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Research on Application of Natural Light in Modern Architecture Design

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Abstract:

The modern construction industry is booming, and the forms of public buildings are emerging one after another. With the transformation of traditional buildings, new building technologies and materials are changing with each passing day. In this development background, people have higher and higher requirements for the architectural light environment. This article conducts a preliminary study on the application of natural light design techniques in architectural design. Through the general layout of the building, interior space, and exterior facade design, some ideas on architectural lighting design are summarized to provide designers with references.

Keywords: Natural light, indoor environment, design techniques

1. Introduction

Sustainable development has become a necessity, and society reflects ecological awareness, it is necessary for us to think about resources and the environment from an operational perspective. Natural light refers to the direct light source of the sun. Natural light has a great impact on space, and can produce light and shadow to make space becoming strong and vibrant, it can also make the space composition and building space environment feel clear. The characteristic of natural light is that it changes with the influence of time, region, season and weather(Ahani, 2011). The modern architectural design uses natural light reasonably and effectively, reduces energy consumption, reduces the operation and maintenance of the building, becoming a modern and final architectural design method when building buildings.

Human dwellings have evolved from primitive wooden structures to nests and dwellings in caves to today's intelligent skyscraper buildings, which has undergone a fundamental change. However, the building's indoor environment maintained by consuming a large amount of coal, oil, natural gas and other energy sources not only has no real proof to bring people a safe, healthy and comfortable life, but also consumes a lot of precious non-renewable resources(Kemsley & Platt, 2013). At present, 20% of the world's population consumes 80% of the world's energy and at the same time creates a corresponding amount of pollution. 50% of the energy consumption is used for the production and operation of buildings. The idea of sustainable development has become the consensus of mankind. In the face of increasingly serious environmental problems, the use of renewable resources has very important practical significance(Moohan-Sidhu, 2018).

1.1. Significance of Research

With the advancement of science and technology, people enjoy the fruits of civilization while also suffering from natural punishments. After experiencing two energy crises in the 1970s and facing the current increasingly destructive global ecological environment, people became worried about their living environment and began to examine their actions(Nash, 1981). As a result, a return to nature complex spontaneously arises, this kind of humanistic thinking arouses people's desire to rebuild a green home. It is under this background that people began to pay attention to nature by protecting the ecological environment of buildings, applying local materials, and rationally using natural resources. How many buildings today are numb and no longer respond to changes in the environment, ignoring warmth, natural light and fresh air. The use of glass, electric lights, and air conditioners solves the contradiction between protection from the cold and lighting, and makes the indoor environment like spring all year round. With the continuous development of science and technology, this kind of man-made comfortable building is becoming more and more perfect and people are more and more happy in it(Day et al., 2020). However, building energy consumption and damage to the environment are increasing, and people are becoming more and more away from the sun and air in nature. Therefore, we have to rethink some problems, such as how to make a trade-off between the relatively 'completely' comfortable artificial environment made by machinery and the embrace of colorful and healthy nature.

Natural light is a very attractive design entry point, which reflects the colorful environment, Aesthetics and human factors are also indispensable factors in modern architectural design. At present, there are relatively few researches on the use of natural light in architectural design in the World. Most of the relevant researches only discusses from the perspective of technology and art on the one hand, it theoretically discusses the lighting of natural light in buildings through scientific experiments and data analysis from a technical perspective. This has caused a misunderstanding that discussing natural light is only the task of architectural physics on the other hand, discussing the artistic value of natural

light from an aesthetic and philosophical point of view seems to lack operability in the actual design of architects. In view of the above situation, this article will try to consider natural light as a usable natural resource from the perspective of 'sustainable development', and discuss the design method of using natural light in modern architectural design in combination with environmental factors.

1.2. Purpose of the Research

This paper discusses the architectural design methods and means of using natural light in modern architectural design. Through the understanding of the characteristics and nature of natural light itself, the importance of natural light to people and buildings, and the analysis of the impact of overall environmental factors on natural light, natural light is considered as a natural factor and natural resource.

These methods regard the use of natural light as an architectural design problem, and considers the form, volume, profile, the organization of the plane, the type, structure and materials of the building as a whole.

1.3. Basic research Framework

The writing of this paper is based on what Louis Kahn said: 'Natural light (sun) never knew how great it was until it hit the side of a building'. The building is regarded as a medium connecting the external environment and the internal space to form a photo paper the discussion framework. The content mainly includes the factors of people, environment and architecture(Uddin, 2008). The relationship between architecture and environment and the relationship between architecture and people are problems that architecture must face directly, and it is also the foundation of architecture. The arrangement of the chapters is based on the path process of natural light entering the building body from the emission point, that is, from the external environment into the internal space of the building through the interface of the building. Different latitudes of the external environment will cause differences in the intensity and angle of natural light. In the design, we should fully understand the environmental factors that affect the use of natural light in the area where the building is located, and take active solutions to the treatment of natural light in response to these objective and restrictive natural factors.

2. Natural Light in Architectural Design

2.1. Natural Light and the Necessity of Modern Architectural Design

The introduction of technology has made economic growth and social progress, but at the same time, the rapid industrialization and modernization. How to achieve rapid development under the premise of maintaining social harmony and sustainable environment and resources has become a major issue that World must face. In order to archive the sustainable development of the environment, it is imperative to thoroughly discuss the use of natural light in architectural design and construct a systematic design concept and design methods(Akadiri, Chinyio, & Olomolaiye, 2012).

- The use of natural light can reduce people's utilization of air conditioners and coal, while can also adjust the indoor temperature.
- Natural light helps to change the visual effect of buildings. With the development of the construction industry, people are very innovative in architectural design. Therefore, in recent years, people have strengthened the use of natural light, making urban buildings more attractive to people.
- The use of natural light can also save resources and energy. Since natural light can improve the indoor temperature and brightness, it reduces the lighting time in the building and reduces the utilization rate of resources and energy by people, ultimately achieving the effect of energy saving and environmental protection.

2.2. The Importance of Natural Light to Man

The distribution of the population on the earth is roughly in a belt-like distribution along the latitude direction, with regular and continuous changes. The origin of this zonal distribution of natural elements is due to changes in solar radiation distribution according to latitude. Sunlight is the source of power and things. With sunlight, all things on the earth can grow, move, and reproduce(Chiang, Olsen, Basler, Bänkestad, & Hoch, 2019). With sunlight, humans can understand the world, and it is possible for humans to conquer nature. Without sunlight, there would be no life, without colors and shapes. Human beings who have lived with natural light for hundreds of millions of years have instinctive demands and psychological dependence on it. At the same time, natural light is an important environmental health factor, and medical researchers are also in the verge of further Researching its potential impact on the body's peace and essence.

2.3. The Influence of Natural Light in Architecture

Natural light mainly refers to the solar radiations reaching the ground, which is absorbed, reflected and scattered by the atmosphere due to the relative movement between the Earth and the sun, resulting in different latitudes, seasons, times, and different elevation angle of the sun. The spectrum of solar radiation can be divided into several bands, the *Ultraviolet band* with a wavelength shorter than 0.38 microns, the *Visible band* from 0.38 microns to 0.76 microns, and the *Infrared band* with a wavelength longer than 0.76 microns(Stickland et al., 1984).Within the wavelengths of the visible spectrum electromagnetic radiations of different wavelengths creates a different color perception for the human eye. This part of the radiation can enter the building and provide not only natural light but also heating the interior space. When solar radiations reach the surface of the earth through the atmosphere, it constantly interacts with air molecules, water vapor molecules, ozone molecules, carbon dioxide molecules, and dust. Therefore, 29% is reflected back into space,

primarily by clouds, but also by other bright surfaces and the atmosphere itself. About 23% of incoming energy is absorbed in the atmosphere by atmospheric gases, dust, and other particles. The remaining 48% is absorbed at the surface (Przyborski, 2009). As shown in the *figure 1*.

Figure 1

The nature of natural light is an electromagnetic wave, which is energy that can be used directly without any media conversion. The attributes of natural light as a natural resource are mainly manifested in three aspects: *Light effect*, *Thermal effect*, *Energy effect*.

2.3.1. Light Effect

Natural light is a safe and clean light source. Light allows people to perceive the size, shape, and colors, etc., and form a comfortable visual, work and living environment, so that the building meets the functional requirements of use. Therefore, the lighting problem of buildings is always the basic problem of buildings, and natural light plays an important role here. Natural light has the characteristics of uniform illumination, low glare possibility, good light color and good durability.

2.3.2. Thermal effect

In buildings, heating is due to shortwave radiation that directly heats the interior of the building, such as windows, or indirectly heats the structure of the building or both. The heat effect of natural light is a double-edged sword. In the architectural design process, we should make full use of it to obtain a large amount of free heat. On the other hand, we should also consciously avoid excessive natural light because of the thermal negative effect caused by including human body (Craddock, 2008).

2.3.3. Energy Effect

Energy refers to natural resources that can be converted into electrical energy, thermal energy, and mechanical energy. Natural light is pollution-free Renewable energy sources (Islam, Islam, & Beg, 2008).

Under normal circumstances, we think that natural light is an efficient lighting method, but if we conduct further research, we will find that it has a wider ecological potential, which can be used for heating, cooling, water heating, and even as a direct power source for production activities.

2.4. The Positive Roles of Natural Light in Architecture

2.4.1. Energy-Saving Advantages

More architects are beginning to realize that lighting is one of the most basic benefits brought by natural light. The use of natural light is becoming more and more important in improving the comfort of users and reducing the energy consumption of artificial lighting. According to the statistics of the International Commission of Illumination, the world consumes *23,398 billion kilowatt hours* of electricity per year of which 15% is on artificial lighting. The production of this electricity will emit more than 10 billion tons of carbon dioxide and more than 10 million tons harmful gases such as sulfur dioxide.

The use of natural light to create a building indoor light environment has great potential for energy conservation, conforms to the national energy conservation policy, and can create a bright environment atmosphere, which can not only protect eyesight and personal safety, but also improve work efficiency and inspire our spirits (Hwang & Kim, 2011). For a long time, people have always misunderstood natural light, thinking that natural light enters the room at the same time. The amount of heat generated at the time is more than that of the artificial light source. In fact, if the same illuminance is provided, the heat generated by natural light is less than that of most artificial light sources. In other words, if natural light is used for daylighting and lighting, it will greatly reduce the air conditioning load, which will help reduce building energy consumption.

2.4.2. Appropriate Sunshine Helps to Create a Comfortable Indoor Thermal Environment

The cold in winter and the heat in summer are due to the difference in solar radiation angle and time. For buildings located in temperate or frigid regions, the thermal effect of natural light can provide free heat for the building, reducing the energy consumption for heating in winter.

2.5. The Negative Effect of Natural Light in Architecture

2.5.1. Light Pollution

When the sun is shining strongly, the glass curtain walls, glazed brick walls, polished marbles and various paints of buildings in the city reflect bright white light, dazzling people's eyes (Tregenza & Wilson, 2013). Studies have found that people who work and live in a white light pollution (white light pollution) environment for a long time will suffer varying degrees of damage to their retina and iris, their vision drops sharply, and the incidence of cataracts is as high as 45%. In addition, white pollution can also make people dizzy and upset, and even suffer from insomnia, decreased appetite, depression, physical fatigue and other symptoms similar to neurasthenia.

Figure 2: Shows the Example of Light Pollution

2.5.2. Greenhouse Effect

Proper sunlight is an important condition for creating a comfortable indoor thermal environment, but excessive radiation can also cause adverse effects. In hot summer and cold winter areas, the high temperature lasts for a long time in summer, and it is often accompanied by the baking of the building envelope by the western sun. During this period, direct solar radiation entering the room will greatly interfere with the cooling efforts of the microclimate inside the building. In particular, the unidirectionality of glass to long-wave radiation causes heat to enter but not to be reflected, which makes the room continue to heat up lead to greenhouse effect.

2.5.3. Urban Heat Islands

Urban heat islands occur when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat (Buyantuyev & Wu, 2010). The large-scale application of various architectural glass curtain walls makes the urban area store more heat, because there are not many facilities to reduce this. Heat radiation is reflected between the buildings, so the heat radiation generated by a large number of glass buildings directly affects itself and cannot cool down. At the same time, the heat of the building complex in this area is higher than other sparse building areas. Therefore, the excessive indissoluble heat generated by glass buildings used for natural lighting has become a booster to intensify the urban heat island effect.

Figure 3: Urban Heat Island Profile

3. Analysis of Natural Light Design Techniques in Architectural Design

3.1. General Architectural Plan Drawings

In architectural design, the design of architectural plan drawings is the first task. The designer should design the drawings according to the specific requirements of the building and the actual local conditions. In the design of plan drawings, natural light design techniques are mainly reflected in two aspects: the distance control between buildings and the layout of buildings. If the distance between buildings is too close, the lighting conditions will be reduced, and too sparse will result in waste of land resources. Therefore, it is necessary to design and adjust the distance between the

buildings according to the actual sunshine conditions. The general principles for building design clearly stipulate that buildings with sunshine requirements must comply with the sunshine interval set by the local planning department. Generally speaking, a distance of 1.5 to 1.8 times the height of the building will be adopted. For one-line residential buildings, the distance between multiple floors should not be less than 6m, and the distance between high-rise buildings and various residences should not be less than 13m. In the design of the layout of the building, it is also necessary to fully refer to the various data of sunlight exposure and carry out the design of natural light. It is necessary to ensure that at least one room in the residential building can receive the full window sunshine not less than 1hour on the winter solstice.

3.2. Light Pipe Lighting System and Reflection Method

In the design method of natural light, the application of light pipe lighting system is a more effective method, which is mainly used to collect natural light.

The *light guide tube* collects natural light and filters the infrared and ultraviolet in the natural light to meet people's needs for indoor sunlight. The light pipe method can make people's safe use of natural light a reality, and avoid the damage of natural light to human skin while fully enjoying the warmth of natural light. At the same time, the light pipe lighting system can make the light more uniform and brighter without glare, relieve visual fatigue, and be more environmentally friendly and comfortable.

Figure 4: The Light Guide Tube

The *reflection method* is a method of daylighting for buildings with ten stories or more proposed by the University of California, which mainly uses light transmitting prisms to collect natural light.

In the lighting design (Boubekri, 2008). The reflection method as demonstrated in (figure 3) can solve the problem of daylighting in the building at a depth of ten meters, and illuminate the internal structure of the building such as basements and underground parking lots to improve the use efficiency of natural light.

Figure 5

3.3. Use of Building Shading Facilities

Most of the natural light design in architectural design is realized by designing the shape and form of the building. Shading facilities can be said to be the simplest and most common method of natural light design in architectural design. By blocking and controlling natural light, the sunlight intensity and room temperature inside the building can be regulated. At the same time, it can also realize the introduction of excess natural light into the depths of the building through refraction and reflection, so as to maximize the use of natural light energy. There are many types of shading facilities commonly used in natural light design, such as blinds, shade curtains, diffusers and reflectors, and so on.

Shading devices offer the opportunity of differentiating one building facade from another. This can provide interest and human scale to an otherwise undistinguished design (Jorge, Puigdomenech, & Cusido, 1993).

Figure 6: Demonstration of Sun Shading

3.4. Construction of Light Wells

In the natural light design methods of architectural design, the application and design of light wells are more used in high-rise buildings with underground warehouses and underground parking lots, as well as in subway construction. In the architectural design, inserting the building into a hole increases the area of contact between the inside and the outside of the building, effectively improving the degree of natural light exposure and collection inside the building, and also beneficial to the ventilation of the building.

Generally speaking, the design and construction of light wells in high-rise buildings are in the form of light shafts, which collect and guide the natural light on the highest floor of the building and use it at the bottom of the building. In addition, the design of building windows is also one of the means of natural light design in architectural design.

By investigating and considering the local natural light conditions, the designer cleverly designed the windows of the building, using skylights, side windows, corner windows, etc., to ensure indoor sunlight and temperature, while keeping the building's the light and shadow changes are more diverse, making the building more beautiful (Tregenza & Wilson, 2013).

Figure 7

Figure 7 Demonstrate the use of light well in high-rise building.

3.5. Building Window Design

For the use of natural light in the architectural space, various parameters of the window have a very important influence, such as size, location, shape, light-transmitting materials, and construction methods (Carmody, Selkowitz, Lee, Arasteh, & Willmert, 2004). If the window design is scientific and reasonable, the activity of the architectural space will be significantly improved, and the changes between light and shadow will be more abundant, which will undoubtedly have a positive impact on improving the artistic effect of the architectural space. In the design of architectural windows, the

choice of location is also particularly critical. For example, skylights, corner windows, and side windows have greater advantages in lighting effects.

3.6. Inductive Lighting Design

In architectural design, inductive lighting design is actually a natural lighting method. Through this method, the lighting conditions inside the building can be maximized, and the energy consumption of artificial lighting inside the building can be reduced. Under normal circumstances, in order to implement inductive lighting, architectural designers often use blinds, optical fibers, and shading facilities. On the one hand, this design method can provide comfortable natural light to the building. On the other hand, artificial lighting is lost. With the support of this method, it has also been effectively controlled, especially in the context of the continuous development of solar collectors and optical fiber technology, modern buildings are constantly developing in the direction of Ecologicalization, which undoubtedly played a huge role and influence on environmental protection.

4. Modern Architectural Forms and Use of Natural Light

4.1. The Exterior Shape of Modern Buildings and the Use of Natural Light

We should not pursue the external shape of the building as a goal. It should be a logical reflection of the internal space and at the same time a means to form and organize the external space. The quality, characteristics and quantity of natural light directly depend on the natural light scheme combined with the shape of the building. Furthermore, the choice of building shape is also related to building energy-saving design. Generally, the shape coefficient is required to be no greater than 0.3. Reduce the ratio between surface area and volume, and use compact building forms to reduce heat loss.

Therefore, in the following, the relationship between the external shape of the building and the use of natural light will be discussed from two aspects *the shape factor* and *energy saving control* (Dubois & Blomsterberg, 2011). The azimuth characteristics of natural light can be used to select a reasonable orientation and optimize the design of the building's shape, making it conducive to heat preservation, heat insulation and daylighting.

4.1.1. Energy-Saving Control of Building Shape Design

4.1.1.1. Body Shape Factor

The body shape coefficient is one of the commonly used body shape control indicators to describe the physical meaning. *Refers to the ratio of the area of the building envelope to the volume of the building.* From the perspective of building energy efficiency, it is to use the smallest possible building exterior surface area to enclose the largest possible building interior space volume. It can be seen that the figure coefficient is an important factor in determining the heat gain and loss of a building, so the establishment of a reasonable building figure is of great significance to building energy conservation.

4.1.1.2. Design Principles for Energy-Saving Figure

The degree of solar radiation influenced by the building and the heat exchange between the exterior and interior walls can be very different due to the difference of the materials and building structure. Therefore, considering all factors affecting the figure coefficient, the external figure design of an energy-saving building should meet the following principles:

4.1.1.2.1. Principle of Integrity of Building Shape

As a building shape design that contains energy-saving awareness, it should have the characteristics of integrity, and the main building should adopt typical shapes (square, triangle, etc.) as much as possible, and unnecessary small-scale unevenness should be reduced.

4.1.1.2.2. The Principle of Compactness of Architectural form Combination

When combining the building shapes, try to make the outer walls overlap to reduce the area of the outer walls. The design principle of energy-saving body shape is proposed not to restrict the architectural design, but to the architect provide a new consideration basis to adapt to the severe challenges of environment and ecology to architects. In the process of body shape design, the concept of energy conservation should be implemented, otherwise a building with 'innate deficiency' will pay a heavy price to become an energy-saving building.

4.1.2. The Influence of Building Shape on Natural Lighting

Buildings of any size and shape can get high-quality natural light. Although, in essence, a small building is very suitable for double-sided or multi-sided daylighting, but a large building cannot be an excuse for ignoring natural lighting with a large volume. Even if the volume is huge, a building can use design techniques such as light wells, courtyards, and entrance halls to form a series of small and deep rooms.

In order to further illustrate the influence of the building shape on natural lighting, the building shape is divided into single the two categories of monolithic and composite shapes are discussed separately, explaining the design advantages and limiting factors of various architectural shapes for natural lighting. Single-integrated shape means that a

building is composed of only one simple geometric shape; the composite shape is composed of several simple geometric shapes, which is suitable for the needs of buildings with more functions.

4.1.2.1. Analysis of Natural Lighting of Monolithic Building

To a large extent, in the natural light design of a single-shaped building, the use of side windows or the combination of side windows and roof windows depends on the overall depth of the building. As the building's depth increases, top lighting will become an increasingly important design technique among them. Buildings with small depths should obtain natural light through double-sided or multi-sided lighting, and the orientation is relatively important.

Factors such as function, orientation, climate, prevailing wind direction and topography should be considered in design, each facade can be treated differently such as selecting appropriate windows, balconies and special sun visors so as to obtain natural light.

- Analysis example of monolithic building: Guest room of the youth education center, located in the Windburg monastery in Lower, Bavaria. Designed by Thomas Herzog.

The building consists of two main parts, a guest room area on the south side and a service space (shower room, stairs, etc.) on the north side which are connected by long corridor. The reason for adopting this form is to increase the area that absorbs solar radiation in the south direction. The south facade uses a large area of glass to directly use solar energy and natural light for heating and lighting, and the scenery outside the window is beautiful. The outdoor space, landscape, and site are all integrated with the indoor space. The light-transmitting area uses light-transmitting insulation material, which can minimize heat loss. In summer, the shadows of the wide eaves and the shading devices on the outer walls can prevent glare from the south and excessive heating of the building. The northern area is an auxiliary space, and the use time is very short, so it is built with wood and opaque infill panels, with small-scale windows open, and only a set of rapid heating system is installed in the corresponding space(Bayerl, 2006).

Figure 8: Youth Education Center Guest Room Side

From this we realize that the location, orientation, window ratio, material and sun shading in a small and deep single-shaped building all provide a cut into the natural light of modern architecture.

However, buildings with large depths often have the same length-to-width ratio with a central core and other spaces are organized around it. In the architectural form of large depth, the outer space of the building usually uses side windows for lighting, the internal space of single-story buildings uses skylights to supplement light, and the multi-story requires an atrium with sufficient depth and width, otherwise it can only meet the lighting of the top space.

Figure 9: Youth Education Center Guest Room South

- Analysis example of monolithic building: The Philip Exeter Library located in Exeter, New Hampshire. Designed by Louis Kahn.

The Philip Exeter library is example of using the atrium for natural lighting. The atrium that runs through the entire height of the building divides the huge building into a series of small deep spaces through side windows. The skylight in the atrium introduces natural light into the use space and obtains a good lighting effect. In the design of the Philip Exeter Library, the side windows provide lighting for the learning space and the traffic space, and the sliding wooden blinds recessed in the wall can adjust the amount of light and the nature of the light in the learning space.

Figure 10: The Philip Exeter Library

The storage space for the books is arranged between the outer space and the inner atrium to prevent the books from being exposed to direct sunlight. The natural light design also shapes the architectural form and space, helping people to clarify the path, thereby forming places with different lighting effects. In the design of Philip Exeter Library, we can find a classic natural light design method used in high-density multi-story buildings. At the same time, a single-shaped building has many variations and combinations. It can be a very simple and independent form, or it can form a complex building through parallel, vertical or cross combination(Pieczara, 2015).

Figure 11: Philip Exeter Library, the Side Windows

4.2. The Interior Space of Building and the Use of Natural Light

4.2.1. Interior Space Function and Natural Light Design

Function as the primary purpose of people to build buildings, it is natural that there is no need to dwell on the fact that the spatial form of the building must be adapted to the functional requirements, and that the relationship between function and internal space should be fully affirmed. The qualitative conditions of an ordinary room need at the very least necessary day-lighting and ventilation. This problem directly relates to all aspects of the design of the interior of the building which use natural light.

Basic requirements for interior space lighting:

- Sufficient illumination level to obtain more natural light.
- Spatial illuminance should be evenly distributed to avoid visual fatigue.
- Avoid glare interference.

4.2.1.1. The Room Openings and the Depth of the Indoor Space Scale Ratio

The opening and depth of the room depends on the functional requirements of various rooms. Therefore, the use of natural light to meet the lighting and heating requirements of the interior space must also make a reasonable choice for factors such as the depth of the opening. The biggest problem facing side lighting is that the amount of light will gradually decrease from the day-lighting opening to the interior. The light near the window is mainly direct light; the weaker the light in the interior, most of the light in the depths of the room is the result of the reflection of natural light on the surface of the room itself. Since these methods introduce natural light from the horizontal direction, the ratio of room opening and depth becomes a key issue. The corresponding room height is an important factor in controlling the top lighting effect.

In a room with a height of 3m and a depth of 6m, the natural light collected from one wall (glass occupies 15%-20% of the wall) can make the natural light coefficient of the backlight surface reach 1.5%-2%. The ratio of non-residential buildings such as the depth and height of different rooms, can create different lighting effects and light levels, which can be designed and controlled according to the different functions of the room to meet their respective needs.

4.2.1.2. The Size and Position of the Window and the Amount and Direction of the Natural Light

The size and position of the window opening mainly depend on the room's requirements for lighting and heating (Marino, Nucara, & Pietrafesa, 2017). For example, the reading room has relatively high requirements for day-lighting, and its window area should account for $1/4 \sim 1/6$ of the room area, the living room has relatively low requirements for day-lighting and the area of non-windows only needs to reach $1/8 \sim 1/10$ of the room area.

Different sizes of windows can create different light effects, small-scale windows emphasizing the virtual contrast between walls and window, glass can help to define the relationship between the interior and the exterior or to draw people's attention. As the window size increases, the contrast between light and shadow and indoor and outdoor decreases. The boundary between large-scale windows is not so obvious as to introduce the landscape of the outdoor into the interior. Successful natural light design does not necessarily require large-scale windows to take into account the relationship between functional requirements and the local climate to balance the effect of light and heat loss.

Roof window lighting is more common in large spaces such as hall exhibition spaces, industrial plants and other public buildings. Compared with the side windows, the construction is more difficult and the cost is higher, but because the area and position are not restricted by the facade modeling, it is easier to obtain a large amount of uniform light according to actual needs. It can be seen that various day-lighting windows are not a question of which one is better and which is inferior. Each has advantages and disadvantages and should be specifically designed according to different usage requirements.

Figure 12

Figure 12 Shows the *Hall of Witness of the United States Holocaust Memorial Museum*. Located in United States Designed by Architect James Ingo Freed.

4.2.1.2.1. Analysis Example

The student dormitory of Massachusetts Institute of Technology located in Boston, USA, designed by Steven Hall. Each dormitory has nine windows that can be opened separately, which are divided into 3 rows and 9 windows in each row, each about 60 x 60 cm, forming a modular prefabricated panel. In this way, students can choose the window according to their own needs to obtain a personalized view of ventilation and privacy.

Based on the understanding of the dormitory's function and the ecological design concept, Hall designed this 10-storey commercial building with a length of 140m into a porous 'sponge.' It is a porous structure that absorbs light through a series of large pores that cut into the building and allow light to pass through the filter in part.

Figure 13: MIT Dorm

4.2.2. Structural System Design and Natural Light

Any kind of structure is not created out of thin air, but to adapt to a certain function. It has value only if the empty form it encloses can adapt to a particular functional requirement. Considering the functional significance of natural light on the internal space of the building, the influence of structural form on it cannot be ignored. For a long time, the openings in classical buildings dominated by pressure-bearing materials such as masonry must be in the place with reasonable structure and minimum stress, so as not to damage the structural system. Gothic architecture shows for the first time the possibility of opening large-area windows on the facade of a stone building. Load-bearing arch voucher structures are used on churches. Most of the flying buttresses and pillars of the outer wall are liberated. Wide open.

From a certain point of view, whether to use wall load-bearing is the key point. People are constantly looking for the possibility of using natural light. Structure and natural light have symbiosis. In modern architecture, we can better optimize the relationship between the two. On the one hand, natural light is used to further clearly show the relationship between structural components.

In the Kimbell Art Museum of Louis Kahn, the vault on the side of the arched structure gable is separated from the infill wall to form an arched day-lighting band. Thin light bands increase the lighting effect at the end and further illustrate the separation of support and enclosure. The conciseness of the structure transmission force (Gill, 2010).

In the design of the Johnson Wax Company Management Building designed by Wright (Figure 12), the top of the long and thin column is processed into a mushroom shape to support the 9-meter-high open office space.

Figure 14: Kimbell Art Museum

These pillars spread across the roof into wide circular concrete lily pads, with a layer of plexiglass tubes 'interlaced' between them.

In this way, light appears in the place where people expect it to be physical (*the roof*), and entity appears in the place where people expect light (*the wall*).

Figure 15

4.2.3. Use Natural Light to Organize the Interior Space of the Building

Under normal circumstances, people do not regard light as a necessary factor to form space. This is because space exists objectively even in the absence of light. But for a person with normal visual perception, light becomes one of the necessary factors for his cognitive space. Without light, people cannot visually perceive the existence of space. The intensity of the light, the direction of the light, the area of the light source of the picture, and the color of the light source will bring different atmospheres to the space (Ching & Binggeli, 2018).

In the interior space of the building, choosing an appropriate location to introduce natural light can play a role in defining, connecting and separating space. People are phototropic, so their attention is often unconsciously attracted to brighter things. According to this behavioral characteristic of people, designers can use natural light to attract people's sight and guide people's activities. At the same time, the guidance of natural light can help people understand the established spatial hierarchy through some hints, such as clear vision in parts with strong light and blurred vision in weak parts. Space is not only produced by physical enclosure; natural light can be used as a special design element to organize the internal space of a building.

4.2.3.1. Limited Space

The limitation of natural light on space means that the area formed by the bright light is a kind of psychological space, although it has no physical enclosure, it still has the attributes of space. Natural light restricts the space mainly by giving special brightness, shape or color to the restricted parts. This technique is commonly used in modern architectural design to define areas with complex functions. It is an effective way to enrich the spatial hierarchy.

4.2.3.2. Connecting Space

The same brightness and uniformity of light pave a unified tone for spaces of different natures, so that people's psychological feelings about the space maintain a certain degree of continuity and consistency when they shuttle between them.

4.2.3.3. Separate Space

The difference between light and dark naturally forms the psychological hint of the division of different spaces in the room.

Figure 16

Analysis example The Therme Vals, located in SWITZERLAND. Designed by Peter Zumthor

The idea was to create a form of cave or quarry like structure. Working with the natural surroundings the bath rooms lay below a grass roof structure half buried into the hillside. Peter Zumthor's technique of using natural light in the design of the Vals Thermal Baths (*Figure 15*) is admirable. On the concrete slab roof supported by the boulders, there are net-like glass gaps about eight centimeters wide. The light penetrates directly into each boulder unit. One side is at the edge of the crack and is washed by the top light to form a scene where the light surface and the thread are intertwined. Here, the light seems to be a sharp weapon that cuts the space, creating a new spatial dimension, suggesting an additional way to interpret the architecture. The route of the light in the interior indicates the interaction between the edge units of the unit and the fourth-dimensional space of light is created.

4.2.3.4. Create Visual Focus

The visual focus in the space can break the unity of the homogeneous space to form a position difference and level to attract people's attention. The principle of creating visual focus is to create difference, and light is the best way to create contrast between light and dark. Introducing natural light to process the entire space into a unified whole by illuminating a certain point together to produce a strong contrast between light and dark the illuminated part is often the object that needs to be emphasized in the space.

Figure 17

- Analysis example The Chapel of the Massachusetts Institute of Technology, (figure7) located in Chapel, UNITED STATES designed by Eero Saarinen

There is a circular skylight just above the altar to allow natural light to fall vertically on the altar. 4 Numerous reflectors are suspended from thin silk wires as carriers of light. Compared with the dim surrounding altar, it is very clear, affirmative and full of charm.

5. Case Studies of Applications of Natural Light in Architecture

5.1. Chapel in Mt. Rokko

Chapel in Mt. Rokko also known as Rokkosan Church, designed by Tadao Ando. The church was built in 1986. It consists of a church main body, a bell tower, a colonnade and a courtyard surrounded by independent walls. The glass colonnades of the church are arranged in parallel to form the main body of the building. Tadao Ando is an architect who is very good at using light to create spatial sequences. In the design of Rokkosan Church, he achieved the initial success of its combination of light and sequence.

Figure 18: Shows the Perspective of the Church

People walk along the slope to the top of the entrance laurel corridor, which is composed of arched glass roof and H-shaped connecting steel beams through the frosted glass, people can feel the existence of natural light and green space in the sky. The soft light fills the long narrow space and people are guided by it. The glass colonnade becomes the transition between the religious chapter and the natural environment. From the colonnade to a 90-degree turn, pass through a guillotine and enter the altar of death. The window on the front wall occupies the wall and half of the wall is passed through the window.

Figure 19: Chapel in Mt. Rokko

The architects cleverly designed natural light to complete the sequence of architectural spaces.

5.2. Viipuri Library

Viipuri Library located in Finland, designed by Alvar Aalto. Construction ended in 1935, the library's massing consists of two simple rectangular blocks that are offset horizontally from one another, but the internal spatial organization is deceptively more complex. Alvar Aalto has adopted kind of shading structure in the design of the top daylight windows which consists of multilayer skins. The light is effectively blocked before it enters the room, and its energy-saving effect is basically the same as that of an outdoor shading system, because the sunshade system is arranged in the interlayer, it is less affected by the weather, and its cleanliness and durability become longer.

Figure 20: Viipuri Library

6. Conclusion

Natural light, which is functional and artistic at the same time, has always added a lot to the world. The color emphasizes the sustainable development of human society. Today, people have begun to pay attention to nature, protecting the ecological environment of buildings and applying local materials to rationally use natural resources. This research aims to think about the operability of natural light use from the architect's point of view by summarizing and systematically arranging the design methods of using natural light in modern architecture, emphasizing the importance of constructing relevant design concepts and methods.

There are a few points to explain here

- The use of the first natural light not only includes the use of positive effects such as natural light, lighting and heating, but also effective responses to its negative effects. In the specific design process, the pros and cons are weighed according to comprehensive factors such as building nature, function, environment, and economy.
- Natural light is an issue that must be paid attention to. Most successful examples are related to. It is not advisable to copy the forms of other buildings in the design that are adapted to the local climate, site and other environmental factors.
- Reasonable heat gain and heat storage system can be established by using appropriate construction technology.

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