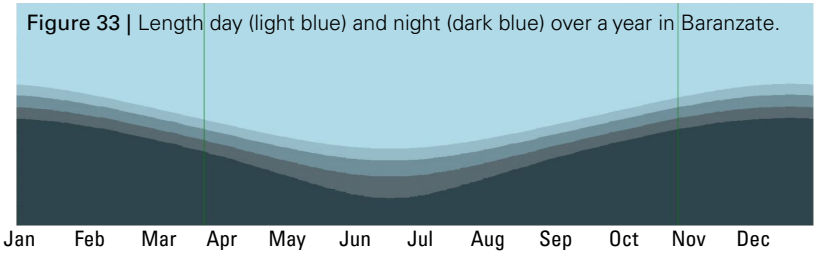

Figure 33 | Length day (light blue) and night (dark blue) over a year in Baranzate.

Case Study - The Mediterranean
Chiesa di San Giovanni Battista

Architect: Carlo Scarpa and Edoardo Detti
Built in: 1959 - 1966
Location: Firenzuola, Italy
Context: Rural, residential
Coordinates: 44°07'06.9"N 11°22'46.1"E

Figure 34 | Satellite view of Firenzuola with Battista church. (Bing Maps, 2021)

Orientation, form and organisation

The Chiesi di Giovanni Battista is located in the centre of Firenzuola, as a result of the reconstruction of the village. Although the building has many characteristics of Modernism, the traditional style can also be traced back to the shape of the building. The interior, on the other hand, is a harmony of different shapes, lines and materials. The rectangular volume can be entered from the west side, which faces the altar and the vertically elongated windows. The construction consists of a reinforced concrete skeleton. In addition to functioning as a church, the building is also intended to house the pastor on the ground floor and first floor and a number of offices (Divisare, 2005).

Figure 35 | Exterior Battista church. (Divisare, 2005)

Figure 36 | Interior Battista church. (Divisare, 2005)

Positioning openings

The west facade is split into a closed part and a large stained glass window, while the south facade looks like a rhythmic mass of stone with small openings (Franzoia, 2020). The translucent vertical windows in the north facade enter a great amount of light into the interior. Thus, the building is characterized by the few windows and their concentrated position. The light only reaches to certain places, which emphasize the sacred sphere. The simplicity of the shapes within the building present an impressive way of creating this atmosphere in a modern church.

Colours and materials

The walls of the interior is much warmer than the bright white colours, which means that the incoming light is also experienced very differently in the space. The roof consists of a wooden hull from which part of the concrete beams emerges. The concrete structure contrasts with the rest of the interior and the warm colour of the ceiling absorbs the light, while the nature stone of the floor in both terracotta and light grey colours slightly reflect the light. The exterior consists of a combination of grey stone and concrete (Franzoia, 2020).

Sun, light and shadow

The thickness of the wall of the southeast facade creates a different way of daylighting, where the contrast of the small apertures with the rest of the wall is key. The large octagonal openings in the columns ensure that the light can reach far, but condensed, into the building. As a result, both sides of the elongated volume are completely different, but the interaction between light and shadow takes place on both sides. The indoor climate is regulated by the wall's thickness, which keeps the interior cool in summer and keeps the heat inside in winter.

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Figure 37 | Front view of church of glass. (Divisare, 2014)

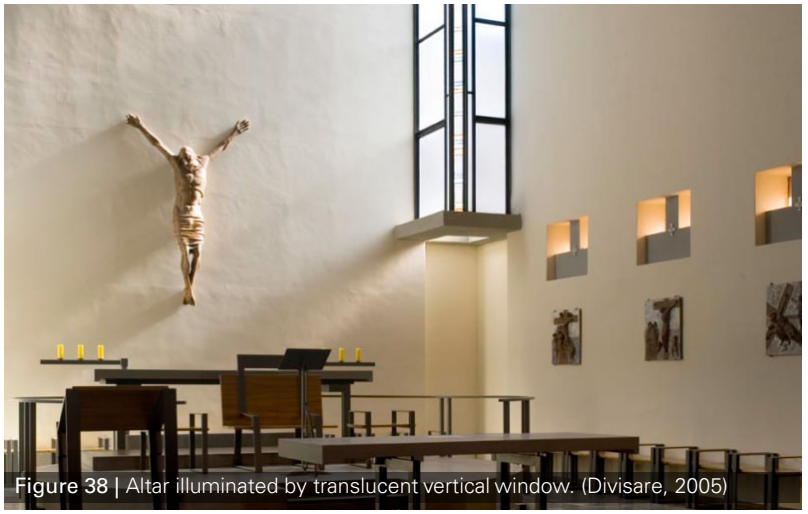


Figure 38 | Altar illuminated by translucent vertical window. (Divisare, 2005)

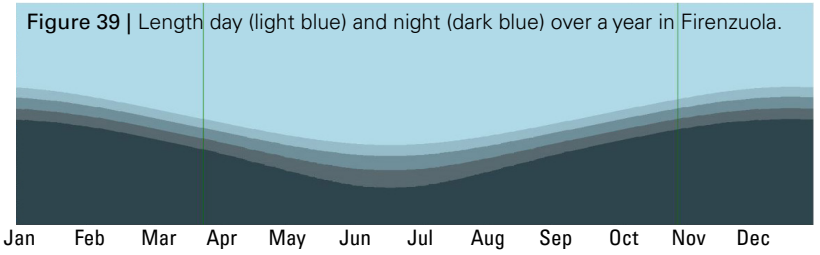


Figure 39 | Length day (light blue) and night (dark blue) over a year in Firenzuola.

Conclusion

In accordance with the characteristics of Modernism, all four projects have a simple building form, the horizontal and vertical straight lines, no ornaments and an open structure. This emphasizes the focus on the incoming light. These projects clearly show that northern areas use a different way of daylight utilization, whereby the scarce light must penetrate through various possibilities.

The incidence of light through higher surfaces, such as the roof or the upper part of the facade are important features in all sacred buildings. In addition, the colour palette also does a lot with the experience of daylight. In the northern churches you can see that many raw, lightly treated materials are used. In all projects a combination of warm and cool colours is used, whereby the furniture and some finishes have a warm colour while the exterior is expressed in a cool colour. The floor is in all cases made of a material that partly reflects the light. The expression of the roof is accentuated by the beams, which provide a contrast between the incoming light and shadow. An exception is the Bagsvaerd church, where the expression with light and shadow from the roof does not come into its own in straight lines, but in wavy lines.

An interesting difference between the northern and southern sacred buildings is the position of the altar in the building. In Northern Europe, the position of the altar is on the long side of the building, which means that the incidence of light created by reflections via the surrounded walls is much wider. In Southern Europe, the light is much more focused and the altar is located on the short side of the building. This is probably related to the incidence and brightness of light of the specific location.

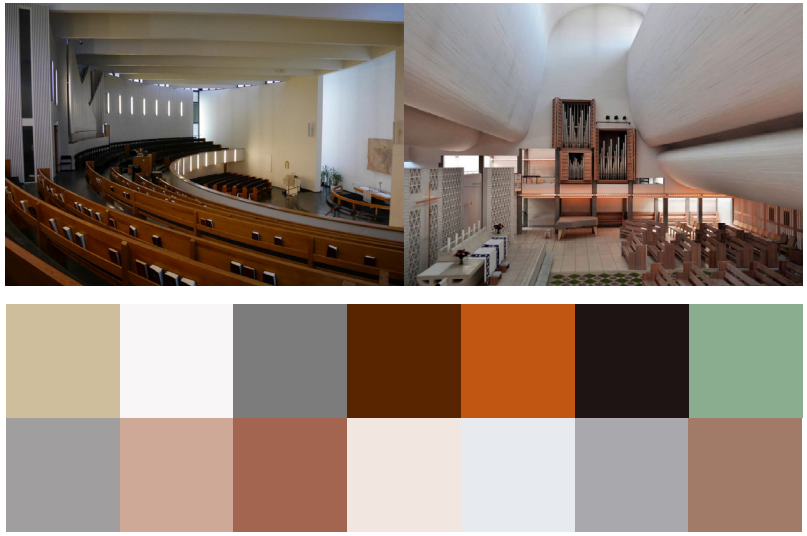


Figure 40 | Interior Scandinavian churches and their colour palettes. (Hietanen, n.d.; seier+seier, 2011)

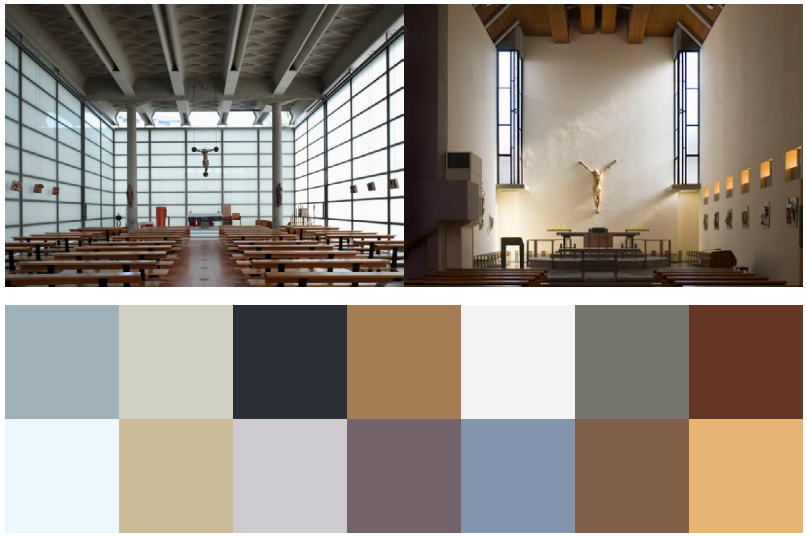


Figure 41 | Interior Mediterranean churches and their colour palettes. (Divisare, 2014; Divisare, 2005)

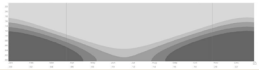
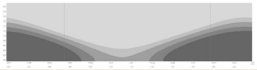
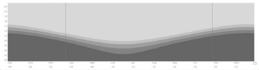
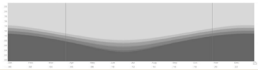
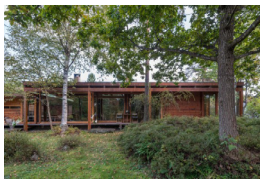
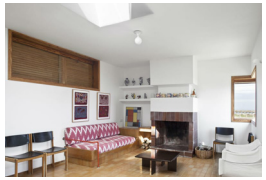
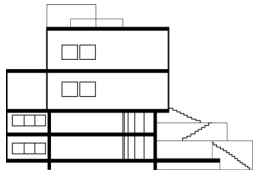
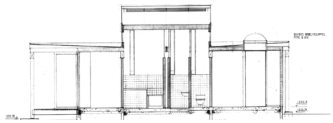
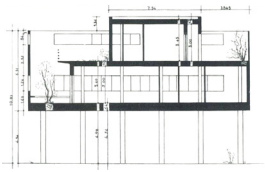
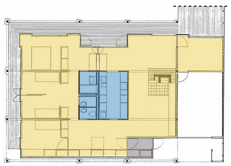
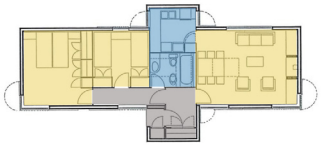
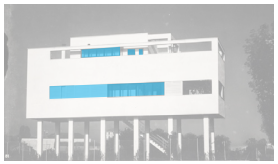
Overview residential buildings	**Villa Stenersen (1939)** Arne Korsmo 59°56'21.0"N 10°41'55.1"E	**Villa Schreiner (1963)** Sverre Fehn 59°57'54.0"N 10°44'43.0"E	**Casa al Villaggio dei Giornalisti (1934)** Luigi Figini and Gino Pollini 45°29'50.6"N 9°12'06.3"E	**Vivenda de verán (1972)** Carlos Meijide 43°33'55.4"N 7°13'40.7"W
Annual sun graph				
Exterior				
Interior				
Colour palette				
Section				
Form and organization yellow- living area blue - sanitary/kitchen grey- circulation area				
Positioning openings blue- opening light blue- translucent opening	 SW	 W	 SE	 NE
Sun, light and shadow blue- perimeter	 N	 N	 N	 N

Figure 42 | Overview of analysed residential buildings in Scandinavia and the Mediterranean.

Case Study - Scandinavia
Villa Stenersen

Architect: Arne Korsmo
Built in: 1937 - 1939
Location: Oslo, Norway
Context: Urban, residential
Coordinates: 59°56'21.0"N 10°41'55.1"E

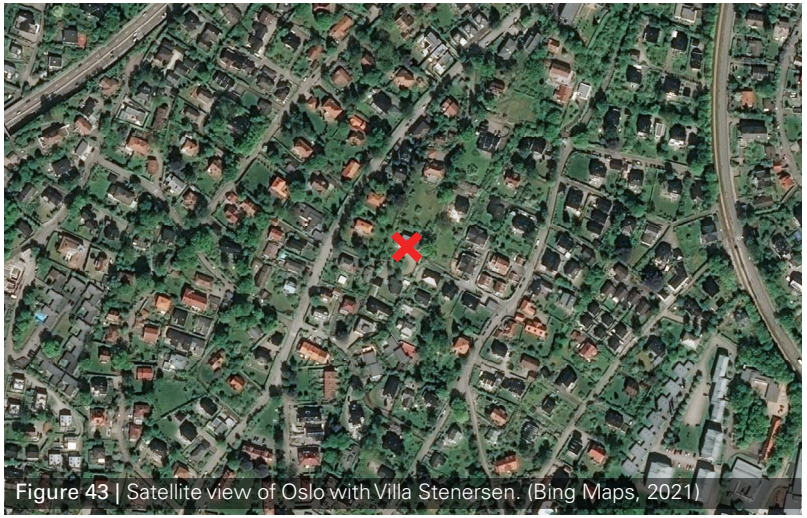


Figure 43 | Satellite view of Oslo with Villa Stenersen. (Bing Maps, 2021)

Orientation, form and organisation

Villa Stenersen was commissioned by financier Rolf Stenersen and is located in a residential area of Oslo. The villa served as a private home and an exhibition space for his art collection. The strong lines and bold colours express the striking appearance, repulsive from the traditional Norwegian houses. The structure of steel columns and concrete floors results in an open floor plan (Divisare, 2018). Spaces are delineated through contrasting curves and angles. The curvy geometry is used in the two lower levels of the building, while the two upper levels are orthogonal. The ground floor consists of a drive in and the first floor contains the main entrance and the living areas. The second floor is designed as both living space and gallery room and the third level contains the private (bed)rooms.

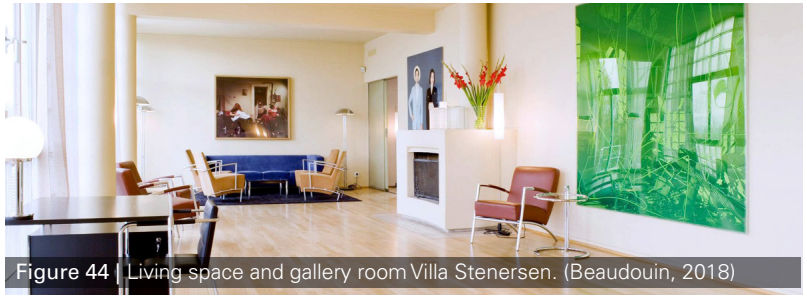


Figure 44 | Living space and gallery room Villa Stenersen. (Beaudouin, 2018)

Figure 45 | Glass brick facade on second floor of Villa Stenersen. (Beaudouin, 2018)

Figure 46 | Front view of Villa Stenersen from the garden. (Beaudouin, 2018)

Positioning openings

Every floor appears different due to the different divisions of the glass surfaces. The facade of the bottom two floors mainly consists of curved surfaces with glass, which gives the opportunity to look over the entire garden. The facade on the second floor is designed to enter enough daylight while the glass bricks filter the light and prevent direct illumination on the art. Besides that, the stairwell is also designated to exhibit art, were 625 glass cylinders are perforated in the roof, resulting in a natural skylight effect (Nasjonaal museet, n.d.).

Colours and materials

The distribution of the surfaces is mainly indicated by the different materials. The floor is finished with wood or natural stone, both of which give a slight reflection of the light (Divisare, 2018). The facade is finished with white plaster and glass bricks or glazing. The blue colour of the southwest façade on the third floor reflects the sky, while the orange drop-arm awnings provide a real contrast to the building and its surroundings. The bright colours are reflected in the ceiling, the floor and the walls and provide contrast in the interior. Different colour motifs are used into the design, such as the interaction between green and yellow on the first floor and the blue hues in the facade and the stairwell's roof. The low reflection of the materials softens the incoming light, creating a warm atmosphere.

Sun, light and shadow

All living areas are facing southwest, towards the garden. The overhang, the sun protection and the inwardly formed facade contribute to keeping the heat outside these spaces during summer while maintaining the view. The bright colours of the facade reflect the sunlight during the winter into the interior, which make optimal use of daylight inside.

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Figure 47 | Interior living area on first floor Villa Stenersen. (Beaudouin, 2018)

Figure 48 | Division of garden and living area Villa Stenersen. (Beaudouin, 2018)

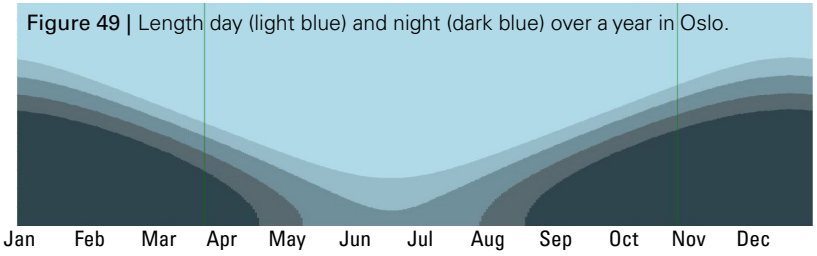

Figure 49 | Length day (light blue) and night (dark blue) over a year in Oslo.

Case Study - Scandinavia
Villa Schreiner

Architect: Sverre Fehn
Built in: 1959 - 1963
Location: Oslo, Norway
Context: Rural, residential
Coordinates: 59°57'54.0"N 10°44'43.0"E

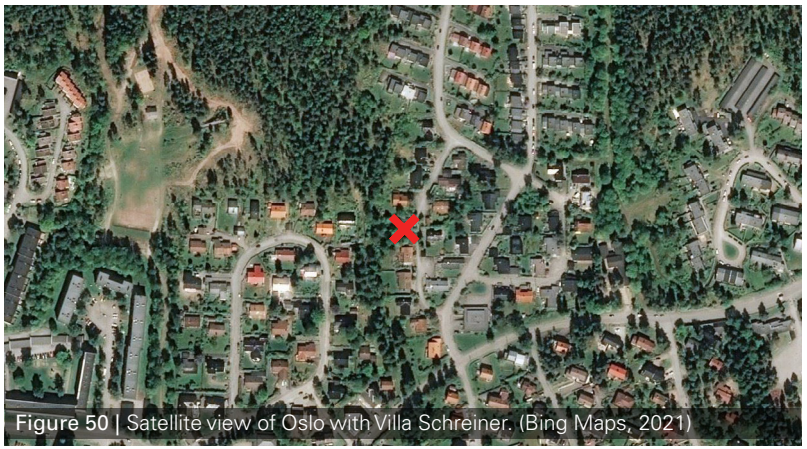

Figure 50 | Satellite view of Oslo with Villa Schreiner. (Bing Maps, 2021)

Orientation, form and organisation

The single-storey villa was commissioned by the economist Per Schreiner and his wife. The detached house is embedded in a natural environment and is also known as 'Japanese home', representing the wooden structure with glass and sliding doors, which connect the living areas directly to the veranda (Archipicture, n.d.). The volume has a rectangular shape and is slightly elevated, so that it seems to float above the grass. A combination of masonry and pine wood beams and columns are used for the construction. As a result, the facades have no load-bearing function. The main entrance is recessed in the east facade, facing towards the street. The veranda continues from the south to the west side of the building from where the green environment can be perceived. The living room is oriented to the west and the bedroom, children's room and dining room are facing south. The core of the building contains the bathroom and kitchen (Atlas of Places, 2020).

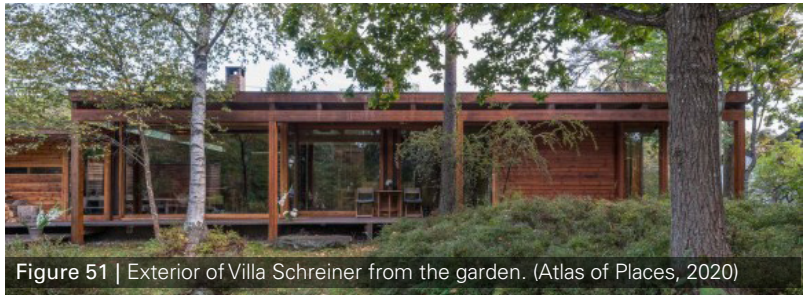

Figure 51 | Exterior of Villa Schreiner from the garden. (Atlas of Places, 2020)

Figure 52 | Interior Villa Schreiner. (Atlas of Places, 2020)

Figure 53 | Kitchen with skylight of Villa Schreiner. (Atlas of Places, 2020)

Positioning openings

The villa is provided with large glass openings on the south and west side creating panoramic views. Due to the fact that the villa is sheltered by the surrounding trees, which mainly during spring and autumn can be disadvantageous, skylights in the core of the house has been applied to distribute a sufficient amount of natural light in every space.

Colours and materials

The outside of the building is cladded with timber. In contrast to the east facade, the other facades mainly exists of large glass surfaces. The finishing of the floor is made out of Terrazzo concrete (Atlas of Places, 2020). The light colour of the floor reflects the incoming light, while the overhang and ceiling with both wooden finishes ensure that the bright light, that is amplified through the snow, is absorbed and does not cause glare during winter. Different colours of red, brown and orange with warm tones are used in the interior to create a comfortable atmosphere. The wooden colours continue in the window frames and exterior.

Sun, light and shadow

During the winter it seems as if the white floor continues into the snow-covered garden. The use of wood as a natural material reflects the environment and, because of the large windows, unites the inside of the house with its surroundings. An additional feature is the veranda that enlarges the outdoor space of the villa and integrates it into the interior. The large windows are provided with shutters, which can be used to adapt the indoor climate.

References

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Archipicture (n.d.). *Sverre Fehn - Norway: Villa Schreiner.* Retrieved from: http://www.archipicture.eu/Architekten/Norway/Fehn%20Sverre/Fehn%20Sverre%20-%20Villa%20Schreiner%201.html

Figure 54 | Exterior Villa Schreiner during winter. (Atlas of Places, 2020)

Figure 55 | Fireplace in centre living area of Villa Schreiner. (Atlas of Places, 2020)

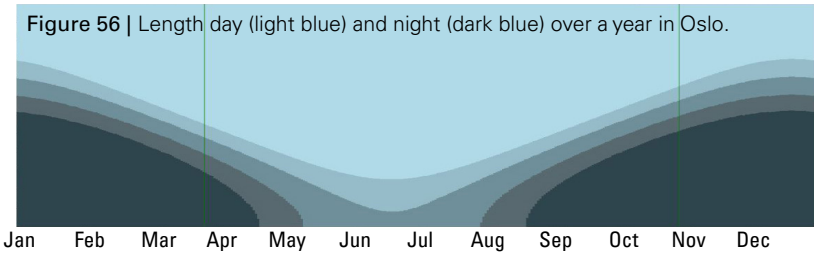

Figure 56 | Length day (light blue) and night (dark blue) over a year in Oslo.

Case Study - The Mediterranean
Casa al Villaggio dei Giornalisti

Architect: Luigi Figini and Gino Pollini
Built in: 1933 - 1935
Location: Milan, Italy
Context: Urban, residential
Coordinates: 45°29'50.6"N 9°12'06.3"E

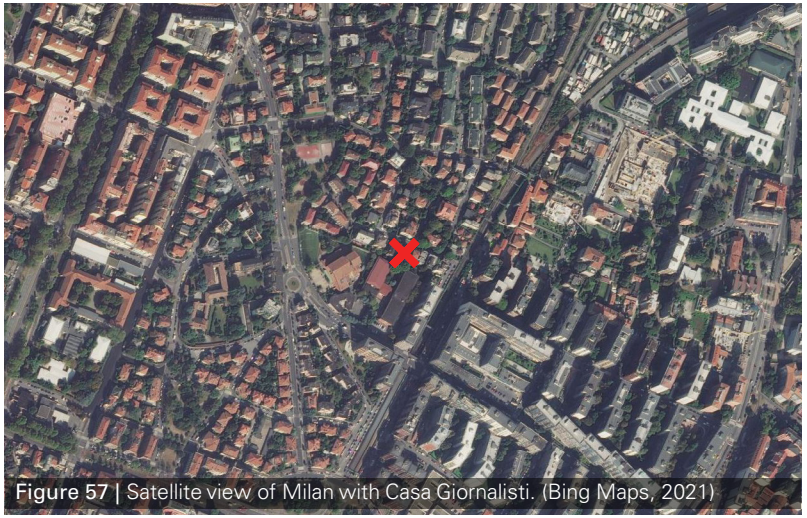

Figure 57 | Satellite view of Milan with Casa Giornalisti. (Bing Maps, 2021)

Orientation, form and organisation

Casa al Villaggio dei Giornalisti is located in an area developed for journalists in the north of Milan and was built for Figini himself. The rectangular shape is characterized by the extra attention to the heliothermal axis, which means that the volume is elongated towards the northeast and southwest to achieve the best amount of daylight and heat control. The concrete reinforced structure with pillars has been used to create the open floor plan. A single section staircase is located on the west side to access the main entrance on the first floor (Wikiarquitectura, n.d.). Here, the living room with terrace, kitchen and service bedroom are located. The second floor contains the bedrooms, bathroom and access to the solarium terrace (Rinalduzzi, 2015).

Figure 58 | Dining room with terrace view of Casa Giornalisti. (Domus, 2010)

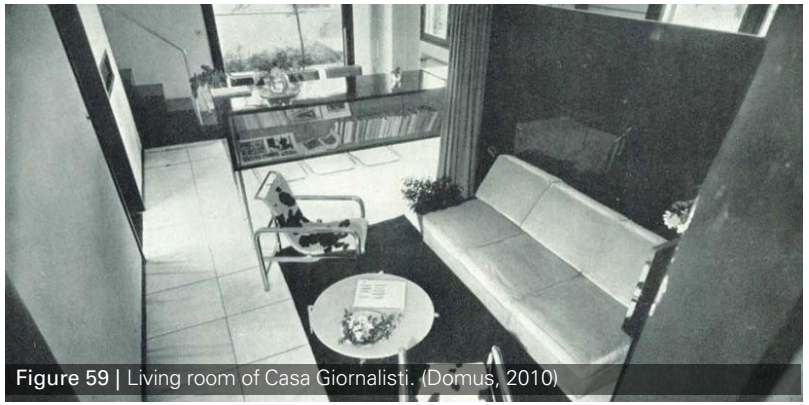

Figure 59 | Living room of Casa Giornalisti. (Domus, 2010)

Figure 60 | Exterior of Casa Giornalisti. (Domus, 2010)

Positioning openings

The facade is provided with ribbon windows and vertical recesses creating panoramic views. The windows of the living areas are mainly located in the southeast facade. The northwest facade is divided into three windows of the bedroom and circulation areas. All the living areas have a view at a terrace. The large glass surfaces towards the terraces ensure an almost limitless transition from outside to inside.

Estimated colours* and materials

White plaster has been used to cover the exterior facades. The walls of the terraces are expressed in green. The window frames are expressed in dark green, which contrasts with the light-coloured walls and shutters. The floors and curtains have a contrasting colour, using ochre, pink, black or white, that demarcates the spaces vertically and horizontally. The marble floor reflects the incoming daylight (Domus, 2010).

* Since most of the images are in black and white, an assumption of the colours has been made based on a description of the interior from the magazine Domus (2010).

Sun, light and shadow

The specific attention to the sun rays can be found in the orientation of the building and also the position of the terraces with the surrounding recesses within the design, ensuring optimal use of sunlight, fresh air and a view of the green landscape and taking into account their variation in time. The south-facing terrace acts as a buffer to prevent heat from entering the building in the hot Italian summer, while the front terrace on the north is used to create a secluded space without affecting the daylighting within the building. The internal organization of spaces at different heights is arranged in such a way that natural ventilation is facilitated. Furthermore, the windows on the first floor can be closed off with shutters to adapt the indoor climate.

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Figure 61 | Terrace on first floor of Casa Giornalisti. (Domus, 2010)

Figure 62 | Exterior of Casa Giornalisti. (Domus, 2010)

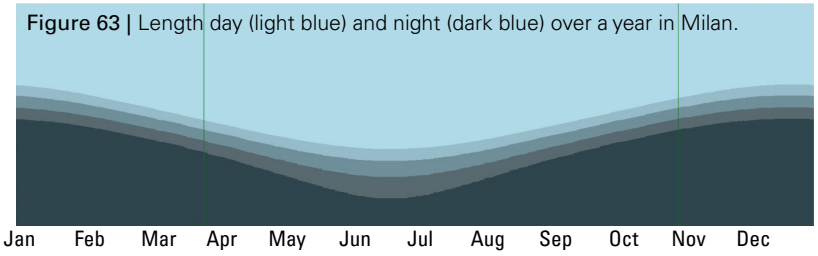

Figure 63 | Length day (light blue) and night (dark blue) over a year in Milan.

Case Study - The Mediterranean
Vivenda de verán

Architect: Carlos Meijide
Built in: 1972
Location: Barreiros, Spain
Context: Rural, residential
Coordinates: 43°33'55.4"N 7°13'40.7"W

Figure 64 | Satellite view of Barreiros with Vivenda de verán. (Bing Maps, 2021)

Orientation, form and organisation

Vivenda de verán is built in a small village for Carlos Meijide and his family on the edge of a cliff that borders the beach. The cross shape has its long facade oriented to the northeast and southwest and can be entered via the north-east facade. The views towards the sea are mainly obtained from the hall, living room and main bedroom. The construction is made out of a load-bearing facade and a wooden roof structure (Divisare, 2017). The facade is accentuated by its vertical lines, while the roof is expressed by its horizontal lines. The skylights form a striking protrusion of the flat building and give the building a playful character, which contrasts strongly with the surrounding traditional buildings.

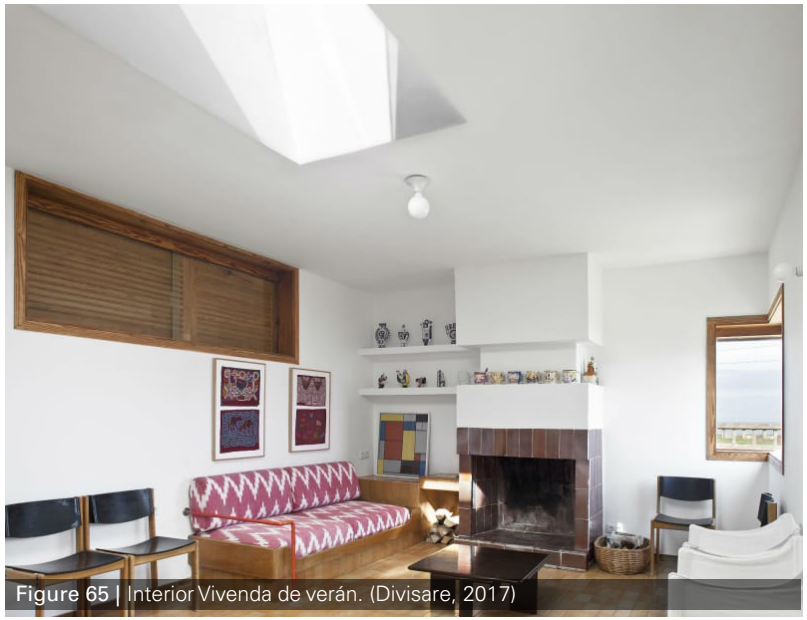

Figure 65 | Interior Vivenda de verán. (Divisare, 2017)

Figure 66 | Exterior Vivenda de verán in the 1980s. (Valverde, 2013)

Positioning openings

Due to its geographic location, the views are a predominant theme for the design and the position of facade openings. The continuous connections of the glazing in the corners of the building ensure that the view is not restricted (Almuíña Díaz, 1977). The facade openings are positioned parallel to the coastline. In addition, the skylights have been added to the core to allow more daylight to enter.

Colours and materials

The original roof was painted brown and made out of folded sheet metal (Valverde, 2013). As a consequence of the damages by saltpetre, the roof was first repaired with fiberglass and after that had to be changed into copper. The facade is made out of granulite and wooden slats. The window frames and slats are made out of wood in a pine tree colour. Due to the adverse weather conditions, reparations had to be made and were painted red. Later, the window frames were repaired to their original wooden colour and this has resulted in a natural colour palette. The inside floor is made out of small brown tiles, which corresponds to the original facade colour, and the walls are white, giving the interior an abstract appearance (Divisare, 2017).

Sun, light and shadow

The skylights, facing southeast, are designed in such a way that they bring in the light of the afternoon sun into the interior of the bathroom and living room, which determined the shape of the hipped roof. Although the windows are mainly located in the north-east facade, daylight and solar heat can still be kept out by using the sliding wooden slats, which also function as protection of the windows from the weather.

References

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Figure 67 | Interior overlooking the sea of Vivenda de verán. (Divisare, 2017)

Figure 68 | Exterior of Vivenda de verán. (Divisare, 2017)

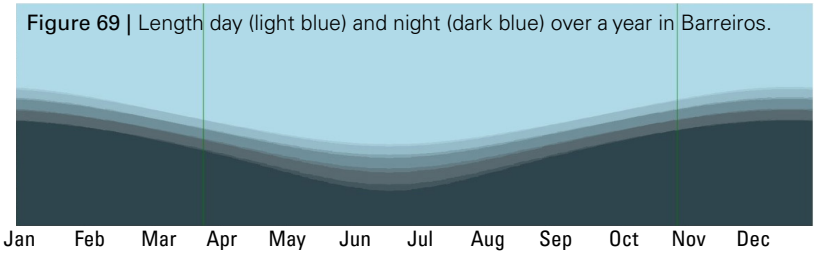

Figure 69 | Length day (light blue) and night (dark blue) over a year in Barreiros.

Conclusion

The influence of location to the design is clearly visible in the different colours that are applied. Only earthy colours have been used in Villa Schreiner and Vivenda de verán, through which it is included in its natural context. The elevated projects stand out, because of the bright white colour, contrasting with their surroundings. The colour palettes show that the interior surfaces of the northern villas contain different warm tones, while the interiors of southern villas are cooler, with just a few colours and a white ceiling. The light in the northern houses is better reflected by the bright coloured surfaces than if these were dull soft colours. In southern areas, this can ensure a soft and subtle reflection of the light. The difference in the finish of the ceiling is the result of the reflection of light, which results in a different perception of light in the villa. In northern interiors, the bright reflection of light from snow should be absorbed to prevent glare, while the white colour in the southern interiors results in diffuse light.

The single-storey villas are provided with skylights above the core, to ensure sufficient direct, in Villa Schreiner, and indirect, in Vivenda de verán, daylight during the day. Especially the living areas of the northern villas are oriented to the south and are folded around the sanitary rooms, kitchen and hallway in order to obtain maximum daylight. The windows of the southern villas are strategically placed to obtain sufficient daylight without overheating, while the northern villas are distinguished by their large glass surfaces. In addition, each architect took the local climate into account in a different way, without affecting the outside views. At Casa al Villaggio dei Giornalisti, two indoor terraces provide a controlled way of letting sunlight and solar heat in and at the same time form a quiet place. In Villa Schreiner, the afforestation has been taken into account, which ensures that the light does not reach far into the rooms, by integrating additional skylights in the centre of the building. In Vivenda de verán, the skylights have been used to avoid nuisance from direct light and to limit solar heating in the rooms. In Villa Stenersen extra attention is paid to the exhibition space, where careful considerations in the use of daylight within the design are required. The use of glass bricks and glass cylinders provides diffused light and also protects the art, while the lower floors are provided with large windows and an overhang, which regulate the indoor climate and ensure direct light.

Figure 70 | Interior Scandinavian villas and their colour palettes. (Beaudouin, 2018; Atlas of Places, 2020)

Figure 71 | Interior Mediterranean villas and their colour palettes. (Domus, 2010; Divisare, 2017)

Conclusion

In this history thesis, the role and use of daylight within architecture is explained. This stems from the different approach to the organization and shaping of a building and its openings that is required at different latitudes. Depending on the 'place' and 'time', different types of architecture are evolved. Through research into the history of the role of daylight in architecture and the effect of place and time on architecture, sufficient information has been gathered to carry out a comparative research into residential and religious buildings between Scandinavia and the Mediterranean. With the conducted research, the following question can be answered: 'How is natural light utilized in modernist architecture in northern and southern climates within Europe during the twentieth century?'

The utilization of daylight and the cultural significance has evolved over the centuries. Until the twentieth century, daylight was mainly used for functional and decorative purposes, to illuminate specific elements in a room. Although solar design was already introduced by organizing the spaces within a building, many possibilities had not yet been developed. The advent of artificial lighting and new materials gave architects more freedom and possibilities in designing and positioning daylight openings. In addition, the benefits of daylight, fresh air in buildings were recognized and the function of the building became key within the progressive architectural style modernism. This also resulted in more differences between the north and south, as it became possible to consciously anticipate the design to the local climate. Local architecture was adapted and responded to the amount of daylight and solar heat, geography and culture. Thus, simplicity and harmony of forms related to the natural conditions of a place were sought. This is also reflected in the comparison between the Scandinavian and the Mediterranean religious buildings and villas. The daylight openings have been used in strategic places to keep the heat out in southern areas and still get a sufficient amount of daylight in without causing glare. In northern areas, the openings were used in different surfaces, so that the scarce light reaches as far as possible into the building in multiple ways. Within these buildings, direct daylight was used or, the vertical or horizontal surfaces were illuminated. In contrast, the southern interiors were illuminated with indirect daylight, generated through thick facades, ceiling structures, or translucent materials. Large glass surfaces were only used in villas. This is because the light from high surfaces enhances the religious character of the church, while the view and the connection with the outside play a significant role in a domestic environment.

The experience of daylight is also influenced by the used colours, in which contrast plays a major role. In churches this is reflected in the wooden furniture that contrasts with the light colours. Furthermore, in the north, raw, lightly treated materials are used, which gives a cool character to the interior. In southern churches warm colours are used to soften the contrast. Churches are related to the historic style, thus, certain traditional elements of a religious building must be maintained within new designs. Although this has been worked out in a different way by the modernist architects, the same goal is achieved, which is to simulate light rays from the sky.

The orientation of the villas was determined by the advent of innovations based on solar radiation, local climate and the internal organization, but was also influenced by the available space on the plot and the outside views. By creating the open floor plan, villas became freely divisible. Within the simplistic building forms, these possibilities ensured that certain elements in a home were highlighted, the interiors were provided with views and a comfortable indoor climate was realized. The two opposing European climates both require that the indoor climate is secluded from the outside for parts of the year. The light in the northern houses is therefore reflected from the brightly coloured surfaces. In winter, the focus is mainly to obtain as much daylight as possible into the interior, through which skylights and large glass walls were used. Snow was also an important element that reflects sunlight, which must be absorbed by the ceiling. In the south, the smallest openings in the summer can provide enough light without heating up the house. Larger openings are only used if these can also be protected from direct sunlight. Moreover, especially soft colours have been used to create a subtle reflection in the interior.

In conclusion, in northern modernist architecture, particular emphasis has been placed on reflections, colour, contrast, direct light and the raw lightly treated materials. The Bagsvaerd church in particular leaves an important impression with the secure implementation of daylight in the building. Softening the incidence of light by using curved shapes was innovative at that time and the precision with which this has been incorporated into the design is inspiring to this day. In the southern modernist architecture, particular attention has been paid to solar radiation, obtaining indirect daylight, the minimal use of bright colours and the architectural solution to block the solar heat. Especially Casa al Villaggio dei Giornalisti can be seen as an innovative residential building of the twentieth century, because of the extra focus on the heliothermal axis, where the shape is determined by the movement of the sun.

Although the projects show many differences, some noticeable similarities are also observed, such as the internal experience that determines the design, the orientation, elaboration of the smooth surfaces of the buildings, the connection of the villas and their surroundings and the effect of obtaining light from above in religious buildings. Thus, the utilization of daylight within modernist architecture was dependent on the local culture, geography, movement of the sun, brightness of sunlight, surrounded colours, reflections and solar heat.

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69 | Length day and night over a year in Barreiros. *Authors own image,* adapted from: https://www.timeanddate.com/sun/@3128625

70 | Interior Scandinavian villas and their colour palettes. *Authors own image,* adapted from: Beaudouin, L., 2018, http://www.beaudouin-architectes.fr/2018/08/arne-korsmo-maison-stenersen/ and Atlas of Places, 2020, https://www.atlasofplaces.com/architecture/villa-schreiner/

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Figure 72 | The change of light. (Eliasson, 2012)

Appendixes

Appendix I- Historical timeline of the role of daylight in architecture

Appendix II- Detailed collage with drawings and photos of the case studies

Appendix I- Historical timeline of the role of daylight in architecture

Ancient Egypt

3100 BC- 300 BC

Ancient Egypt
Aim of daylight utilization is to prevent glare by minimizing openings in facade and roof.

- ✓ limitation opening sizes due to spanning ability stone
- ✓ application of clerestories and roof slits
- ✓ thick walls to diffuse and soften daylight

Ancient Rome

700 BC- 500 AD

Ancient Rome
Aim of daylight utilization is to resist external climate and to obtain optimal orientation.

- ✓ new technologies such as the round arch, the dome and the barrel caused new possibilities to create larger spans and openings
- ✓ application of square and circular wide sheets of light, larger skylights, clerestories and glazing
- ✓ rectangular building elongated along east and west side to gain heat during winter

Byzantine

300 AD- 1500 AD

Byzantine
Aim of daylight utilization is to emphasize the centre of the building using coloured glass.

- ✓ application of small stained glass windows where portions are filled with translucent marble slabs to make the dome float optically
- ✓ rectangular floor plan where the four corners (pedentives) allowed support of the primary dome and half domes were used to cover secondary spaces
- ✓ openings are rectangular with a semicircular head

Gothic

1100 AD- 1600 AD

Gothic
Aim of daylight utilization is to provide a maximum of daylight from south facade.

- ✓ primary role wall is not load-bearing, which resulted in major stained glass surfaces with buttresses
- ✓ sophistication of groined vaults and stone masonry
- ✓ introduction of pointed arches allowed different widths of the roof vaults
- ✓ primary facade of almost every major cathedral is facing west and can be recognized by two towers

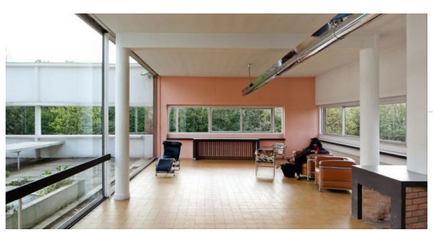
Baroque

1500 AD- 1800 AD

Baroque
Aim of daylight utilization is to play with light and perspective by creating hidden openings.

- ✓ complexity of building design
- ✓ differentiation between lightened higher levels and dark and dimly lit lower levels
- ✓ architecture as revolution of different historical building styles resulting in imitation and eclecticsim

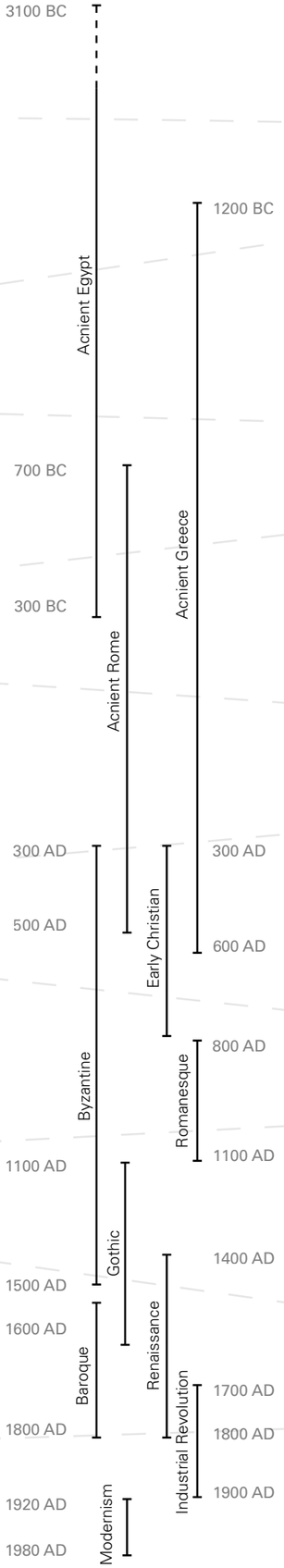
Modern Movement



1920 AD- 1980 AD

Modern Movement
Aim of daylight utilization is to create the free layout of the floor plan.

- ✓ focus on new possibilities, orientation, daylight and ventilation creating healthy architecture
- ✓ the need to seperate knowledge because of the extensive growth of structural, mechanical and electrical systems
- ✓ free and open design of the floor plan and the facade, by replacing supporting walls with reinforced concrete columns and implementing horizontal windows



Ancient Greece
Aim of building is to be seen rather than to be inhabited. Period of creating shade and spatial layering.

- ✓ openings only important to illuminate objects or accentuate ornamentation
- ✓ application of colonnades and porches
- ✓ small openings such as narrow shafts of light as a result of limitation spans
- ✓ orientation temples to east side to illuminate objects at sunrise

Early Christian
Aim of daylight utilization is to enhance the character of religious spaces.

- ✓ reduction of load on walls due to timber trusses
- ✓ application of larger openings and sloping roofs
- ✓ smaller clerestories and the converging light to the apses enhanced nature of religious spaces

Romanesque
Aim of daylight utilization is to evolve different features of Roman period.

- ✓ reintroduction of round masonry vaults instead of timber trusses
- ✓ application of cross floor plan, elevated dome at center of cross and groin vaults
- ✓ small openings equipped with clear glazing and appearance of rose windows
- ✓ mystic and dim atmosphere in the interior

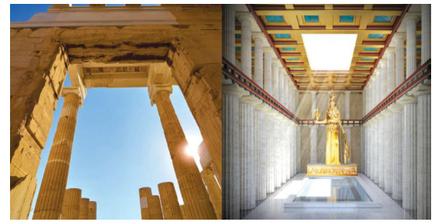
Renaissance
Aim of daylight utilization is to rediscover features of Ancient Greece and Rome.

- ✓ focus on proportion, classical elements and playfullnes with lighting
- ✓ sophasication of openings to express the architectural shape of the exterior and exaggregate the interior
- ✓ houses were equiped with unobstructed and large openings which were grouped vertically
- ✓ windows had a square or semicircular shape and were dependent on the local climate (Italian buildings had small windows while North-European buildings were provided with large climate windows
- ✓ location of different spaces was also dependent on orientation and climate (thicker walls with recessed openings or walls with more openings and direct views)
- ✓ bright atmosphere in buildings

Industrial Revolution
Aim of daylight utilization is to increase access to natural light around building perimeter.

- ✓ focus on slim structure containing steel columns which resulted in a reduction of weight and increasing of space
- ✓ facade only serves as a seperation between exterior and interior
- ✓ the emergence of steel resulted in a new kind of architecture with considerably more design possibilites, whereby the previous limitations of weight, opening size and spans had largely been resolved
- ✓ the larger openings and glass sizes also caused the possibility of glare, winter heat loss and summer solar heating

Ancient Greece



1200 BC- 600 AD

Early Christian

300 AD - 800 AD

Romanesque

800 AD - 1100 AD

Renaissance

1400 AD - 1800 AD

Industrial Revolution

1700 AD - 1900 AD

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Appendix II- Detailed collage with drawings and photos of the following projects:

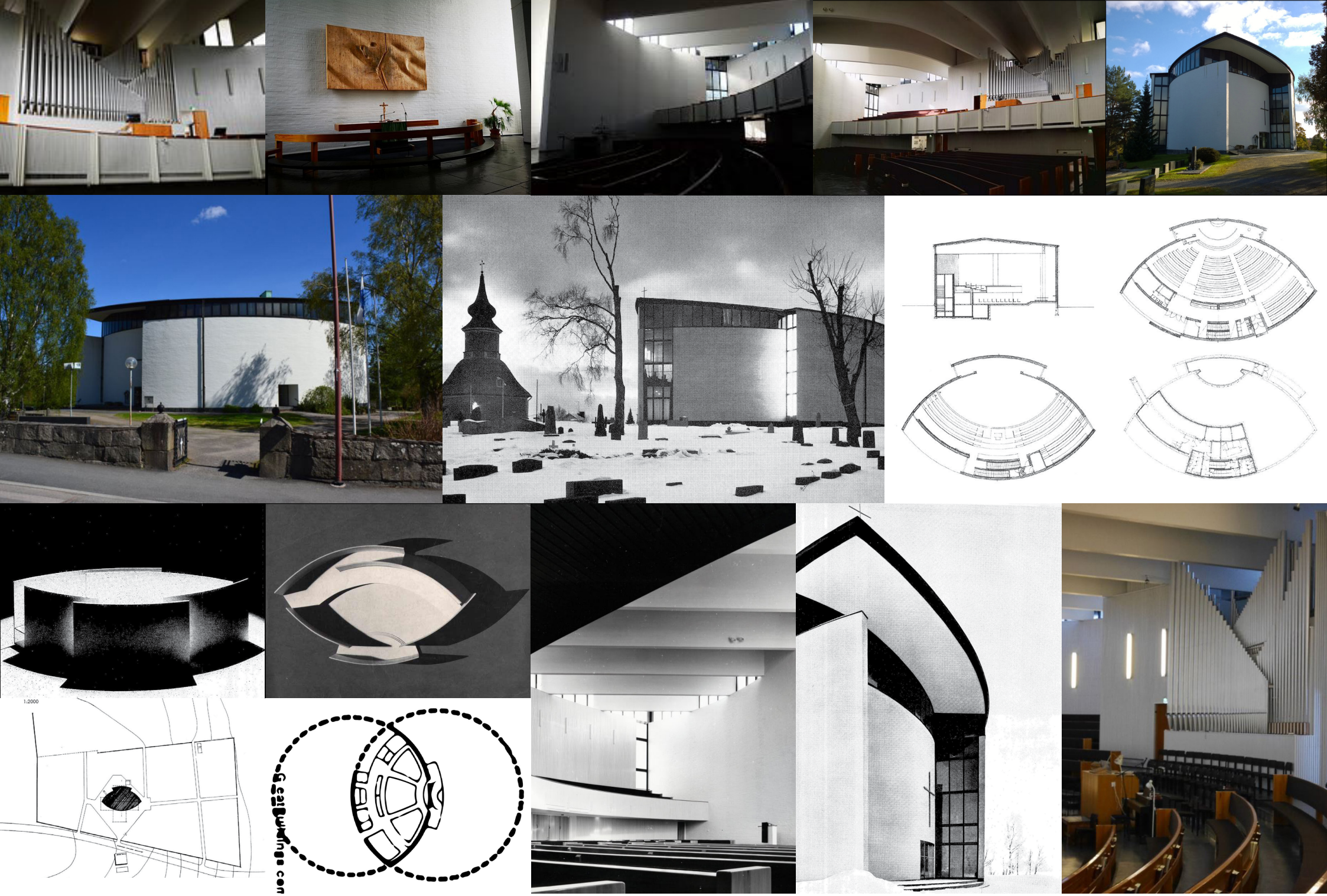
Religious architecture

- Orivesi Church by Kaija and Heiki Siren
- Bagsværd Church by Jørn Utzon
- Nostra Signora della Misericordia by Angelo Mangiarotti, Bruno Morassutti and Aldo Favini
- Chiesa di San Giovanni Battista by Carlo Scarpa and Edoardo Detti

Residential architecture

- Villa Stenersen by Arne Korsmo
- Villa Schreiner by Sverre Fehn
- Casa al Villaggio dei Giornalisti by Luigi Figini and Gino Pollini
- Vivenda de verán by Carlos Meijide

Daylight & Architecture - Orivesi Church



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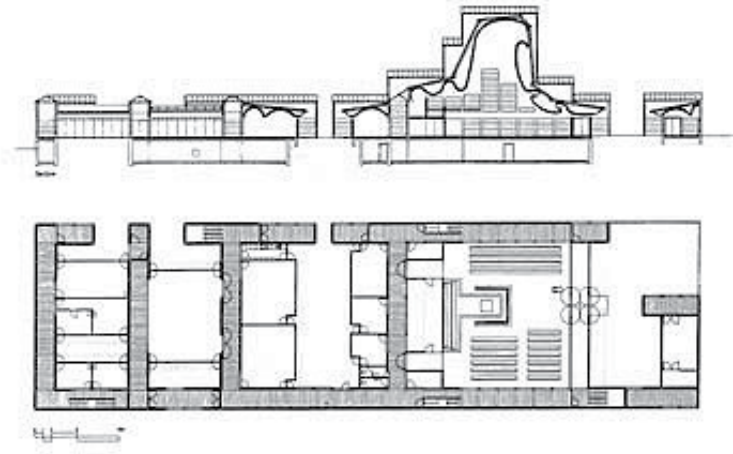
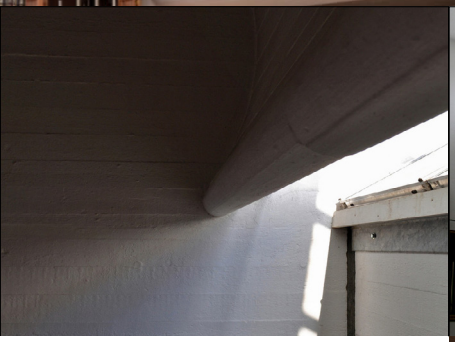
Daylight & Architecture - Bagsvaerd Church

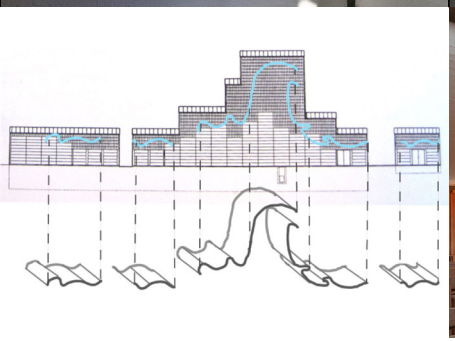






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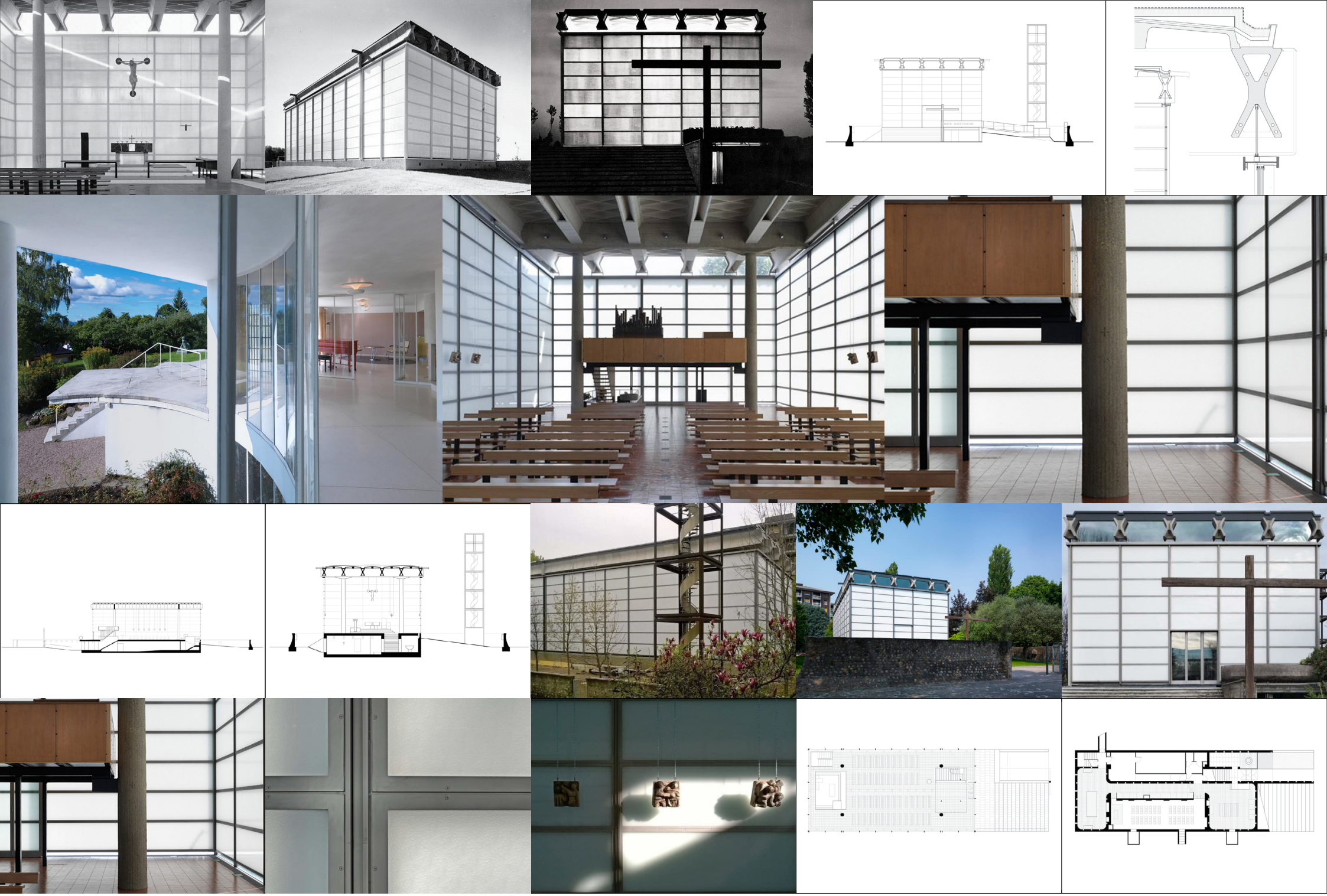
Daylight & Architecture - Nostra Signora della Misericordia



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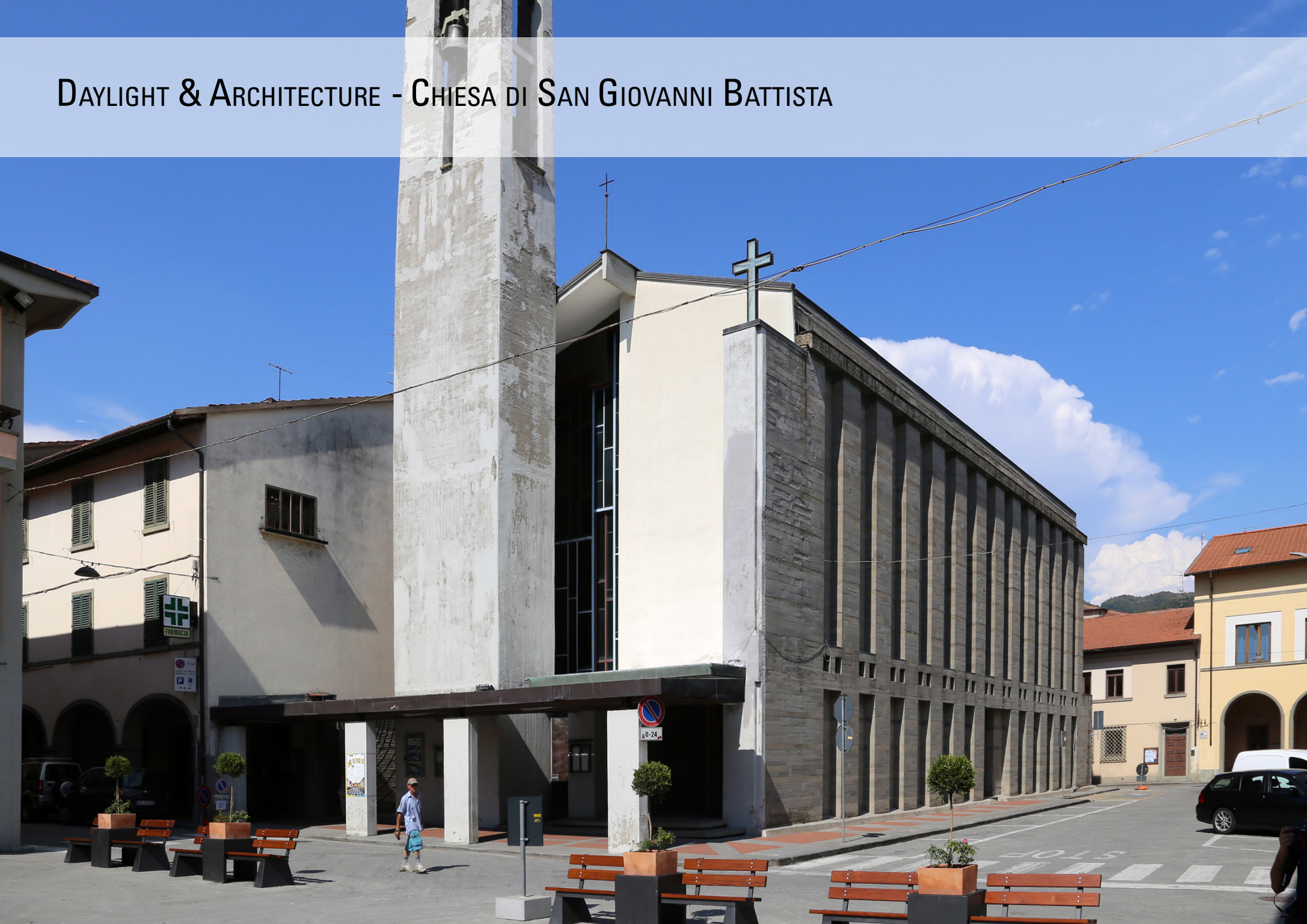
Daylight & Architecture - Chiesa di San Giovanni Battista



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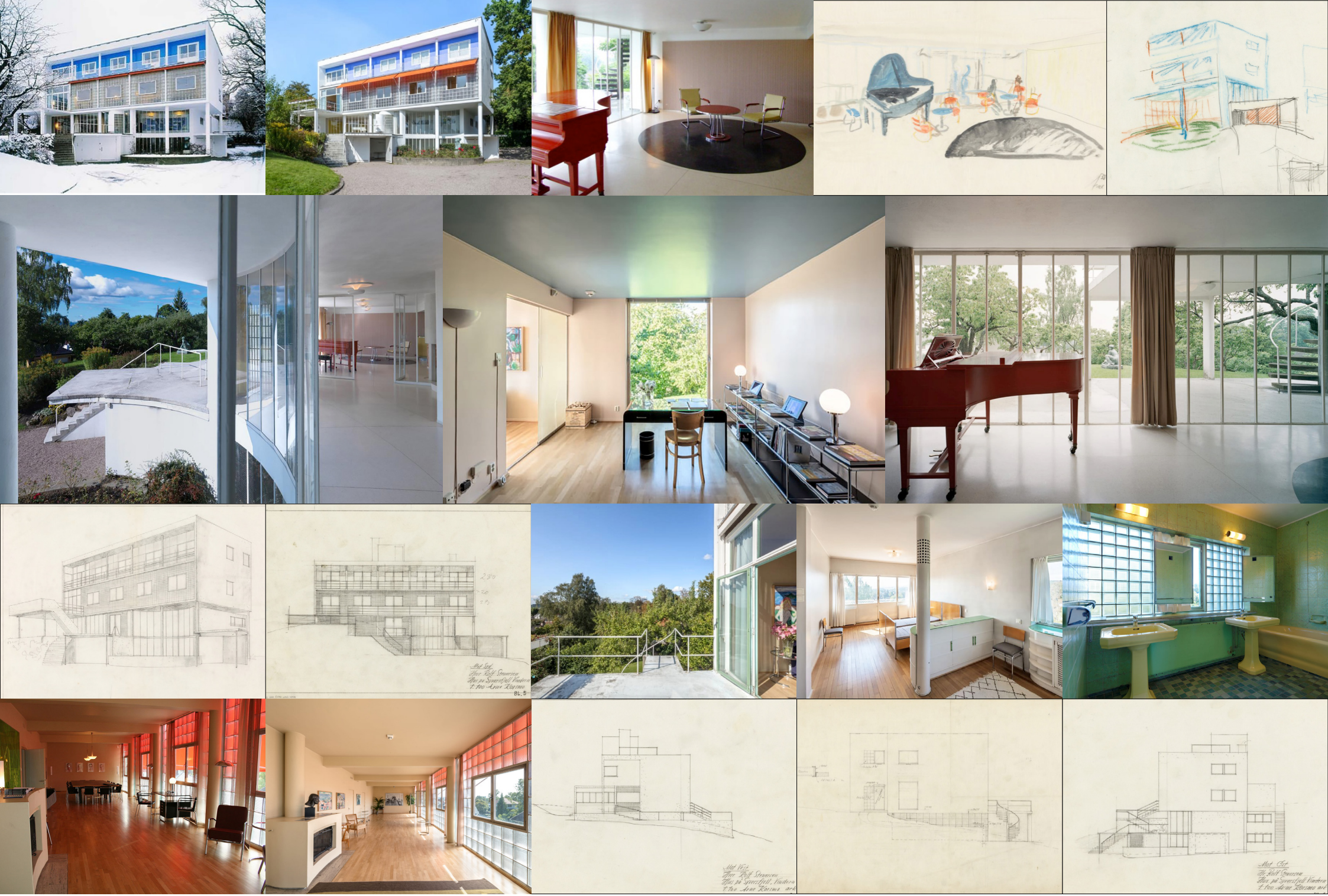
Daylight & Architecture - Villa Stenersen



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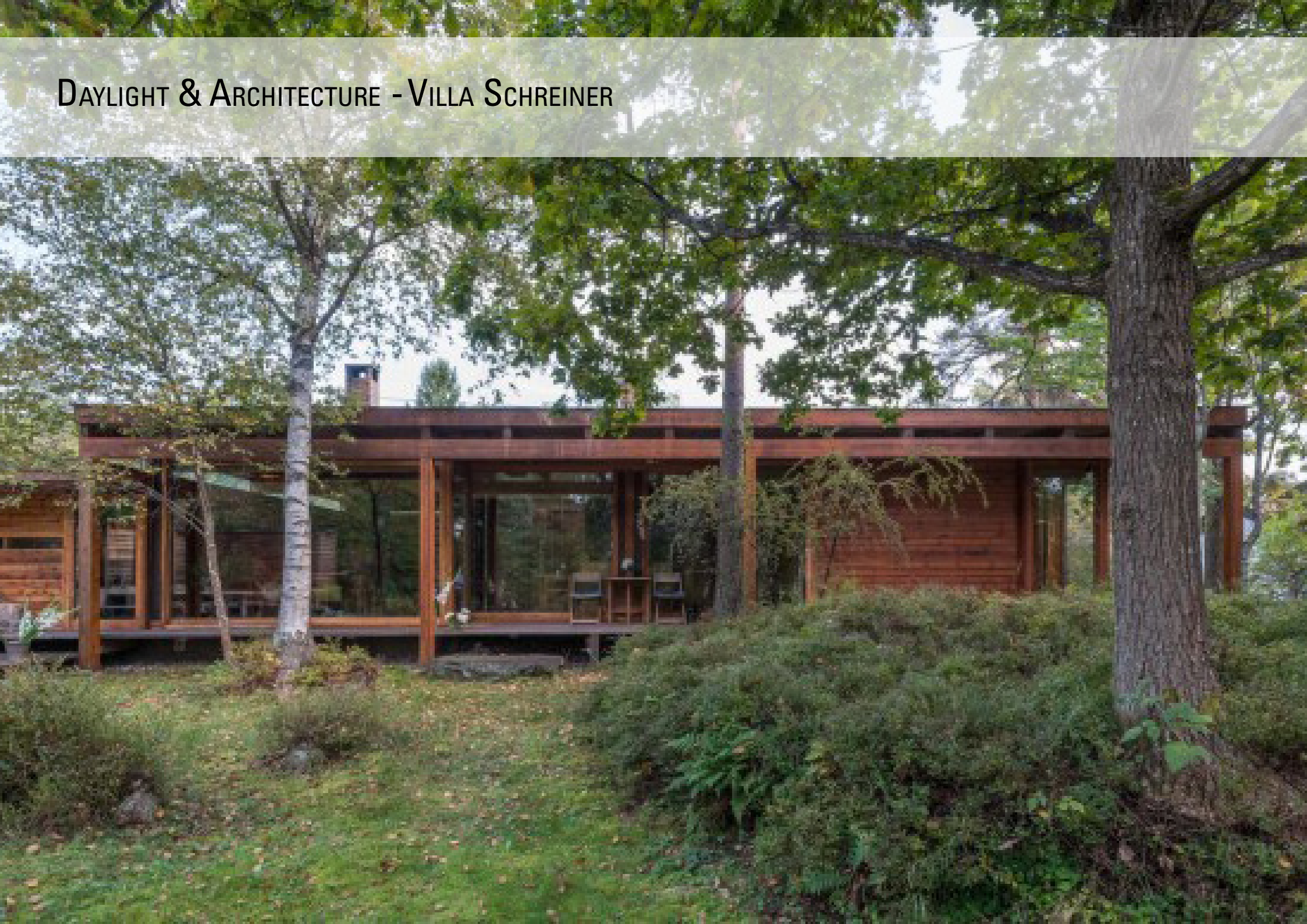
Daylight & Architecture - Villa Schreiner



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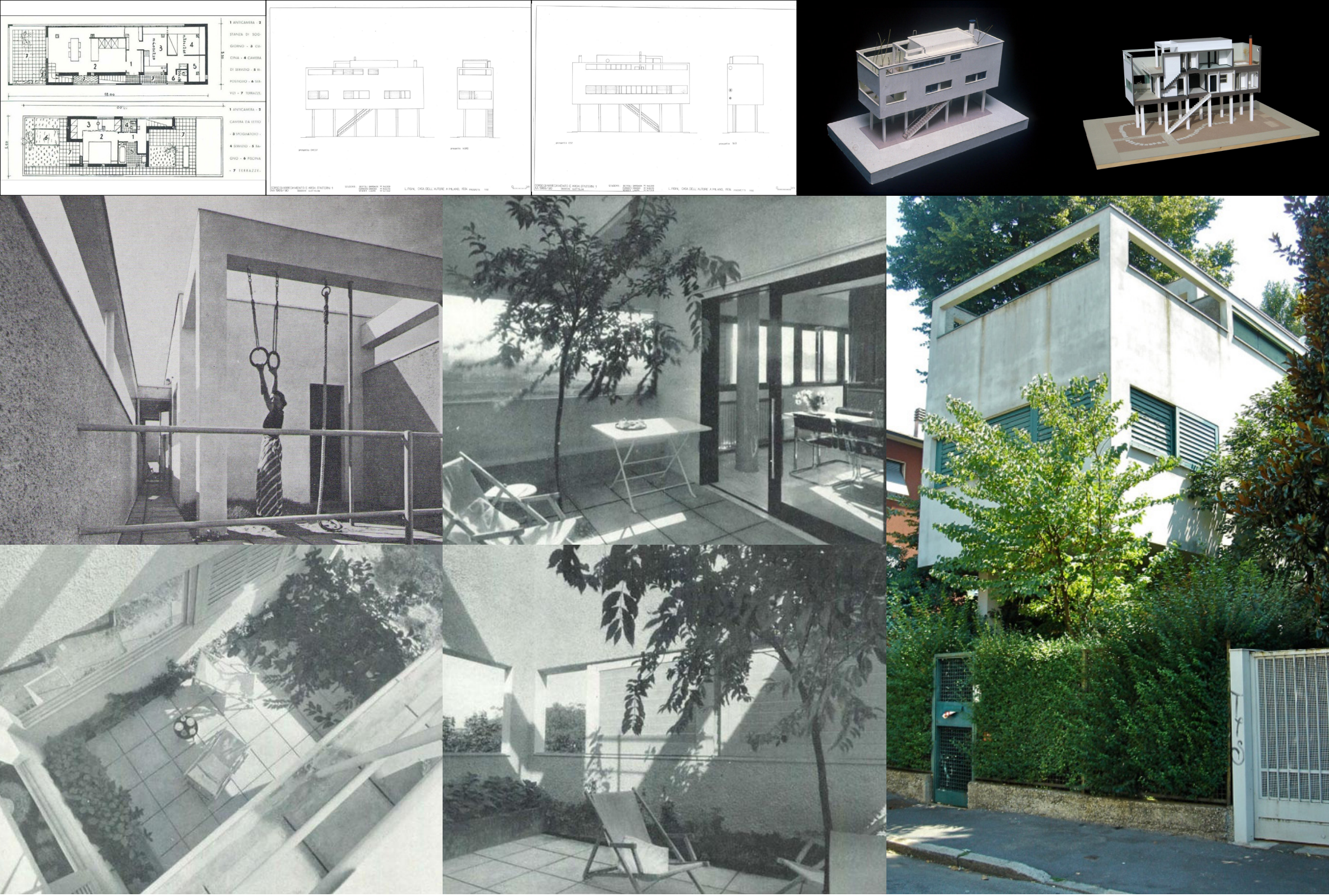
Daylight & Architecture - Casa al Villaggio dei Giornalisti



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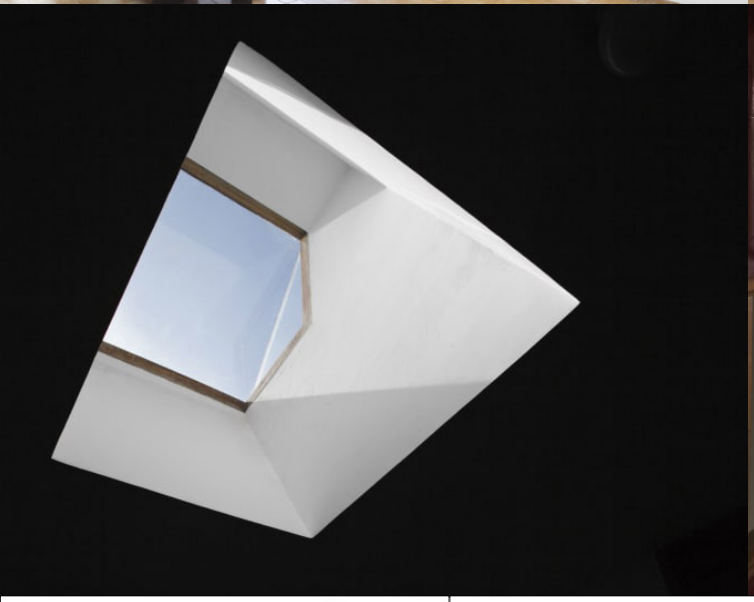
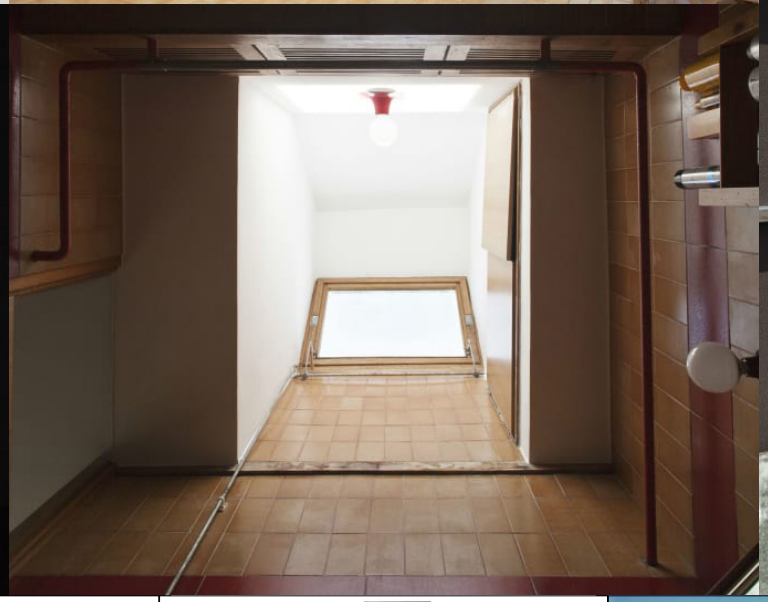
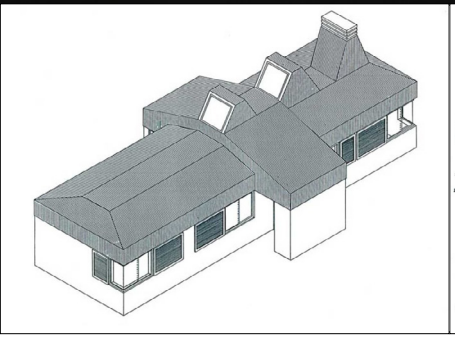
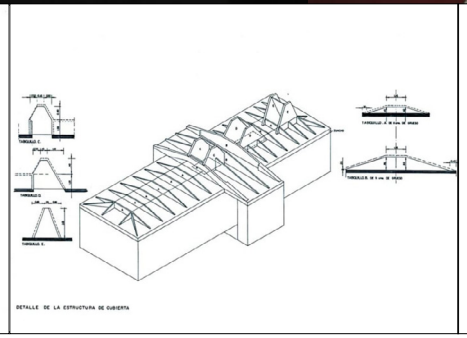
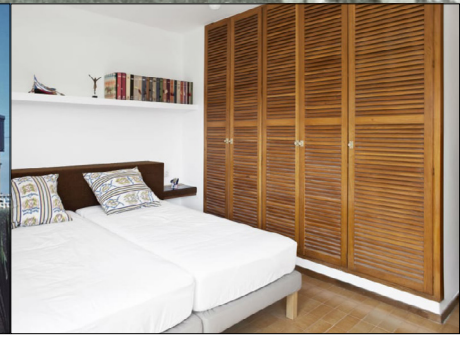
Daylight & Architecture - Casa Vivenda de verán







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